

THE ENGINEER

NOVEMBER 2019



Engineering a superbug fightback

Can technology help address humanity's most pressing healthcare challenge?

32



INTERVIEW: ALAN NEWBY - ROLLS-ROYCE DIRECTOR OF AEROSPACE TECHNOLOGY AND FUTURE PROGRAMMES

34



SPACE RACE: THE AMBITIOUS UK LED PROJECT AIMING TO INTERCEPT A PRISTINE COMET FOR THE FIRST TIME

58



FROM THE ARCHIVE: MAY 1937 - HMS HERCULES, THE MOST POWERFUL WARSHIP IN THE BRITISH NAVY

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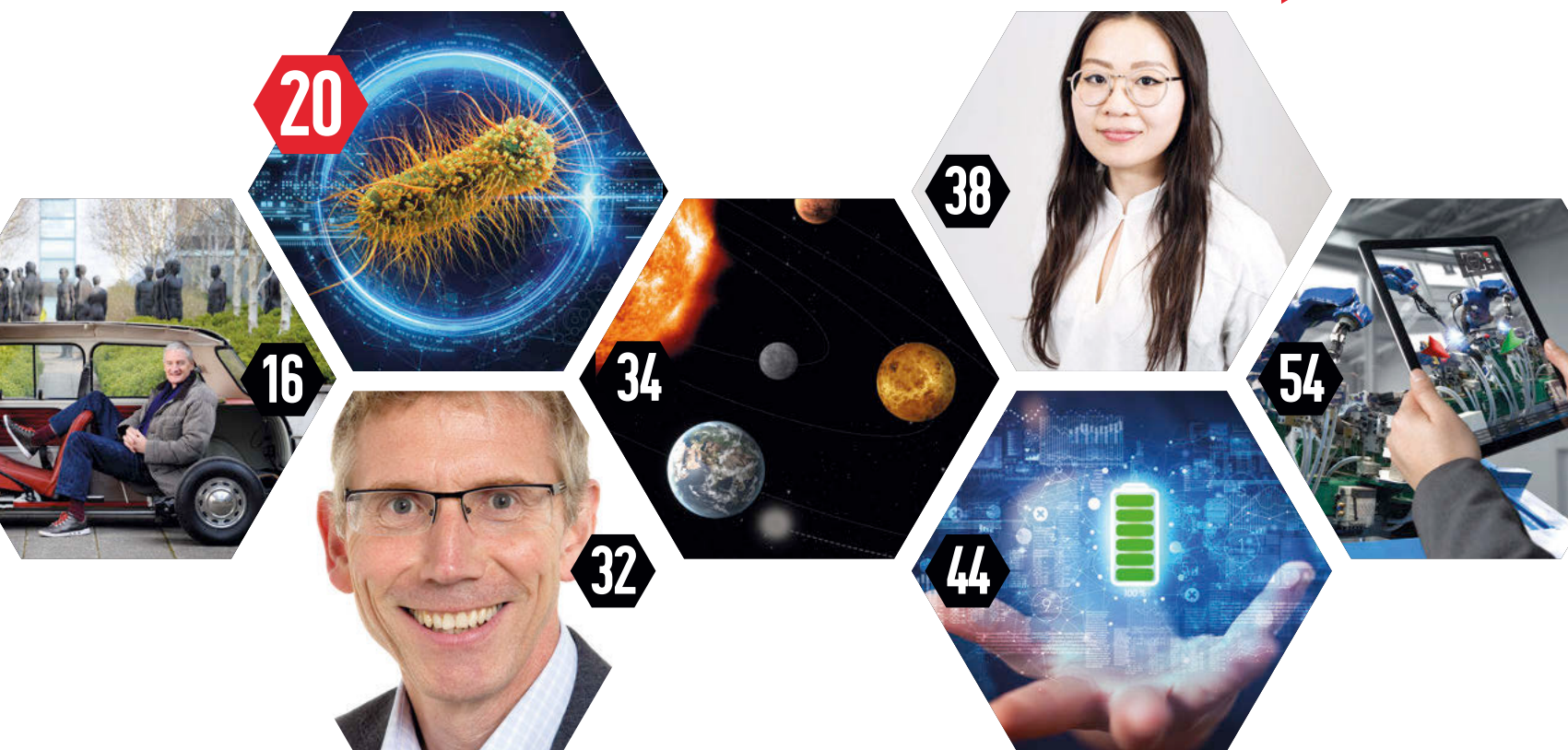
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**7 EDITOR'S COMMENT**

Welcome to the latest chapter in *The Engineer* magazine's long and distinguished history

8 NEWS

Newcastle University team investigates new technique for detecting drug resistant bacteria strains

16 BUSINESS NEWS

James Dyson pulls the plug on £2 billion electric vehicle project

18 NEWS ANALYSIS

Should the car industry be worried about driverless scepticism?

20 COVER FEATURE

Engineers are playing a vital role in the crucial battle against drug resistant superbugs

24 VIEWPOINT

A call to arms from outgoing chief medical officer Prof Dame Sally Davies

28 TALKING POINT

Should the big energy companies be made to pay the price for the global climate crisis?

30 MAILBOX

As Tesla hails the "million mile" battery is range anxiety on the way out?

34 SPACE

How the UK led Comet Interceptor project aims to get up close and personal to a long-period comet

38 ENTREPRENEURS

The young innovator who's helping disabled children sit more comfortably

42 CONSUMER TECH

The engineering innovations beneath the seat of Japan's hi-tech toilets

47 C2I AWARDS

Meet the winning entries from *The Engineer's* 2019 Collaborate to Innovate (C2I 2019) awards

54 SOFTWARE

Leading software suppliers offer their perspectives on the trends that are shaping the field of simulation

56 LATE GREAT ENGINEERS

The monumental career of France's greatest engineer: Gustave Eiffel

58 ARCHIVE

May 1937: HMS Hercules - the most powerful warship of the age

61 SECRET ENGINEER

In-built obsolescence is damaging the environment, and engineers must shoulder some of the blame

COVER ILLUSTRATION: Oliver Burston

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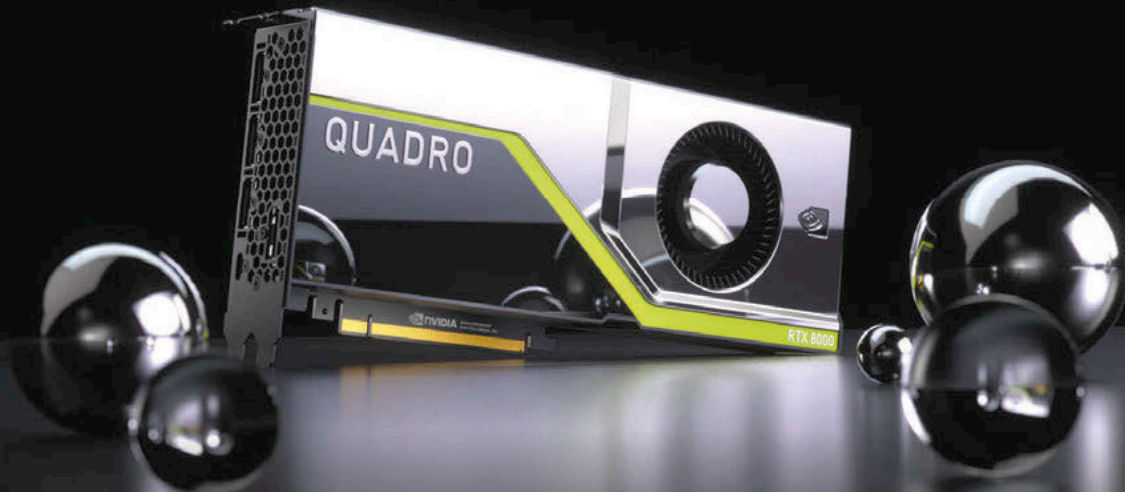
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JON EXCELL

Welcome to an exciting new look for The Engineer magazine.

Since moving to a new home earlier this year (London's Mark Allen Group) we've been exploring how we can supercharge The Engineer: how we can build on our 163 year history, maintain our seat at the ring-side of technological innovation, and engage existing readers whilst reaching out to the next generation. The redesigned magazine that you hold in your hands represents the first phase of this exciting new chapter.

Whilst there is much that will be familiar to regular readers over the following pages, there's also plenty of new content to get your teeth into: from "talking point" (p28) which provides a snapshot of the heated debate that can be found on our website, to the first in a new series of articles celebrating some of the UK's most exciting emerging engineering entrepreneurs. We've also bolstered our coverage of some of the technologies and personalities that have laid the groundwork for the modern age of innovation through an expanded delve into our classic archive (p58) and a new series of articles profiling some of history's "Late, great engineers" (p56).

Meanwhile, championing the role that engineers play in addressing some of our most pressing challenges remains at the heart of the publication's remit. And what better way to mark our relaunch than by exploring what's increasingly regarded as the biggest challenge we face as a species: the rise of the drug resistant superbug.

As we report (p22), it's a huge, potentially civilization-threatening problem, requiring action on many fronts. And from the development of new diagnostic techniques to infrastructure innovations that can help prevent the spread of infection, engineers have a major role to play.

According to the government's outgoing chief medical officer Prof Dame Sally Davies in this issue's Viewpoint (p24), it's also a problem that requires specialists of all disciplines to step out of their silos and work together.

It's a pressing and terrifying issue. But as the winning entries to The Engineer's annual C2I awards (p47) illustrate, there are plenty of reasons to be hopeful that the engineering community is equipped with the collaborative mindset required to rise to the challenge.

You can read more about all of this year's winners and shortlisted finalists at our website (www.theengineer.co.uk). In the meantime, we hope you enjoy our new look!

Jon Excell

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Bloodhound LSR in South Africa; the pros and cons of electric cars; and aerial firefighting technology

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MISSION STATEMENT

The aim of The Engineer is to champion and promote engineering innovation and technology development across all of the UK's key engineering sectors.

5

THINGS WE'VE LEARNT THIS ISSUE

- 1 Unless tackled, antimicrobial resistance (AMR) could lead to 10 million deaths per year by 2050
- 2 If the aviation sector were a country it would rank 20th in the world by GDP
- 3 Under EU regulations, new toilets must have a large flush capacity of no more than six litres
- 4 The UK-led Comet Interceptor will be the first in a new class of fast-tracked ESA space missions
- 5 Multi physics simulation will be key to the development of next generation electric and autonomous vehicles



NEWS

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AEROSPACE

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AUTOMOTIVE

- Algorithm helps autonomous vehicles to avoid pedestrians

CIVIL & STRUCTURAL

- The great bell of Moscow

DEFENCE & SECURITY

- Interview: Thales UK chief Victor Chavez

ELECTRONICS & COMMUNICATIONS

- Cancer therapy candidate is viable organic semiconductor

ENERGY & ENVIRONMENT

- Lithium-ion battery pioneer wins 2019 Nobel Prize in Chemistry
- Electronic solid could improve eco profile of cooling

MEDICAL & HEALTHCARE

- Texas team turns graphene into bacteria-killing filter

POLICY & BUSINESS

- RAEng awards £22m research funding

Sensor seeks antimicrobial resistant bacterial strain

Special polymers are designed to bond to bacteria

DAVID FOWLER REPORTS

Researchers at Newcastle University are investigating the development of a technique to detect antimicrobial resistant bacterial strains using special polymers designed to bond to bacteria.

The technique involves using molecularly imprinted polymers (MIPs), also known as polymeric antibody-mimics because of their ability to bond to a target molecule.

They are made from monomers that resemble amino acid structures and interact with bacteria in similar ways to antibodies, said Dr Marloes Peeters of the Advanced Materials group at Newcastle's School of Engineering, and principal investigator for the EPSRC-funded project. The polymers can be tailored to give them an affinity to bond to a target, such as a strain of bacteria that has developed resistance to antibiotics.

Dr Peeters' group previously demonstrated that the binding of the target to an MIP altered the conduction of heat through the polymer, leading to a temperature differential that is dependent on the concentration of the target bacteria. This can be measured in the lab by inserting the sensor into a flow cell, connected to a thermal sensor. This has been patented as the Heat Transfer Method.

The current project seeks to improve the sensitivity of the method by replacing MIP microstructures with nanolayers.



The original structures were built on a polyurethane substrate, which was several microns thick and impaired the heat flow, said Dr Peeters.

Experiments with electrochemical deposition methods were disappointing but the team has now developed an effective approach using photolithography. This allows more control over the structure and thickness of the layers, is quicker, and is easier to fine tune to suit different monomers, said Dr Peeters.

The group has recorded successful results with antibiotics, and instead of trying to use the technique to try to directly identify bacteria with antimicrobial resistant properties, it is now planning to monitor the susceptibility of bacteria to antibiotics.

The flow cell allows bacterial concentration and the

concentration of antibiotics to be measured over time. This can be done in situ and provides instant feedback.

Work is also under way to 'array format' the MIP structure to make it possible to measure multiple compounds simultaneously, which also required a redesigned flow cell.

The MIP sensor would be imprinted in such a way as to target a mixture of bacteria simultaneously. Microbiologists have identified the fact that there is a limited set of bacteria that are most commonly found in infections or in contaminated food or water.

"Ideally you would have a sensor that is not directed towards just one target, but could pick up different things, so, say you've identified the four most hazardous strains of bacteria that cause 90 per cent of all infections, that's ideally what we would like to do because that's what industry wants," said Dr Peeters.

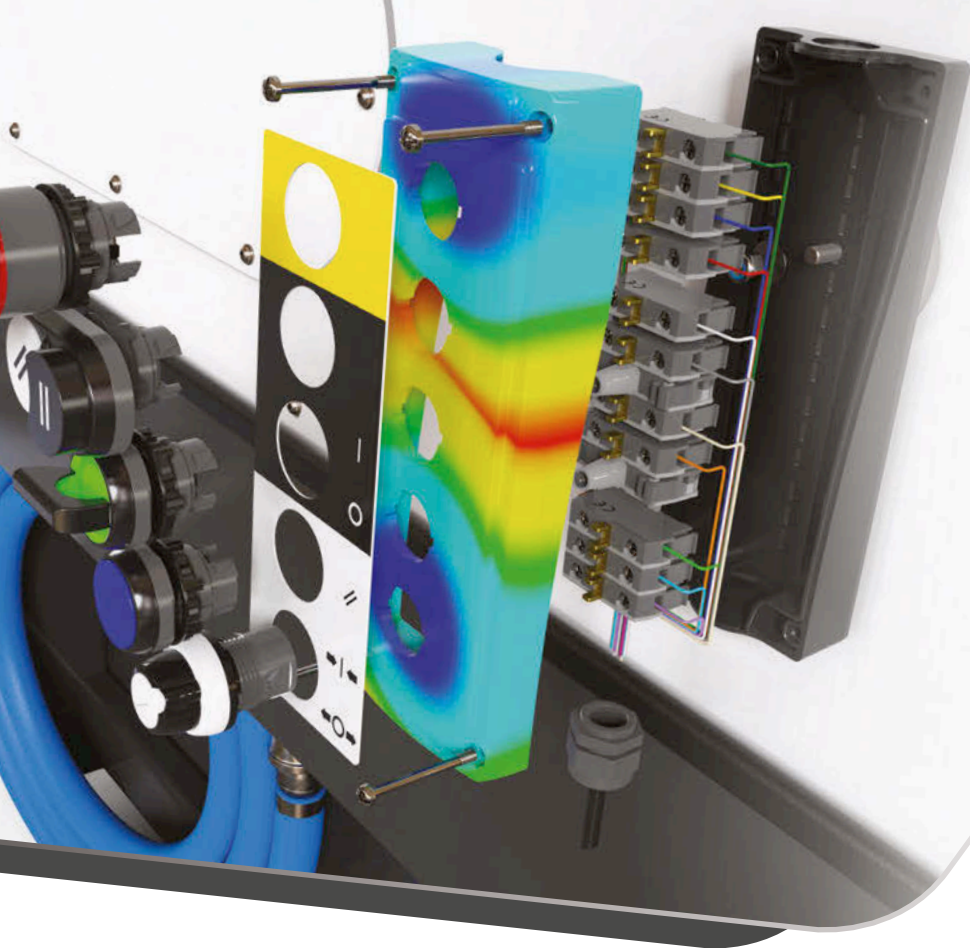
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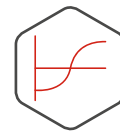


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Digital Crew applies AI for persistent observation

Software can monitor feeds from any digital source

DAVID FOWLER REPORTS



Thales has developed an artificial intelligence solution to the problem of information overload and tedium in security operations.

Designed for continuous observation of digital imaging streams, the Digital Crew tool uses pattern recognition to identify people and objects but also has the ability to learn.

It can simultaneously monitor numerous feeds from any digital source such as CCTV, a digital imaging camera, or a smartphone.

"Observing a scene, it could recognise a vehicle approaching in the distance before a human and would recognise it as a tank rather than a car," said Amyas Godfrey, Thales external communications business partner (land). "It could

then recognise the tank as a Russian T-72."

The software uses convoluted neural networks, which mimic the way the human brain learns, to build up a library or database of images it can recognise. It is provided with an initial database of objects (or persons) of interest as a starting point and examines images pixel by pixel to search for patterns.

For example, Digital Crew could be shown a flashcard of a T-72. If it then saw a moving T-72, it would recognise the tank when it came into a similar orientation to the original image. "It then records every frame/pixel combination as the tank drives past, so it can in future recognise it from the side, back, or in a cloud of dust," said Godfrey.

It can be applied to any long-term observation, said Godfrey, such as a 12-hour silent watch or a surveillance operation where one person might be monitoring several screens. Digital Crew can monitor multiple feeds and issue alerts, and never gets tired. "Its real benefit is its persistence," said Godfrey.

The idea was devised at Thales's Glasgow site in 2016 by an engineering doctorate intern who was looking into applying convoluted neural networks to thermal imaging. It received development funding from the Defence and Security Accelerator.

It was developed in-house in the UK, with academic support from local universities.

Virtual Crew is not offered as an off-the-shelf product but as a software application capable of being tailored to a given requirement. Thales works with prospective customers to devise an initial database for the application at hand. The device and its database are self-contained in a shoebox-sized package – it does not need large bandwidth to interrogate a database in the cloud.

TETRAPLEGIC MAN TAKES GIANT STEPS IN EXOSKELETON SUIT

A tetraplegic man has taken his first steps in a laboratory thanks to an exoskeleton suit developed by biomedical research centre Clinattec and the University of Grenoble.

Thirty-year-old Thibault was paralysed from the shoulders down following a fall four years ago. After his accident, which broke his spine and the level of the fourth and fifth cervical vertebrae at the base of the

neck, Thibault (who has not revealed his surname) spent two years in hospital.

Led by Prof Alim-Louis Benabid, president of the Clinattec executive board, the team began its treatment by placing two implants, each incorporating 64 electrodes, onto the surface of Thibault's brain over the sections that control sensorimotor function to the upper limbs. These electrodes communicate wirelessly with computers to interpret the signals they collect. Benabid and his colleagues published their research in *The Lancet Neurology*.

Thibault used the implants to control characters in a computer game before

moving on to the 65kg exoskeleton. Walking was the first task he managed, with arm control coming later and being more difficult because of the number of muscles involved, and the complexity of coordinating their movements. Currently, the service does not incorporate assistive control of fingers, although this is a future target of Benabid's team.

The Clinattec team stressed that this research is still in its early stages. The suit is cumbersome and the patient needs to be strapped in. It cannot prevent falls or allow the user to recover from them, which is why Thibault is supported by a harness. **SN**

NEWS IN BRIEF

IN THE SOFT PRINT

Birmingham University researchers have developed a technique to print soft biomaterials that could be used to repair defects in the body. The process – Suspended Layer Additive Manufacturing (SLAM) – uses a polymer-based hydrogel in which the particles have been manipulated to create a self-healing gel. According to the University, liquids or gels can be injected directly into this medium and built up in layers to create a 3D shape.

JUKE OF SUNDERLAND

Nissan has started production of the new Juke at its Sunderland plant, following a £100m investment. Designed, engineered and manufactured in the UK, the new Juke has been developed specifically for European markets, with Sunderland the only production location for this second-generation compact crossover. Developed by Nissan's European design and R&D teams in England, 70 per cent of Juke production will be for EU markets.



HYBRID TUG

A hybrid tug powered by hydrogen and diesel has been ordered by the Port of Antwerp, which is working on a strategy to become carbon neutral. Built by Compagnie Maritime Belge (CMB), the 'Hydrotug' will comply with EU Stage V emissions regulations and will feature a particulate filter and catalyser to complement its dual-fuel system. It is due to be delivered within two years.

Read more at www.theengineer.co.uk

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Loughborough academic to model 'living' micro-machines

ERC awards £1.25m for five-year project

DAVID FOWLER REPORTS

A researcher at Loughborough University has been awarded over £1.25m by the European Research Council to investigate 'living' micro-machines that assemble themselves.

The five-year project will combine two areas, colloidal self-assembly and active liquids, using computational simulations on Loughborough's high-performance computers.

Dr Tyler Shendruk is a member of the interdisciplinary centre for mathematical modelling in the Mathematical Sciences

department. This is a new group "applying computational physics methods to understanding different dynamic systems than physicists would usually consider", he said.

Colloids, suspensions of tiny particles in a fluid, can act as building blocks for more complex structures but need to be brought together to 'self-assemble'. In liquid crystals, fluids composed of rod-like molecules that lie in straight lines, colloids self-assemble into chains, zigzag lines and lattice structures. These are known as colloidal liquid crystals. However, they are limited to simple, static structures.

Dr Shendruk will investigate a new class of 'active' liquid crystals. These are typically biological and can store energy and transmute it into spontaneous mechanical motion. An example is fluid extracted from cell cytoplasm and purified, or a dense suspension of bacteria. Their internal motion can be used to model the dynamics of herding sheep or shoals of fish.

It is hoped that in such fluid, colloids will be able to self-assemble into more complex and dynamic structures. "The goal is to see if the interaction of the colloids in the liquid crystal, causing them to self-assemble, is enough to hold them together while the activity of the fluid moves them around, so that they can act as the components of a micro-robot might do," said Dr Shendruk.

He added: "I'm trying to steam ahead with the theory and ask: what can you do with these active fluids?" While experimental scientists work to discover new examples of the fluids, "we want to see if we get these structures spontaneously forming, and do they propel themselves along?"

Applications could include acting as a carrier of drugs to places the drugs would not otherwise go, at a cellular level. Two different colloids could also carry two inert components of a drug, which would remain inert until brought together.

AI LAB-BOT JOINS DRUG-DISCOVERY PROGRAMME

The identification and synthesis of molecules for new medicines could soon be undertaken in a lab where decisions are made by artificial intelligence, an advance likely to speed up drug discovery.

It can take years for scientists to refine the shape and property of target molecules, and up to a million molecules might have to be tested before the right one is discovered.

Now, Dr Richard Bourne, Associate Professor in the School of Chemical and Process Engineering at Leeds University, is leading a project to develop an AI-driven 'lab-bot' to refine the process. According to Dr Bourne, the initial aim of the project is to find medicinally active chemicals that can be used to treat arthritis and cancer.

To this end, Dr Bourne has been awarded a Senior Research Fellowship by the Royal Academy of Engineering to further the investigation, which adds to a £3.5m EPSRC grant awarded to Dr Bourne and partners to make advances in 'cognitive chemical manufacturing'.

 Read more at www.theengineer.co.uk

DRIVEN TO AUTONOMOUS SUCCESS

DAVID FOWLER REPORTS

Driverless cars have been put through their paces on London streets in a landmark demonstration by the DRIVEN consortium.

A fleet of Ford Mondeos, driven by autonomous software developed by Oxbotica, gave a week-long demonstration around a circuit in Stratford in east London earlier in the autumn.

Over 450 trips were made carrying local residents and members of the

general public, driving on congested roads around the Queen Elizabeth Park, Stratford centre and Stratford International rail station.

The cars operated completely autonomously, with a safety driver to take control if necessary.

The £13.6m 30-month project, match-funded by the government's Industrial Strategy Challenge Fund, brought together partners covering the autonomous vehicle 'ecosystem'.

Prof Paul Newman, co-founder of Oxbotica, said the trial demonstrated the system's ability to work on typical London roads.

Prof Newman stressed that the Oxbotica system is "totally infrastructure-free" needing no roadside beacons, GPS or third-party maps. This



means it can operate through tight urban canyons where there is no GPS coverage.

The vehicles use an internal model of the route to confirm its location, which is updated dynamically as the vehicle drives around, for example, to take account of road works, and navigates using vision sensors, radar and lidar.

Simultaneously, autonomous vehicles were being demonstrated in a quarry and a forest.

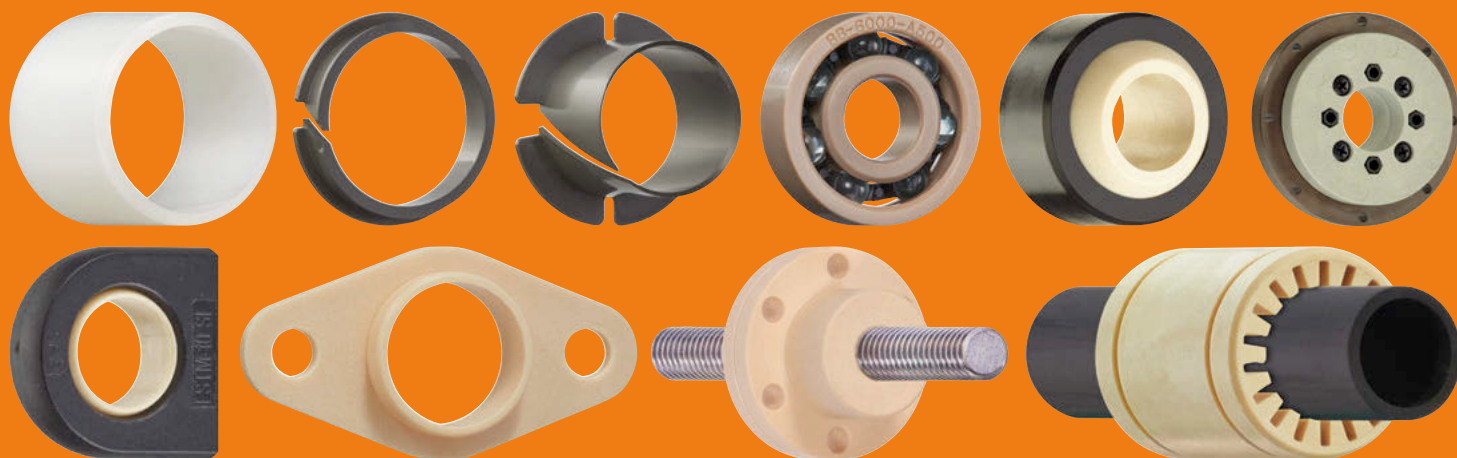
The consortium said the London trial "confirms that autonomous vehicles can operate smoothly, safely and legally in complex real-life situations, on typical public roads".

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Funding boost for weight-saving

Electric vehicles and urban delivery vans are initial target market for composite wheels

DAVID FOWLER REPORTS

The first low-cost commercially viable composite automotive wheel could soon be a reality after a consortium of specialist UK businesses won a match-funded grant of £135,000.

Electric vehicles and urban delivery vans are the initial target market for the wheel, which promises a weight saving of up to 50 per cent compared with a typical 15in steel wheel.

The ACRIM (All Composite Reduced Inertia Modular Wheels) project comprises UK composite specialists Carbon ThreeSixty and Far UK, and polymer specialist Bitrez. The consortium won a

share of £2.5m funding through the Niche Vehicle Network's Low Carbon Vehicle Technology R&D Competition and is working with GKN and Manchester Electric Vehicle Co and Microcab to test the wheel's effectiveness.

The six-month project aims to take the wheel through proof of concept to a stage where production can be scaled up.

Composite wheels currently available are manufactured for the high-performance market and are offered as options on supercars.

Ed Allnutt, managing director of lead partner Carbon ThreeSixty, said ACRIM's aim was to improve efficiency for vehicles that make a



large number of starts and stops, such as small city cars and 'last-mile' delivery vans.

ACRIM aims to reduce the cost of the wheel to £200, said Allnutt: this is still more than steel, but the composite wheel would offer compensating advantages.

Reducing the static weight of the wheel also reduces rotational inertia, so that it takes less energy to start and stop the wheel spinning. "It's considered that taking 1kg out of the wheel is equivalent to taking 2kg out of the static mass, depending on the duty cycle," said Allnutt. In addition, reducing the

unsprung mass makes possible improved handling, and also allows suspension components to be reduced in weight. Overall efficiency gains of 5-10 per cent are predicted.

The wheel is likely to be primarily made from industrial-grade carbon fibre with an epoxy resin system, said Allnutt, formed into shape using a resin transfer moulding process.

However, for part of the wheel a different process will be investigated, fabricating it as a two-piece co-manufactured composite and using compression moulding.

PUBLIC DEBUT FOR AUTONOMOUS BUS

Vehicle makes precise manoeuvres at NEC

DAVID FOWLER REPORTS

The UK's first full-sized autonomous bus gave its first public demonstration at the National Exhibition Centre in October 2019 for visitors to the Coach & Bus UK show.

Members of the public travelled on an 11.5m Alexander Dennis bus as it manoeuvred around part of the NEC car park.

The demonstration replicated work done by Fusion Processing, Alexander Dennis and bus operator Stagecoach earlier in the year to demonstrate buses navigating autonomously around a depot.

Fusion Processing chief executive Jim Hutchinson said: "Every night there is a big operation at a depot to wash, fuel and park the buses ready for the next day. By automating this it can be made more efficient."

The NEC bus manoeuvred between areas representing a bus wash, fuelling station and parking space. It negotiated obstacles and a moving cyclist.

Hutchinson said: "This was an opportunity to get public engagement - making sure everyone's comfortable [with autonomous technology]. There's no better way than getting people on board."



Only slow speeds were possible, but the trial demonstrated the precision with which the system operates, positioning the bus to within 5cm.

The three companies are collaborating on the CAVForth project, whose launch is due next summer. This will be a public pilot carrying fare-paying passengers on a 15-mile route from a park and ride site in Fife, over the public transport-only Forth Road Bridge to the Edinburgh Park train and tram interchange.

A fleet of five buses, with GPS but navigating mainly by cameras, radar and lidar, will operate at Level 4 autonomy at speeds of up to 50mph.

NOBEL PRIZE FOR LITHIUM-ION BATTERY PIONEER

Prof John B Goodenough, one of the pioneers of lithium-ion battery technology, has been awarded the 2019 Nobel Prize in Chemistry.

Goodenough has been awarded the prize for his work at Oxford University in the 1980s, when - along with Koichi Mizushima, Philip C Jones and Philip J Wiseman - he identified the cathode material that enabled development of the rechargeable lithium-ion battery.

He received the award jointly with Stanley Whittingham of the State University of New York at Binghamton and Akira Yoshino of Meiji University.

Goodenough identified and developed the critical materials that provided the high-energy density needed to power portable electronics, initiating the wireless revolution. Batteries with his cathode materials are used in myriad applications.



Read more about batteries at www.theengineer.co.uk

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BOEING AND VIRGIN MOVE FURTHER INTO SPACE

Boeing aims to capitalise on the commercialisation of space with a US\$20m investment into Virgin Galactic, the company pioneering commercial human space flight.

The investment is contingent on Virgin Galactic's merger with Social Capital Hedosophia Holdings Corp, which is expected to close in the fourth quarter of 2019.

In February 2019, VSS Unity, Virgin Galactic's reusable spaceplane, flew at 295,007ft (89,918m) and reached Mach 3.04 (2,255mph) during a successful second flight test.

According to Sir Richard Branson, founder of Virgin Galactic, the agreement marks the start of an important collaboration for the future of air and space travel, which he said are the natural next steps for the company's human spaceflight programme.

"Virgin Galactic and Boeing share a vision of opening access to the world and space, to more people, in safe and environmentally responsible ways," he said.

Virgin Galactic has so far invested US\$1bn in building reusable spaceflight systems.

EV project runs out of road

James Dyson pulls the plug on £2bn electric vehicle project

ANDREW WADE REPORTS



UK engineering firm Dyson has pulled the plug on the £2bn electric vehicle project it announced in 2017.

In an email to employees, founder and chairman James Dyson said that the company could "no longer see a way to make it commercially viable".

Attempts to sell the Dyson Automotive division, which employs some 523 people, had proved fruitless.

The email went on to say that the company is attempting to find

roles within other divisions for those who had been working on the project.

Patents from the EV development that were first published in 2019 remain under Dyson's control and the company said it will continue its work on solid-state batteries.

"This is not a product failure, or a failure of the team, for whom this news will be hard to hear and digest," Dyson said.

Dyson's move into the EV market in 2017 was met with much

fanfare, but the company came in for criticism when it announced in 2018 that the vehicles would be manufactured in Singapore rather than the UK.

Since 2004, the company has transferred much of its manufacturing base to Malaysia and Singapore, while continuing to invest in R&D in the UK.

Despite the EV setback, Dyson said it will continue to invest and expand at its Malmesbury, Hullavington and Singapore sites, as well as other locations around the world.

"Since day one we have taken risks and dared to challenge the status quo with new products and technologies," the statement continued. "Such an approach drives progress but has never been an easy journey – the route to success is never linear. This is not the first project which has changed direction and it will not be the last."

Dyson said the company is seeking alternative roles for employees impacted by the decision.

Read more at www.theengineer.co.uk

Hinkley Point C costs set to rise

Chances of delays on both units at the Somerset site have increased

The UK's next-generation nuclear plant at Hinkley Point C has had a revised cost estimate, with £1.9bn-£2.9bn of additional spending predicted.

This will bring the overall cost of the project to between £21.5bn and £22.5bn. According to EDF, the cost increases "reflect challenging ground conditions which made earthworks more expensive than anticipated, revised action plan targets and extra costs needed to implement the completed functional design, which has been adapted for a first-of-a-kind application in the UK context".

EDF also stated that the chances of delays on both units at the Somerset site had increased, with setbacks of 15 months on unit 1 and nine months on unit 2. In terms of where the project is currently, EDF said the nuclear island "common raft" for Hinkley C's first unit was completed in

June 2019, with the next major milestone of the common raft for unit 2 due to be finished by June 2020.

EDF said: "The management of the project remains mobilised to begin generating power from unit 1 at the end of 2025.

"To achieve this, operational action plans overseen by the project management are being put in place. These involve the EDF Group's engineering teams in Great Britain and France, buildings and ancillary works contractors, and suppliers of equipment and systems throughout the supply chain."

EDF said delays and cost increases will have no direct impact on customers, with risks priced into the Contract for Difference agreed with the UK government. However, the additional costs could put pressure on the financing for projects such as Sizewell C in Suffolk.





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Autonomy anomalies

Should the automotive industry be wary of findings that repeatedly suggest reticence toward autonomous vehicles?

WRITTEN BY JASON FORD

Great strides are being taken to bring autonomous vehicles onto our roads, but is there a danger that the technology is being developed for a largely unreceptive market?

Advocates of the technology will point to reduced emissions and less congestion as just two virtues making autonomous cars an attractive proposition.

“With autonomous vehicles comes increased road safety,” said Stefan Marxreiter via email, chief operating officer at Mobica, which is working with OEMs including JLR to develop the technology behind autonomous vehicles. “It’s been estimated that self-driving cars will reduce traffic deaths by 90 per cent - saving 30,000 lives per year - in the US alone.”

Self-driving cars will also take the drudge out of driving but an ICM poll for the Institution of Mechanical Engineers (IMechE) found that 60 per cent of UK adults would rather drive themselves despite statistics that show 90 per cent of road accidents occurring because of human error.

IMechE’s Public perceptions: Driverless cars found also that 32 per cent of people polled want driverless cars restricted to 30mph and that 66 per cent are uncomfortable with the very notion of travelling in an autonomous car.

ANSYS’ global Autonomous Vehicles Report found 43 per cent of those polled in Britain saying they’d ‘never be comfortable’ with riding in a self-driving car compared to 26 per cent of respondents in Germany and three per cent in China.

The good news for the

automotive industry and its suppliers is greater acceptance among younger people, both in the UK and overseas markets. ANSYS’ survey of 22,000 people found 87 per cent of 18-to-24-year-olds and 88 per cent of 25-to-34-year-olds saying they’re ready to ride in autonomous cars ‘in their lifetime’.

It remains to be seen whether the technology will be used as a service or remain part of the current ownership model, but the market for connected and autonomous vehicles (CAVs) is considerable. In 2017 the Transport Systems Catapult estimated the global market for CAVs to be worth £907bn globally and the government’s Industrial Strategy has paved the way for more

highway trials of autonomous vehicles by 2021, including a program of public engagement (see pages 12 & 14).

“I can understand why the general public would perceive that autonomous vehicles are less safe than human drivers, but from a testing standpoint you could argue they are held to a much higher safety standard than people,” said Dr Keith Hanna, VP of marketing, MSC Software. “Human drivers are not required to drive 11 billion miles before obtaining a licence but using well-designed simulations, we can ensure that our autonomous systems have experienced and been taught to handle nearly every imaginable scenario before the tyres even hit

the tarmac.”

A trial that has gone a long way to assuage the public took place in the London borough of Greenwich where the GATEway project invited the public to ride in or experience a fleet of driverless pods before revealing their thoughts on the experience.

The project ran for three years with 5,000 people signing up to participate in the self-driving shuttle service trials. IMechE agrees that this sort of initiative will help inspire confidence in autonomous vehicles following high-profile accidents in the US and real fears around vehicles – or the connected devices of vehicle operators - being hacked.

In South London, FiveAI has been testing a fleet of five Ford Mondeos in Croydon and Bromley prior to passenger trials planned for 2020. The company is developing software to give Level 4 readiness to autonomous vehicles, which essentially hands over all driving functions to the car.

Despite this obvious progress, Safa Alkateb, CEO of Autocab, a Cheshire-based software and GPS fleet management company, believes it is likely to be another 11-to-13 years before autonomous vehicles become ubiquitous, which he said via email is in line with the growth of the subscription model in transport.

Echoing this view, Dr Stefano Longo, a senior lecturer at Cranfield university said: “The biggest problem in autonomous driving today is testing the complex algorithms. The UK is not ready yet for the deployment of autonomous vehicles, but it is ready to fully assess their safety in highway, urban and geofenced driving.”#ENGINEER

/// IT’S BEEN ESTIMATED THAT SELF-DRIVING CARS WILL REDUCE TRAFFIC DEATHS BY 90 PER CENT - SAVING 30,000 LIVES PER YEAR - IN THE US ALONE ///

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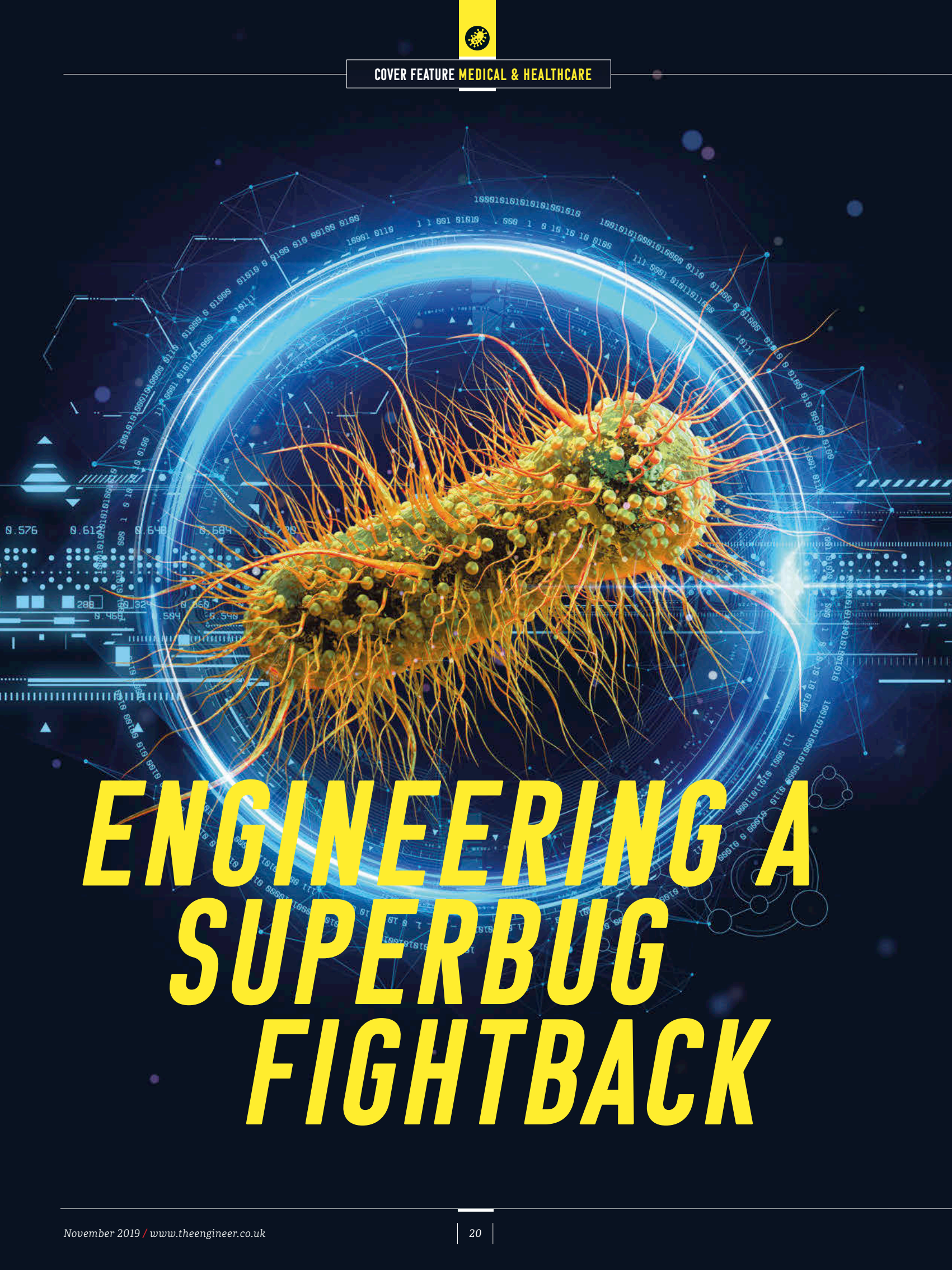
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ENGINEERING A SUPERBUG FIGHTBACK

The rise of the untreatable superbug is arguably the biggest global threat we face. Jon Excell reports on the vital role that engineers are playing in addressing this pressing problem

From organ transplantation and stem cell therapy to surgical robots and advanced prosthetics we live in an age of medical marvels: where once fatal diseases have been eradicated and cures to some of humanity's most devastating illnesses lie within reach.

And yet, around the world experts are increasingly concerned that we stand on the brink of a dark age of medicine, where once common diseases become untreatable and routine medical procedures become a matter of life and death.

It is feared that the astonishing progress of the last century could unravel in the face of the growing problem of antimicrobial resistance (AMR): the ability of microbes such as bacteria to resist the drugs - in particular antibiotics - that have underpinned many of the healthcare advances we take for granted.

According to the World Health Organisation, an estimated 700,000 people every year now die from drug resistant diseases, and this figure is projected to grow rapidly. The UK government's 2014 O'Neill Review, carried out by British economist Lord Jim O'Neill, warns of a post antibiotic apocalypse that could kill 10 million people a year by 2050; force up to 24 million into extreme poverty; and devastate the global economy.

The most frequent response to this crisis is a call for new drugs, in particular new antibiotics. But whilst replenishing the pipeline of treatments is vital, it's only one part of the solution to a mind-bogglingly complex problem.

Whilst resistance is to some extent a naturally occurring phenomenon,

the increasing use of antibiotics since the second half of the 20th century has helped to create the perfect breeding ground for resistant microbes; with antibiotics from healthcare, agriculture and drug manufacturing entering the environment, killing off non-resistant strains of bacteria and leaving resistant strains to flourish.

There's now a growing consensus that getting to grips with AMR requires not just new drugs, but a fundamental rethink on the way we manufacture, use and handle antimicrobials; the measures we take to control their release into the wider environment; and the way we think about infection control and disease prevention.

As the government's outgoing chief medical officer Prof Dame Sally Davies writes in this issue (page 24) it's a battle that must be fought on many fronts: requiring a global, multidisciplinary push on an unprecedented scale. And it's a battle in which engineers are playing an increasingly important role.

Perhaps the best-known contributor to AMR is the enormous over prescription of antibiotics.

In a landmark 2018 study, public health England examined more than 3.5 million UK prescriptions and concluded that almost a quarter of them were potentially unnecessary. A 2019 University of Michigan study sifted through 15 million prescriptions and came to the same conclusion.

Clearly, reducing these percentages could have a major impact, and Leeds University's Prof Christoph Wälti is one of a number of engineers developing technology aimed at achieving just that.


"Part of the AMR problem is that there's a massive over prescription of antibiotics," he told *The Engineer*. "Simply reducing the number of

unnecessary prescriptions would have a positive impact on the non-occurrence of resistance."

Wälti and his team are developing a disposable electronic device that could be used by GPs and nurses to rapidly determine whether a patient is suffering from a viral or bacterial infection and help them decide whether or not to prescribe antibiotics.

The device works by detecting the presence of biomarkers (such as C-reactive protein) that are produced when the body has an infection. Whilst there are already some point-of-care technologies that flag individual biomarkers, Wälti's technology differs in that it can detect a number of these tell-tale substances thereby providing a much more reliable indication of what's going on.

The system is effectively an electronic biosensor with a microfluidic sample handling stage that applies a blood sample to a series of "pins" optimised to detect five different biomarkers.


Leeds University's Prof Christoph Wälti is developing an easy to use device that could enable GPs to rapidly figure out whether or not a patient has a bacterial infection. Image: University of Leeds



Whilst the underpinning technology is complex, and has required the involvement of experts from a variety of disciplines, a key element of its design is that it's exceptionally easy to use. "We have a panel of advisors including GPs and pharmacists," said Wälti, "one very clear message is that if they want to have a chance of being able to use something like this it has to be simple."

Wälti's team is currently running preclinical trials with patient samples in order to evaluate the approach and →



hopes to soon run trials in GP surgeries, where the system will be evaluated alongside standard processes.

Whilst Wälti's technology is effectively a yes or no test aimed at establishing whether or not there's a bacterial infection, Glasgow University biomedical engineer Dr Melanie Jimenez, is working on systems that could help clinicians identify specific pathogens more rapidly.

Currently, in order to identify a specific bacterium, clinicians will culture bacteria from blood samples, which can take days. During this interim period the patient is typically treated with broad-spectrum antibiotics, which can contribute to the development and spread of resistance.

Jimenez is attempting to fast-track this process by engineering a culture-free alternative that uses micrometre-scale channels to precisely control fluids and cells and separate pathogens from patient blood samples within minutes. "We design these channels to isolate pathogens based on different parameters such as their morphological or mechanical properties but also specific molecular patterns," she explained.

Once the pathogen has been isolated, existing identification techniques can be used to identify it, and ensure the right antibiotic is used.

Alongside improved diagnostic tools, engineers are also exploring new methods of drug delivery that could optimise the impact of prescribed drugs and limit the chances of them being exposed to conditions that encourage resistance.

One such effort is being led by Professor Ryan Donnelly of Queens University, Belfast, who is working on a skin patch that painlessly administers drugs directly into the bloodstream through thousands of individual "microneedles"

"One of the biggest problems is that the huge majority of the drugs are taken orally," said Donnelly. "This means that a small quantity of the compound often finds its way into the colon, creating the perfect breeding ground for drug-resistant bacteria."


Donnelly believes that his patches could provide a solution. "If

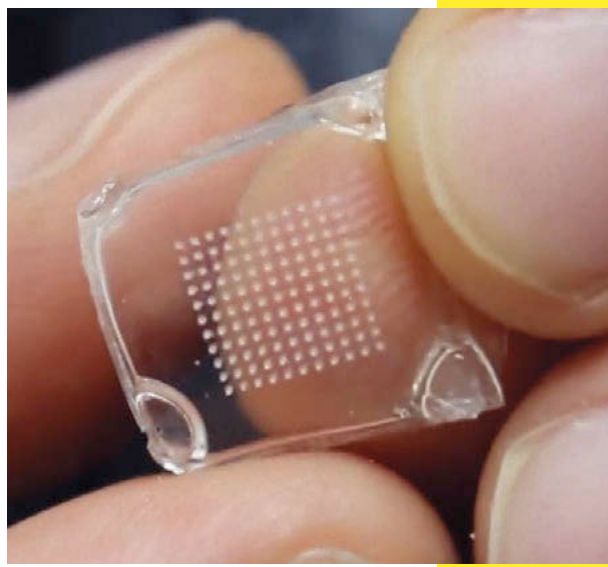
we are successful, this approach will significantly extend the lifespan of existing antibiotics, allowing time for development of the next generation of antibiotics," he said.

Assuming they make their way to market sooner rather than later, such technologies will play an important role in the fight against AMR, but they only address part of the problem.

One of the biggest causes of AMR is the widespread contamination of the broader environment with antibiotics from human and animal waste, and pharmaceutical manufacturing processes. By repeatedly dosing our environment in this way, we have unwittingly shifted the genetic balance of the natural world, increasing the proportion of resistant superbugs.

Earlier this year, in the first ever global study of its kind, a University of York led team looked at levels of commonly used antibiotics in rivers


Microneedle patches for antibiotic delivery could help limit the chances of the drug being exposed to conditions that encourage resistance. Image: Queens University, Belfast.



// THERE IS NO LEGISLATION ON WHAT IS AN ACCEPTABLE LEVEL OF ANTIBIOTICS IN WATER SYSTEMS //

in 72 countries across six continents and found antibiotics at 65 per cent of locations analysed. In some places levels exceeded safe limits by 300 per cent.

Closer to home, research carried out by a group at London's UCL found that many of Central London's freshwater sources contain high levels of antibiotic

resistant genes. The worst afflicted was the Thames which contained genes providing resistance for bacteria to common antibiotics such as penicillin, erythromycin and tetracycline.

Dr Lena Ciric from UCL's Department of Civil, Environmental and Geomatic Engineering, who led this research, said that it points clearly to the need for water treatment methods for antibiotic removal.

Ciric and her team have been exploring a number of techniques that could be used for this including a modification to the slow sand filtration method that is already widely used for water treatment.

But despite showing great promise, Ciric said that the big challenge is ensuring that effective techniques are deployed at scale. And that will require fundamental changes to the global legislation governing the levels of antibiotics in water systems. "There is currently no legislation on what is an acceptable level of antibiotics in water systems, whether it's drinking water or what waste-water plants are discharging," she said.

A global legal push will be particularly important if we are to address what is arguably the sharp end of the AMR pollution problem: untreated waste from antibiotic manufacturing facilities in China and India.

There is growing evidence that these facilities, which produce much of the world's antibiotics, are contributing to the creation of superbug hotspots that could have potentially disastrous global consequences.

"Superbugs In the Supply Chain" a 2016 report published by campaigning group Changing Markets found high levels of drug resistant bacteria close to multiple antibiotic production sites in India.

The samples, which were collected by investigative agency Ecostorm and analysed by Cambridge University biologist Dr Mark Holmes uncovered antibiotic resistant bacteria at 16 of 34 sites. At four of these sites, resistance to three major classes of antibiotics was detected, including so-called antibiotics of 'last resort', those used to treat infections that fail to respond to all

other medicines.

Clearly, addressing this is a daunting challenge, but UCL's Ciric points to a growing global appetite to get to grips with the problem. "Globally there's a real push to ensure that we work internationally and collaborate and make sure we try to deal with the problem on a global scale and it needs to be a global effort. Somebody might get an infection in one country, come to a hospital in the UK and spread it here."

One of the people at the forefront of driving a more globally focused approach is Professor Timothy Leighton, founder of NAMRIP (Global Network for Anti-Microbial Resistance and Infection Prevention), an organisation established to encourage multidisciplinary, international collaboration on AMR.

Leighton, a professor of ultrasonics and underwater acoustics at the University of Southampton, believes that in our efforts to address the problem we've become too focused on particular areas of expertise and that researchers are in danger of missing the bigger picture.

Addressing AMR, he said, requires a fundamentally different approach, one that considers factors ranging from cleaning regimes in UK hospitals right through to the way in which the farming practices in parts of Asia are influenced by theology or the even the behavior of local warlords.

According to Leighton, getting to grips with the complexity and scale of the problem requires specialists of every discipline - geographers, engineers, biologists, clinicians, etc. - to work together. "If you're going to make a societal change with your AMR work this big picture is critical," he said.

NAMRIP's cross-disciplinary approach has, he said, already achieved some notable successes.

One example relates to Leighton's celebrated work on the development of ultrasonic cleaning technology.

Back in 2015, his research group demonstrated StarStream, a handheld device that induces tiny bubbles that deliver an antimicrobial scrubbing effect into streams of water. He is now in the process of commercialising a suite of products through the company Sloan Water Technology, and will be

supplying ultrasonic devices to sterile services departments at a number of NHS hospitals over the course of the next year.

Another notable NAMRIP project brought together a multidisciplinary team of engineers, microbiologists, chemists and geographers in effort to raise awareness of the way that contaminants are transmitted around a hospital.

Chemists in the group created transparent gels that mimicked the stickiness of three key bugs - MRSA, E.coli and Pseudomonas - and which glowed different colours under a UV

// EVERYONE HAS A ROLE TO PLAY IN THE FIGHT AGAINST AMR - A GLOBAL MULTISECTORAL APPROACH IS KEY //



Villager points out illegal streams coming from Shri Kartikeya Pharma factory in Pallapalli, Hyderabad.



light.

The group then hired a hospital ward, complete with real nursing staff, and patients in the form of shop dummies. These dummies were dosed up with the gels in the areas of the body where the bacteria would be expected to occur, and the nurses were encouraged to treat them as they would normal patients

In order to track the movements of contaminants around the ward the whole process was filmed under UV cameras. The results provide a shocking illustration of the ways in which germs are unwittingly transferred around a

hospital setting. "For instance, if the nurse came along, pulled the curtains around the bed, put on gloves, touched the patient and then reached up to pull back the curtain we were able to note how contaminants built up on the curtain over time," explained Leighton.

Whilst such projects illustrate the benefits of a more joined up approach, Leighton believes that what's now required is a fundamental change to the way research is funded, and that the research councils are too hung up on pushing funding into specific silos. "We have to have a much more joined up way of thinking about how we support research," he said, "The kind of research that you want to fund, i.e. multidisciplinary stuff that is groundbreaking but also proven through translation, doesn't get funded."

Despite the frustrations however, there does at least to appear be a

growing acceptance that collaboration is critical. "Everyone has a role to play in the fight against AMR "and a global, multisectoral approach is key," said Glasgow's Prof Jimenez. "Engineers need to be involved in discussions with stakeholders to identify a path of technological innovations to protect humans, animals and our environment from this growing threat."

It remains to be seen whether this growing understanding blossoms into the kind of effort required to avert the global medical crisis many are anticipating. #ENGINEER

Why should we care about antimicrobial resistance? Until recently, I was the UK's Chief Medical Officer and it was my job to protect the nation's health. Antimicrobial resistance (AMR), which describes the phenomenon of infective microbes being resistant to the drugs used to treat them, is a clear threat to that. A review led by economist Jim O'Neill predicted that, without appropriate action, AMR will cause 10 million deaths per year worldwide by 2050 as we lose the ability to treat common infections.

Much of the progress we have made in medicine over the last century is down to the existence of antimicrobials, particularly antibiotics against bacteria. Many medical procedures which increase the risk of infection or suppress the immune system depend on effective antimicrobials, including caesarean sections, routine joint replacement, chemotherapy, and cystic fibrosis care. Treatment for the 'big three' infectious diseases - tuberculosis, HIV, and malaria - is under risk as they too evolve resistance.

But as I discovered, AMR cuts across many sectors. It is not just a threat to human health, and it cannot be tackled in the medical sector alone. Antimicrobials are used in food production, to protect health but also to promote growth in livestock animals. There is also an increasing focus on the environment as a potential reservoir and conduit for AMR. Antibiotics can enter the environment in several ways, such as through effluent from pharmaceutical factories and run-off from high-use farms and hospitals. When antibiotics enter waterways, evolutionary pressure leads to the emergence and spread of resistance. Researchers from the University of Exeter have found that surfers in the south west of England are three times more likely to harbour resistant organisms



PROFESSOR DAME SALLY DAVIES

Antimicrobial resistance: a call to arms

Engineers of all disciplines have a role to play in tackling antimicrobial resistance writes former chief medical officer Prof Dame Sally Davies

than non-surfers because they swallow much more seawater which contains high levels of resistant bacteria, most likely from sewage and waste pollution.

All of this means that AMR impacts many aspects of our lives. The O'Neill Review predicted that AMR will cost the global economy up to \$100 trillion dollars by 2050. This is approximately equivalent to losing the UK economy from global output every year. The World Bank predicts there could be 28 million extra people driven into extreme poverty by AMR. It clearly threatens sustainable development, most notably the six UN Sustainable Development Goals (SDGs) of no poverty; zero hunger (AMR threatens global food security); good health and wellbeing; clean water and sanitation; decent work and

economic growth; responsible consumption and production.

How can we stave off this threat? We need to:

- ⊙ Improve infection prevention and control: if we can reduce the incidence of infections, we reduce the need for antimicrobials in the first place through hygiene measures and vaccination.
- ⊙ Promote careful appropriate use, also known as 'stewardship' of antimicrobials: the more antimicrobials that are used, the higher the rates of resistant infections. If we can ensure that antimicrobials are used only when appropriate and necessary, we can minimise resistance rates.
- ⊙ Improve diagnostics: better diagnostics will help identify the cause of an illness and the best way to treat it, avoiding the use of inappropriate or unnecessary antimicrobials.
- ⊙ Improve surveillance; so we can better understand the threat and develop appropriate strategies to counter it.
- ⊙ Eliminate substandard and falsified medicines, which contribute to resistance.
- ⊙ Develop new drugs, so that we

have a bigger arsenal to counter the reduced effectiveness of existing drugs.

⊙ Support research and innovation, not just in new drugs but also vaccines, alternative treatments, behavioural science, the environment, and more.

None of these are simple tasks, and all of them will need to draw upon a wide range of expertise. That includes engineering skills, as the examples in this issue illustrate. Whether developing better wastewater treatment solutions, sterilisation techniques which do not contribute to resistance, nanoparticles which can target bacteria, or more hygienic farms which reduce the need for antimicrobials in food production, there is no shortage of demand for engineers to get involved.

We all have our part to play. I stepped down as Chief Medical Officer in September. In that role I worked with committed colleagues and partners to drive action against AMR in the UK and put AMR on the international agenda. Now, as the UK's Special Envoy on AMR, the biggest contribution I can make is to keep calling for global action.

This is a problem which crosses borders and cannot be tackled by nations on their own. I engage with countries and organisations across the world, in the public and private sector, covering humans, animals, and the environment. AMR affects each and every one of us, and we all need to take action.

So I urge all of you to step up. AMR is pervasive and I suspect that many of you work in areas which can impact resistance in some way. If each of you uses your expert knowledge and skills to help tackle AMR in whatever way you can, we can help preserve the miracle of modern medicine and all that it gives us. #ENGINEER

⊙ **Professor Dame Sally Davies is UK Special Envoy on Antimicrobial Resistance. Before this, she was Chief Medical Officer for England.**

// AMR IS NOT JUST A THREAT TO HUMAN HEALTH AND CAN'T BE TACKLED IN THE MEDICAL SECTOR ALONE //

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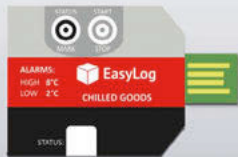


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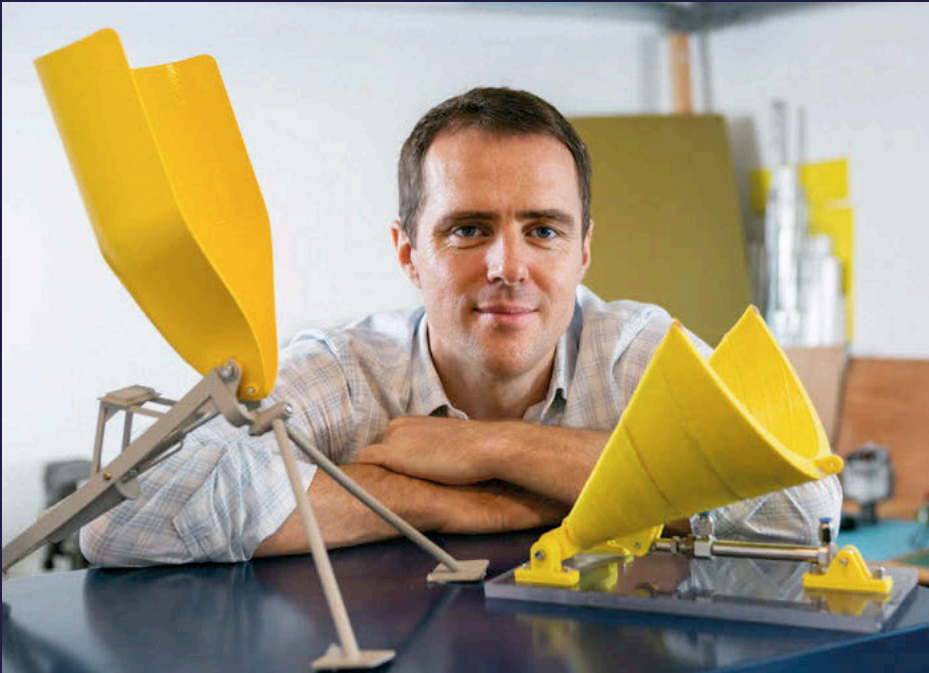
Founder
CCell

Will founded CCell to harness the power of nature to grow beautiful artificial reefs.

He's developing the world's first eco-based coastal protection, powered by renewable wave energy.

CCell's ultra-light curved paddle, both harnesses and dampens the energy within ocean waves to generate electricity.

This is used alongside an electrolytic technique, to grow artificial reefs that provide long-term coastal protection and a foundation on which to grow corals at an accelerated rate.



Given the opportunity, one engineer can change their world and ours.

Glen Fraser

Electrical Detail Designer
BAE Systems

Glen struggled through school and was diagnosed with severe dyslexia at an early age. His condition worsened, to the point where he was told by a teacher that 'engineering wasn't for him'.

With the help of Dyslexia Scotland, five years ago he secured a place on BAE Systems' Technician Programme and hasn't looked back since.

As well as being an award-winning engineer, Glen is also a STEM ambassador, inspiring young people to consider a career in engineering.





Paying the piper

Andrew Wade asks whether energy companies should be held legally responsible for the climate crisis

On October 23 2019, a landmark case got underway in New York. Energy giant Exxon Mobil is accused of lying to its investors and misrepresenting the economic risk of climate change to its business. It's alleged that the US company is one of several oil and gas firms that conducted research into climate change and its causes as far back as the 1980s, with some accurately predicting the effect on sea level rises and the increase in extreme weather events.

As the global climate movement finally builds momentum after years of handwringing and procrastination, there is a growing push for energy companies to acknowledge their role in creating

the crisis and obfuscating the science to maintain their profits. Furthermore, environmentalists are demanding that these global corporations contribute financially to the remodelling of our energy infrastructure, as humanity looks to wind down fossil fuel dependence and convert to renewable sources.

But is it too easy to lay the blame for the climate crisis squarely at the door of big oil? For their part, the energy companies say that they have merely been supplying the natural resources that society has demanded, helping to drive economic growth and reduce poverty. They also claim to be actively investing in new, green technology to help cut emissions, though almost all are investing in upstream discovery at

the same time.

Environmentalists would argue that continuing to develop new oil and gas resources is not compatible with the goals set out in the Paris Agreement. The counterargument is that we are still massively dependent on fossil fuels for our energy needs and – despite the growth of renewables – new exploration and extraction is needed to keep the lights on for the foreseeable future. Writing in *The Guardian's* recent investigative series 'The Polluters', journalist and environmental activist George Monbiot claimed that this dependence is itself a function of the energy industry and other big corporations, as well as the governments that have supported them for decades.

"We are guided by an ideology

so familiar and pervasive that we do not even recognise it as an ideology," wrote Monbiot. "It is called consumerism."

"It is locked in by transport, town planning and energy systems that make good choices all but impossible. It spreads like a stain through political systems, which have been systematically captured by lobbying and campaign finance."

According to Monbiot, as a society we are in essence addicted to the fossil fuel energy that these corporations have been providing for decades, in much the same way as smokers are addicted to nicotine. And just as big tobacco sought to muddy the waters on the link between smoking and cancer, big oil is accused of doing likewise with fossil fuels and global warming. Today, energy companies publicly recognise the science behind climate change, but in the past have funded organisations seeking to discredit climate science and, in some cases, continue to do so.

The *Guardian's* investigation found that just 20 companies – including Exxon Mobil, Chevron, Shell, BP, Gazprom and Saudi

Aramco – can be directly linked to 35 per cent of global emissions since 1965. This year is significant as there is evidence to suggest that both industry and governments, particularly in the US, were aware then of the long-term impact of burning fossil fuels.

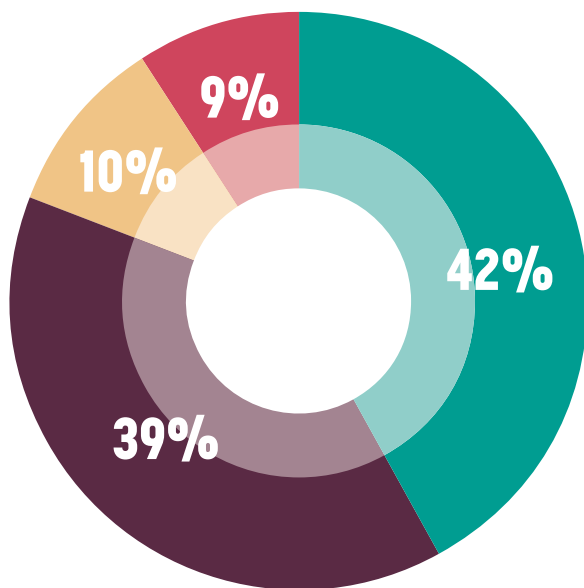
Referring to a 1965 US government report, the president of the American Petroleum Institute told its annual gathering that year: “One of the most important predictions of the [president’s report] is that carbon dioxide is being added to the Earth’s atmosphere by the burning of coal, oil and natural gas at such

a rate by the year 2000 the heat balance will be so modified as possibly to cause marked changes in climate beyond local or even national efforts.”

While the Exxon case is based on the company misleading its investors on the business impact of climate change, it could also potentially lay the foundations for criminal culpability in misleading the general public and continuing to push the planet deeper into climate crisis. In light of that, we asked our readers what level of responsibility, if any, energy companies should take for the climate crisis. **#ENGINEER**

Poll: should energy giants pay the price for climate crisis?

527 readers took part in our online poll on the topic and were quite evenly split, with 42 per cent saying that energy companies should contribute financially to mitigation efforts. Right behind that, 39 per cent felt that no responsibility rests with the companies and they have simply been providing essential natural resources to power the global economy. Just nine per cent thought the energy industry should face criminal action, while 10 per cent chose the ‘none of the above’ option.



- Yes, they should contribute financially
- No, they should simply have provided essential resources
- None of the above
- Yes, they should face criminal action



HAVE YOUR SAY

Visit our website to take part in the continuing debate on this emotive topic



SCAN ME

IN YOUR OPINION

“I see why people might wish to make energy companies pay - but sometimes it is hard to see where the fault lies,” wrote Peter Spence. “Much should depend, I believe, in OFGEM and National Grid as they set the purchasing guidelines and regulations.”

Another Steve commented: “The fact is we are all responsible for the mess we are in, and it’s naive to think if Joe Public had had all the facts that he’d necessarily have changed his ways. Most people have been aware for a long time of what was going on but chose to play dumb.

“A line in the sand should be drawn, moving forward, such that an admission is agreed of the effect on the environment and if they continue with such behaviour then they should be prosecuted and financially penalised.”

Other readers were less forgiving of the energy companies, though still highlighted the complicity of society in the continued use of fossil fuels.

“Energy companies have provided a service necessary to fuel economic growth and we were the ones asking them to do it (and paying for it),” commented Richs. “However, intentionally misleading people is another thing entirely and should be treated as fraud, just as with VW and the diesel scandal.

“Consumers ultimately decide the direction businesses move in by voting with their wallets and as the public shift away from fossil fuels, these companies should be investing in order to futureproof their businesses. There are a number of energy tariffs that are 100 per cent renewable electricity now, though enviro-friendly heating infrastructure seems to be a bit off. It is up to consumers to back up their armchair comments with actions, otherwise nothing changes.”

Reader Miles commented: “I think the elephant in the room no one has mentioned is the globalisation policies over the last 20 or so years. We have moved manufacturing from low carbon footprint countries such as Europe to the most inefficient producers of CO2 in the world so we can’t totally blame the energy companies of the west.”

“If we don’t charge a CO2 levy on cheap foreign imports to account for the extra pollution involved in their manufacture, we will never encourage the rest of the world to decarbonise their production methods.”

Andy wrote: “Love em or loath em, we’re going to need the cooperation of the energy companies to overhaul society’s energy systems. The language businesses speak is money, so a carrot-and-stick approach of incentives and penalties will see the desired change driven through.

“If they’ve been actively suppressing information then they should face punishments for that, but going after them just as a general principle would be counter-productive. We’ll get far more done by getting them on side. The UK has been a good example of how successful this can be. Not so long ago it would have been inconceivable to supply the national grid without coal, now we do so regularly and soon coal-fired power plants will be consigned to the dustbin of history. We’ve already managed to substantially decarbonise the grid, and now need to make similar progress with transport, heating and carbon-intensive industries like steel and concrete.”

“If we don’t charge a CO2 levy on cheap foreign imports to account for the extra pollution involved in their manufacture, we will never encourage the rest of the world to decarbonise their production methods.”



The 'million-mile battery'

A recent news story looked at new lithium-ion battery chemistry capable of powering vehicles for over a million miles



✉ This is very exciting and offers a far-reaching optimisation of battery structures. An in-depth consideration for the end-of-life recycling and balance of the resources needed will be important factors to consider. **Theo Paradise-Hirst**

✉ I can't envision buying another petrol or diesel car. Granted, long-distance lorries and buses are still a problem – perhaps a use for hydrogen? The question is: how quickly can this invention be brought into production? **Alex T**

✉ Promising news – but I still can't envisage an all-electric transportation future. **Richard Masters**

✉ I don't understand why we're not talking about swappable battery packs. When I want my gas

cylinder filled I don't actually get more gas in the cylinder. I swap my empty cylinder for an identical full one. Why are we worried about charging times for batteries? We should be swapping the flat battery pack for a new full one. **Ekij**

✉ You rent the battery (like a gas cylinder). When it's getting low you roll into the service station and, while you're swiping your credit card or phone, a robot drops the expired battery out, puts a recharged one in and you're on your way without even getting out of the vehicle (unless you need some sweets – but then they can be put in a vending machine alongside). **andyg**

✉ One set of batteries for at least four cars, so you just buy three replacement cars without batteries in them. The only 'green' issue is what does it take to get the components. How many countries

will be abused with opencast mining? They're effectively at least 75 per cent more efficient and so are probably a non-starter as there's no profit for corporate greed. **David Bean**

✉ I agree with Nick about hydrogen being the best method for longer journeys. However, if a battery can last the effective life of a car, innovative methods of integrating the battery into the car structure could be

✉ Now that we are aware of the failure of the 'Solar Highways' project, I wonder has anyone thought of installing built-in solar panels on the Tesla cars in order to extend life or recharge a car battery? **Alina**

developed as they would not normally need to be removed for replacement. **Mark Cargill**

✉ Battery technology is improving rapidly and will provide many useful benefits as it develops. Power station 'black-start' systems used to have massive banks of batteries to start gas turbines, but many of the driven machines could now be started using inverter drives, similar to the UPS used in LV systems. **Jack Broughton**

✉ What about the charging rate? Even waiting an hour (to get access as well?) on a rapid charger on existing technology renders many long-distance journeys impractical. Hydrogen fuel cells are still the only flexible and practical means of using energy if we ignore fossil fuels and intermittent renewables. **Nick Cole**

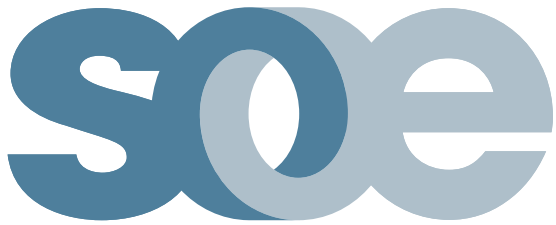
✉ Does any manufacturer quote the range of a vehicle when the demand for battery power is at its highest, i.e. heater, air con and lights all on in a cold climate? **Martin Bingle**

✉ I would really like to see in-depth articles on just how 'green' the manufacturing of these batteries are: from the ground to the full manufacturing process to the recycling/reclamation of used and/or damaged (auto accidents) batteries. What are the hazardous material issues in case of vehicle accidents and possible resulting fires and the environmental impact to surrounding areas and emergency services personnel? **Rex Willoughby, Sr.**

✉ Hasn't graphene technology already achieved this, with other advantages such as rapid charging and no-temperature-rise issues? **John Douglas** #ENGINEER

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AIR OF POSITIVITY

Rolls-Royce's Alan Newby believes that the aviation industry needs to be bolder in stressing its positive contribution to the modern world.

STUART NATHAN REPORTS

The aerospace industry isn't having the easiest of rides in the public eye at the moment. It's widely seen as an environmental malefactor, responsible for carbon emissions, noise and other pollution misdemeanours, and a movement started in Sweden known as flygskam (or 'flight shaming') aims to convince people to give up air travel whenever possible in favour of trains or boats.

Against this background, Alan Newby, director of aerospace technology and future programmes at Rolls-Royce, would appear to have an uphill struggle. Engineering industry insiders are well aware of the progress that Rolls-Royce and other aerospace companies have made in improving the environmental performance of their product since the advent of jet-powered air travel in the 1950s, but Newby believes that this message – and the advantages that air travel has brought to society – are still largely lost to the public in general and, to an extent, to policymakers.

"I think it's important that we stress the importance of aviation itself as an industry, both as a means of connecting people, but also from a trade point of view," he told *The Engineer*. "It's a matter of stimulating business, allowing people to understand different cultures, and, particularly with the defence business, of delivering humanitarian aid." Newby believes that communicating the benefits of air travel is a task for the entire aerospace industry, although Rolls-Royce should play a part in that effort, he concedes.

The benefits are also economic, he added. "A significant part of world trade is transported by air, the sector is a huge employer and supports many jobs in other industries as well, and if you were to rank aviation in terms of its size, compared with the GDP of the world's countries, it would rank 20th, so that is a pretty massive

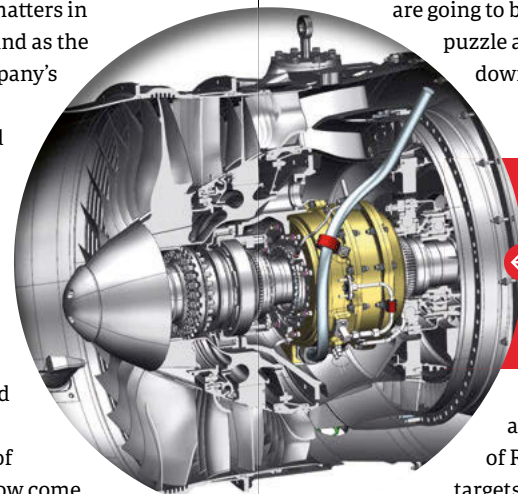
contribution to economic well-being around the world."

Since the advent of jet technology, carbon-dioxide emissions from aviation have reduced by 80 per cent, Newby said, and engines are 75 per cent quieter. This is all a matter of making engines more efficient, he stressed: an efficient engine produces more thrust with less fuel, and therefore emits less carbon. Noise is also an artefact of low efficiency and improving the efficiency of the airflow through the engine ensures that less energy is lost as sound and more is channelled into propelling the aircraft forwards.

The advent of Rolls-Royce's Trent gas turbine engines roughly coincided with the rise of environmental matters in public consciousness, and as the Trents are still the company's major product range, with the Trent 7000 and Trent XWB the latest to enter service, the progress of emissions and noise reduction in these engines provides a useful guide to how the company has performed since air travel came under its current level of scrutiny. Trents have now come full circle, Newby added, with the 7000 model replacing the first Trents on the wings of Airbus A330s. "We've been working on the Trents since the back end of the 1980s, and the first of these engines entered service around 1995," Newby said. Since the introduction of the Trents, CO₂ emissions have declined by around 15 per cent, NO_x emissions by around 30 per cent and noise by around 10 per cent.

Rolls-Royce is fully signed up to – and played a part in setting – the industry goals set under the ATAG and ACARE programmes, which respectively commit the aerospace sector to 1.5 per cent fuel efficiency improvement from 2009 to 2020 and to subsequent carbon-neutral growth, halving net emissions by 2050 relative to 2005; and 75 per cent reduction in CO₂, 90 per cent reduction in NO_x and 65 per cent improvement in perceived noise, all by 2050 relative to a new aircraft in 2000. "Some of this will be through commercial mechanisms such as offsetting and emissions trading schemes, especially in the near term, because it won't necessarily all be available through technology, but new technology ideas and sustainable fuels are going to be the final piece in the puzzle and they will bring us down to our 2050 targets."

Rolls-Royce is looking



(Left) Gearboxes and electric starter-generators (in gold) are among innovations in new gas turbine engines; (right) flight-testing blue composite fan-blades

at two parallel strands of R&D to meet these targets. For shorter range flight – which it defines as anything less than about 4,000 nautical miles – it is increasingly looking towards electrical solutions, either with electric motors providing propulsion, or hybrid systems (which Newby refers to as "more electric"). But above that 4,000 nautical mile limit, the company still sees gas turbines as being the primary source of propulsion, and so it is looking at ways to improve the performance of its large gas turbine



engines, with programmes called Advance3 and UltraFan. Both programmes are now in test phases, although no decision has yet been taken as to whether the resulting engines will be branded as a continuation of the Trents or given a new name when they come into service next decade.

As part of these two programmes, Rolls-Royce is developing a new engine core with efficient combustion systems to reduce both NO_x and CO₂, and fan systems based on lightweight carbon-titanium composites (comprising both the fan blades themselves and the surrounding fan case) to produce more efficient thrust by moving large amounts of air more slowly, which, as Newby explains, is the best way to reduce noise. To accommodate the new, fast-rotating core and the slower-moving fan, the company is developing a gearbox system capable of handling up to 100,000hp, currently

eventual introduction of this new evolution in gas turbine power.

But while liquid-fuelled gas turbine engines remain a major part of Rolls-Royce's future plans, the future is increasingly electric, and with the company's acquisition of Siemens's eAircraft business in June, the company now has a larger number of electrical engineers specialising in aerospace applications (although Newby points out that it already had considerable expertise in electrical systems, mainly from its businesses in the rail and marine sectors).

The electric propulsion paradigm will be seen in a

// NEW TECHNOLOGY IDEAS AND SUSTAINABLE FUELS ARE GOING TO BE THE FINAL PIECE IN THE PUZZLE AND THEY WILL BRING US DOWN TO OUR 2050 PERFORMANCE AND EMISSIONS TARGETS //



under test in Germany. The new engine core also represents an advance in technology, with the use of silicon carbide composite turbine blades that can operate at higher temperatures than single-crystal nickel superalloy blades; this is also currently under test. New testbeds, such as one under construction currently in Derby, will be needed to test this new generation of engines, which have a 140in (3.56m) fan case diameter making them too big for existing facilities to handle. Integration of these 'demo blocks' of composite fan, gearbox and engine core will take place over the next few years, leading to the

number of aircraft designed to tackle different ranges: from personal air mobility (such as flying taxis) for flights up to 200 nautical miles, which would use entirely electric propulsion; to small and large regional aircraft, for flights up to 850 nautical miles and even narrow-body and small-to-medium business jets, which would use hybrid-electric systems.

Newby highlights electrical projects such as an attempt to break the world electric flight speed record, which, he points out, "is a fantastic learning experience for the management and integration of aviation

battery systems and is a massive STEM project in terms of getting young people interested in aviation. This is a zero-carbon propulsion system, which is going to do something quite interesting in breaking records." Rolls-Royce has also recently developed an electrical starter generator integrated with a gas turbine engine, which will generate electricity for onboard systems and has synergies with the engine it is developing for the new British Tempest fighter aircraft, which will also generate power for ranged laser weapon systems. #ENGINEER



FAST SHOW

Andrew Wade reports on an exciting new UK-led project to intercept a long-period comet for the first time.

There's an assumption with space missions that they must be years in the planning before they're approved for launch. In the case of Comet Interceptor, a new UK-led project to observe a long-period comet up close for the first time, that assumption couldn't be more wrong.

The first in a new type of F-Class (the F stands for 'fast') mission, Comet Interceptor was selected by ESA in June 2019, with the request for proposals having gone out less than a year before. Rather than years in the making, the entire concept for the mission is barely 18 months old.

"We had the idea a few months before [ESA's call for proposals in July 2018], but actually, no, we started then," mission

proposal lead Prof Geraint Jones told *The Engineer*, shattering those aforementioned assumptions.

Jones is head of the Planetary Science Group at UCL's Mullard Space Science Laboratory. Together with deputy mission lead Dr Colin Snodgrass from the University of Edinburgh, he tailored a plan based on the parameters of ESA's request. Those included a launch mass of less than 1,000kg and a budget of €150m.

The chosen entry would also be hitching a ride with ESA's Ariel space telescope, set to launch in 2028 to the L2 Lagrange Point, 1.5-million kilometres from Earth in the opposite direction to the Sun. This was ideal for Comet Interceptor, as its final target is currently unknown. The spacecraft will lie in wait at L2 until a suitable long-period

➔ Currently under construction, the LSST in Chile will help identify targets for Comet Interceptor

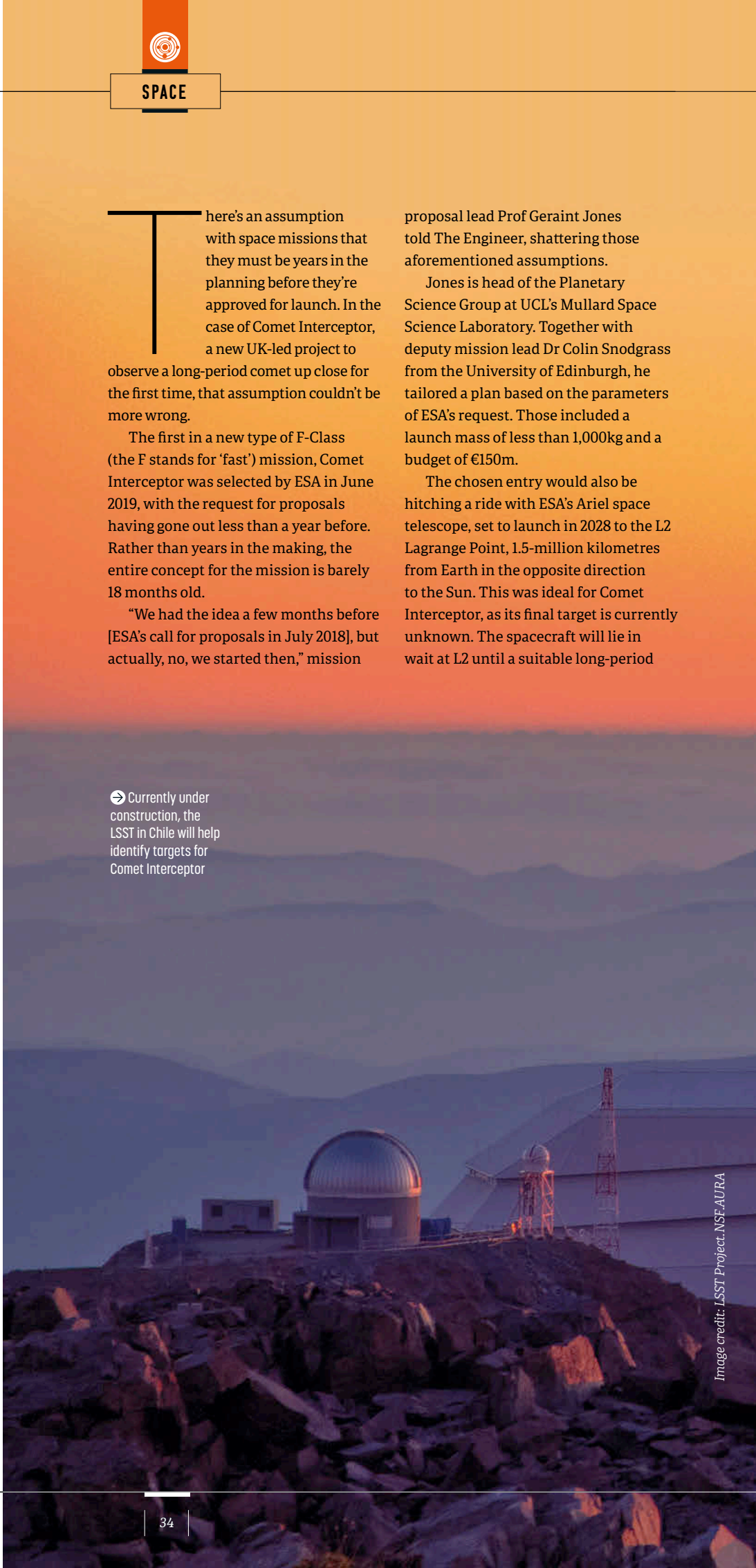


Image credit: LSST Project, NSF, AURA

comet – or even an interstellar object such as Oumuamua – is identified from Earth. It will then travel to intercept its target, splitting into three separate craft that will help create a 3D profile of the celestial body.

“The really nice fit with our mission is the fact we’re being delivered to Lagrange point L2 and we can just sit there and wait,” Jones explained. “For almost every other mission to a small body you have to identify your target beforehand and then you’ve got launch windows where you can only launch at certain times of the year.

“Other missions could be delivered to L2 and then just leave when they needed to go to their targets, but it’s not the most efficient way of doing it. For our proposal, it’s part of the whole concept that we sit there and wait for the right

target to come along.”

The mission’s goal is to characterise the comet’s surface composition, shape and structure, as well as the make-up of its gas coma. Each of the three spacecraft will carry a unique sensor suite, comprising cameras, imagers and spectral analysers. When we spoke to Jones, the team was still in consultation with ESA over the exact payload, with the space agency due to make its final decisions at the end of October. According to the professor, this type of wrangling is typical as the costs and benefits of individual instruments are weighed up. What’s important is that the core scientific objectives of the mission are maintained.

“The whole point that we’re doing this for is ultimately for

↓ Prof Geraint Jones, head of the Planetary Science Group at UCL’s Mullard Space Science Lab



the science,” he said. “So, we do want to be assured that whatever does get descope or removed potentially, that it doesn’t impact the science too much.

“We do have an input, but ultimately it’s ESA’s decision. We’re working closely with them. For the proposal, we had to provide a science traceability matrix showing all the scientific objectives and goals that we have, and which instruments would meet them. So, if any area looks like it might be reduced in terms of scientific return, we can point out the implication so that’s also taken into consideration.”

Most space missions tend to rely on tried-and-tested equipment where possible. For Comet Interceptor, the accelerated timeline makes this especially →

“IT’S PART OF THE WHOLE CONCEPT THAT WE SIT AT L2 AND WAIT FOR THE RIGHT TARGET”



pertinent. Its instrumentation is influenced by previous ESA endeavours, including the Rosetta mission that captured the world's attention back in 2014 when its Philae lander touched down on comet 67P/Churyumov-Gerasimenko. Comet Interceptor's plasma package and mass spectrometer have taken cues from Rosetta, while echoes of other missions can be found throughout the payload.

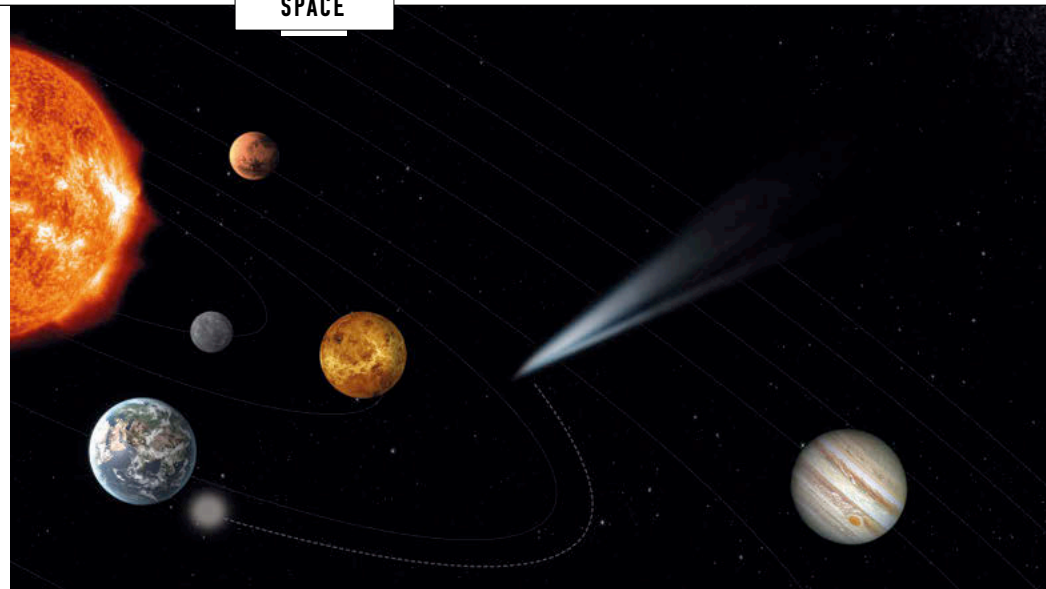
"Every instrument has got strong heritage or is largely a re-flight of a previous instrument," Jones explained.

"So the main camera, CoCa [Comet Camera], led from the University of Bern, large elements of that are actually based on the CaSSIS [Colour and Stereo Surface Imaging System] camera that is on the ExoMars Trace Gas Orbiter that's orbiting Mars now: another ESA mission."

It's not just ESA's experience that the mission will be tapping into. One of Comet Interceptor's three spacecraft will be developed by JAXA (Japan Aerospace Exploration Agency) and is set to carry a Lyman-alpha hydrogen imager, as well as a wide-angle camera and plasma suite. Members of Jones's team had already been working with the Japanese agency on imaging hydrogen around comets, so the collaboration was a natural fit.

"Although it's a much reduced-cost mission compared to the usual-sized missions that ESA launches, it still has to reach a minimum threshold of design maturity and JAXA clearly has the expertise to do that," said Jones. "It has flown a small satellite in deep space arguably before anyone...it's fantastic to have them on board."

As well as liaising with JAXA, ESA



Graphic concept illustrating the mission's journey from L2 to intercept a target (Credit: ESA)

and numerous space scientists around the world, Jones himself is heading up development of the EnVisS (Entire Visible Sky coma mapper) instrument. Based on the JANUS camera that will fly on board ESA's JUICE (JUUpiter ICy moons Explorer) mission in 2022, EnVisS will map the entire sky around the comet's head and near tail, revealing changes in the structure of its dust and gases.

Comet Interceptor's multinational team includes scientists from the length and breadth of Europe, as well as India, Japan, the US, Canada, Russia and Chile. The last of those countries is likely to play a pivotal role in the mission's outcome, as Chile is home to the Large Synoptic Survey Telescope (LSST). Currently under construction high in the Andes, the LSST will use three primary mirrors and the world's largest digital camera (3.2 gigapixel) to photograph the entire visible sky anew every three nights or so. When it's fully operational in 2023 it will be the most likely source of targets for Comet Interceptor.

"LSST in particular is expected to

basically revolutionise things," said Jones. "So, we probably will find more comets, but what's most important for us is that they're found further out."

With Comet Interceptor not launching until 2028, it's entirely possible that the mission's target may already be identified by then, either by the LSST or other comet-hunting telescopes such as Hawaii's Pan-STARRS.

"That's what we're hoping for," said Jones. "We're preparing a plan for choosing targets as well. We may have - if we're lucky - two or three and have to decide between them. If there's an interstellar object, for example, I would expect that to trump all the others."

Intercepting an interstellar object is particularly enticing, as astronomers have only recently confirmed their existence. Two years ago, the oblong-shaped Oumuamua set pulses racing when it was detected by Pan-STARRS, with suggestions it may even have alien origins. Although that theory has been debunked, the mysterious tumbling asteroid has raised a whole host of new questions for astronomical science.

On 14 October 2019, a second interstellar object, Borisov, was confirmed. Its shape and behaviour align with conventional comets, with only its hyperbolic speed indicating origin outside our solar system. This only serves to highlight the strangeness of Oumuamua, as well as how little we know about these interstellar visitors. Whether Comet Interceptor gets to observe one up close remains to be seen, but the possibility is certain to keep stargazers excited over the coming years. **THE ENGINEER**

Artist's impression of Oumuamua (Credit: ESO/M. Kornmesser)



Image credit: credit_ESO_M. Kornmesser

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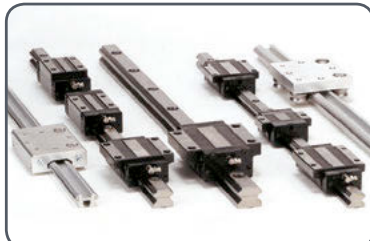
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SEATING PLAN

Life for disabled children and their families is difficult enough without having to contend with constant discomfort. Children with developmental and other disabilities depending upon wheelchairs or supports to help them sit upright face a number of difficulties: owing to lack of muscle tone and sometimes uncontrollable movement, they tend to slump into seating. Not only is this unpleasant, it can lead to organs becoming compressed, which, in turn, can lead to further developmental problems. Moreover, it can make communication – often affected by disability and tricky in any case – even more difficult.

All of these were problems which Hsin-Hia Yu faced while growing up. Suffering from scoliosis (curvature of the spine) following an accident as a child, she spent years in a wheelchair. “It’s affected me: the way I sit or the way I feel comfortable day to day,” she said. It was this experience that led to her interest in the social impact of engineering on individuals as she undertook her double Masters postgraduate degree in mechanical engineering and product design at Imperial College London and the Royal College of Art.

As part of this degree, Yu studied a module called Machines for Living, which involves designing for people with physical disability. Her project in this module was called Aergo, and involved designing a seat for wheelchair-using children with the sort of postural problems that had affected her as a child. “I was working with a special needs school called Treloar in Hampshire. It’s a boarding school, and most children there have cerebral palsy. I realised that the pain I experienced as a child is even worse for them. They rely a lot on external equipment just to fix them in position. And because their posture is not aligned, they tend to slump in different directions. That’s not just painful; it means they can’t communicate smoothly, and they tend to get discriminated against even more because of the way they’re sitting. And that’s why, in relation to my own

The Royal Academy of Engineering’s Enterprise Fellowship Scheme links young engineers with ideas with people who can help turn them into businesses. Stuart Nathan talks to Enterprise Fellow Hsin-Hua (Sheana) Yu, whose business Aergo helps severely disabled children sit more comfortably

STUART NATHAN REPORTS

personal experiences, the pain I experienced from scoliosis growing up, and the social challenges these children face with disabilities, I wanted to come up with a better solution that would empower them not just physically, but also socially.”

The answer Yu came up with relies on inflatable air cells embedded in an adjustable child-sized wheelchair seat. These cells are connected to pressure sensors that continuously collect data as the child moves in the seat. “They calculate and monitor what is the pressure levels at different air cells to determine the user’s position, then inflate and deflate different pockets to reposition the user,” Yu explained. In the current version of the seat, six cells are positioned at various points: one in the lumbar region, two in the laterals, hugging the user just above the hips, two acting as pelvic support directly under the user, and one at the front of the seat to raise the knees.

Children find it hard to sit still at the best of times, and wheelchair users tend to wriggle out of the prescribed seating positions constantly. “The constant feedback the Aergo system receives from instances and the dynamic inflation and deflation of the air cells hugs them in a more comfortable scaffold system and prevents them from falling out of the optimum position for their development, communication and comfort.”

Children can always be depended upon to grow, and so Aergo has designed seats in four sizes, to accommodate users up to the age of 16. “We are trying to accommodate and have early



PRODUCT DETAILS

The Aergo chair is adjustable manually to fit its user, as well as containing the automatic air cell monitoring and control system to stabilise the user’s seating position





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Sheana Yu
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Sheana Yu suffered discomfort from scoliosis as a child, inspiring her later work



ENTREPRENEURS

intervention when the spine is still growing to make sure that before adulthood the user wouldn't develop any more complications," Yu explained.

One of the guest lecturers at Imperial was Prof Sir Saeed Zahedi, a fellow of the Royal Academy of Engineering and technical director of prosthetic specialist Blatchford. "Zahedi came to Imperial to share the Blatchford portfolio of how it went about designing prosthetics and how it worked with amputees; he also talked about moving into the more speciality area of the market because it is looking at preventing pressure injuries. I re-approached Zahedi after I graduated, and he encouraged me to apply for the Enterprise Fellowship. He's played a very important role since the very beginning of the Aergo journey," said Yu.

The Royal College of Art provided the initial help for Yu to start a company, contributing seed funding, office space and business mentorship. Once her application for the Royal Academy of Engineering Enterprise Fellowship was successful, Zahedi became increasingly important, she explained. "Because I'm a sole founder, he's helping me at a personal level in terms of leadership management and project planning. And that's a big benefit to the business.

"On the other hand, he's come to the office to discuss with the four members of the R&D team about how we should approach medical device regulation, what are the hurdles with my students, and what we need to start addressing now in terms of the design of the device. He's very familiar with the industry, and that has been really helpful for my engineering lead to oversee the process in making sure that all the technical file product spec is compliant with the medical device standards."

Yu and her team are currently preparing Aergo for a full commercial launch at the end of this year, to coincide with the Occupational Therapy Show at the National Exhibition Centre,



// OVER THE PAST THREE YEARS, WE'VE BUILT RELATIONSHIPS WITH THE MARKET'S GATE-KEEPERS //



☛ Aergo's lightweight construction helps in its use in different modes, with or without its wheeled base

but in the meantime, they have several trials in progress around the country. "We work with Alder Hey, which is an NHS children's trust that operates around Liverpool. It's played a critical role in advising us about the position of the air cells, how supportive they should be and how fast they should react, and it has also provided some of the users to test the device. Alder Hey told us that we shouldn't approach the NHS directly as a purchaser, because it would insist on huge discounts and skew the margins. Unless you can produce in very large volumes it can make things difficult. Alder Hey's advice was the private sector was a better target as we were starting out, and it put us in touch with its distributors and charities who help parents to buy equipment. Parents tend to be very savvy in looking for equipment for their children: they attend exhibitions and share information through online forums. Through that, our advertisements, and through charities tweeting about the device, we've had quite a lot of people approach us about testing the chairs."

The medical devices market is a challenging one in which to launch a company, said Yu, which is why Zahedi's mentorship was so valuable. "There are considerable barriers to entry. Our system is a combination of mechanical engineering, electronics, software, and a lot of design, even down to the upholstery, making sure that the fabric choices are also biocompatible to the user's skin. There's a level of development that went into making Aergo the safest and most robust it can be, because the target users are so fragile, and safeguarding children is a very high priority. There's a lot of gatekeepers in the market. Over the last three years in parallel to development, we've established our network and built relationships with these gatekeepers and really, really got the word out there that we're an inclusive company."

Another possible market for Aergo's technology is the ageing population. Older people who are confined to bed or wheelchairs are often highly susceptible to pressure sores, and the constant monitoring of sensors and dynamic adjustment of the air cells is an effective way to avoid this (similar technologies are used to prevent foot sores in diabetic people). Other applications for less medical markets are also possible. "We patented the air cells individually," explained Yu. "They're modular and can be integrated to a range of weight-supporting systems, because our goal is to evolve into a licensing model where we work with manufacturers in the beginning of the production of seating to have this air technology integrated, so that people or office workers who are quite prone to lower back pain could benefit from the technology. As well as pressure beds in hospitals, or car seats or airlines. In the future, we hope that we could make everyone more comfortable." **#ENGINEER**



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Japan's electronic toilets are something of a cultural touchstone for the rest of world. They embody the country's forward-thinking, futuristic society, as well as its deep respect for water and ritual ablution, rooted in the Japanese ethnic religion of Shinto. For many in the west, these high-tech toilets are as quintessentially Japanese as sushi or karaoke. Yet the concept did not originate there.

The first toilets with integrated bidet or 'shower' features appeared in the US in the 1960s. These were non-electronic devices that sprayed water at ambient temperatures and were largely used in hospitals. It was not until Japanese toilet manufacturer Toto took up the baton that the concept truly took off and made its way into domestic bathrooms.

Toto's first Washlet product was released in 1980 – an attachable electronic toilet seat with integrated rear washing, drying and heating functions. In 2019 the company celebrated its 50 millionth global sale. In the intervening years, the term 'washlet' has been genericised in Japan, becoming synonymous with 'shower toilet' in much the same way that 'hoover' has with vacuum cleaners in the UK.

"Around 32 per cent of homes have a dishwasher in Japan," explained Floyd Case, specification and projects manager for Toto Europe. "Whereas 80 per cent have a washlet."

It's an astounding level of adoption that's yet to be replicated outside Japan, but Case believes this is slowly changing and Toto's impressive London showroom is testament to the company's efforts to spread the good word. Although best known for its Washlets, Toto was founded all the way back in 1917 and is one of the world's biggest toilet manufacturers. It employs 25,000 people, 900 of whom work in R&D. For western luddites not quite ready for the full-blown electronic bidet experience, Toto can point to plenty of other high-tech wizardry.

Around 2002, the company decided to reimagine the toilet from the ground up, incorporating a rimless design, a hydrophilic zirconium glaze and



Royal flush

↑ TECH SPECS

As well as electronic bidet features, many Japanese toilets also have heated seats that open and close automatically. Some even include built-in noise generators that mask any sounds during use.

Japanese toilets incorporate a fascinating array of technologies and are starting to take off in the UK

ANDREW WADE REPORTS

an entirely new flush dynamic called Tornado Flush. This last feature employs complex CFD analysis to remove waste more efficiently, using less water and comprehensively cleaning the inside of the bowl with a swirling action from multiple entry points.

"It's basically a twin-axis flushing system, so the water is made to rotate vertically in the bowl, but also horizontally," said Case. "The key thing

is we're making the water work much harder, accelerating the energy in the water... we're using physics as opposed to brute force to get rid of the waste."

According to Case, the company is constantly looking for incremental improvements in this flushing mechanism, using some of Japan's most powerful supercomputers to optimise its ceramics modelling. The result is claimed to be a toilet with a quieter



flush that outperforms competitors in removing waste.

“What that means on a practical level is that Mr & Mrs Jones flush the toilet once and it works,” said Case. “Or if you’re a hotel or a commercial building, you’re saving water and you’re reducing blockages, which is key, because there’s less maintenance.”

The flushing mechanism is complemented by the hydrophilic glaze on the ceramic that not only reduces friction but also attracts water, creating a sheen that enables the bowl to self-clean. A Toto subsidiary, Hydrotect, specialises exclusively in these types of coatings and licenses the technology for self-cleaning glass for skyscrapers and anti-bacterial tiles.

“Conventional ceramic, under a microscope, isn’t very flat,” said Case. “You’ve got all these microscopic pits in the surface, which is where bacteria and dirt can get a foothold.

“A hydrophilic surface means that water acts differently to conventional ceramic. When you put these things together with that powerful flushing system, the toilet maintains itself much better.”

Embedded within Toto’s ceramic are titanium dioxide, zirconium and other minerals and elements that create a photocatalytic reaction that helps eliminate bacteria. While it works perfectly fine by itself with no electronic

assistance, several of the features on Toto’s Washlets are designed to enhance this photocatalysis.

Before use, the Washlet sprays a pre-mist that prevents waste sticking to the bowl. After flushing, a mist of electrolysed water – or e-water – with antibacterial properties is then sprayed. Finally, once the seat is closed, a UV light in the lid comes on, reacting with the oxygen in the electrolysed water and the ceramic coating to break down dirt and keep the toilet clean. According to Case, Toto is the only sanitaryware company to use electrolysed water in this way.

“We’re using normal water but we’re changing its properties within the seat itself by passing a small current through it,” he explained. “Using an anode and cathode principle we can extrapolate the hypochlorous acid in tap water and increase the potency of it... creating a disinfectant from normal water.

“After the Washlet’s been used it goes through a clean cycle where normal water goes in, we create the e-water, and that’s used then to clean the wand and sprayed into the bowl. It’s done after every use and it’s not a

↓
TECH SPECS
The wand on Toto’s Washlets is made from a silicone-based material that naturally repels bacteria. It sprays pre-warmed water at an angle of precisely 43 degrees, which prevents any waste from coming into contact.



stagnant tank, you don’t have to fill it up, you don’t add any chemicals.”

The wand is kept behind a flap and housed above the rim of the toilet itself, in a clean area away from the ‘action’. When called upon, it emerges to spray pre-warmed water at a precise 43-degree angle, apparently the most efficient for cleaning without itself coming into contact with waste. It’s made from a silicone-based material that’s naturally anti-bacterial and is cleaned inside and out between each use.

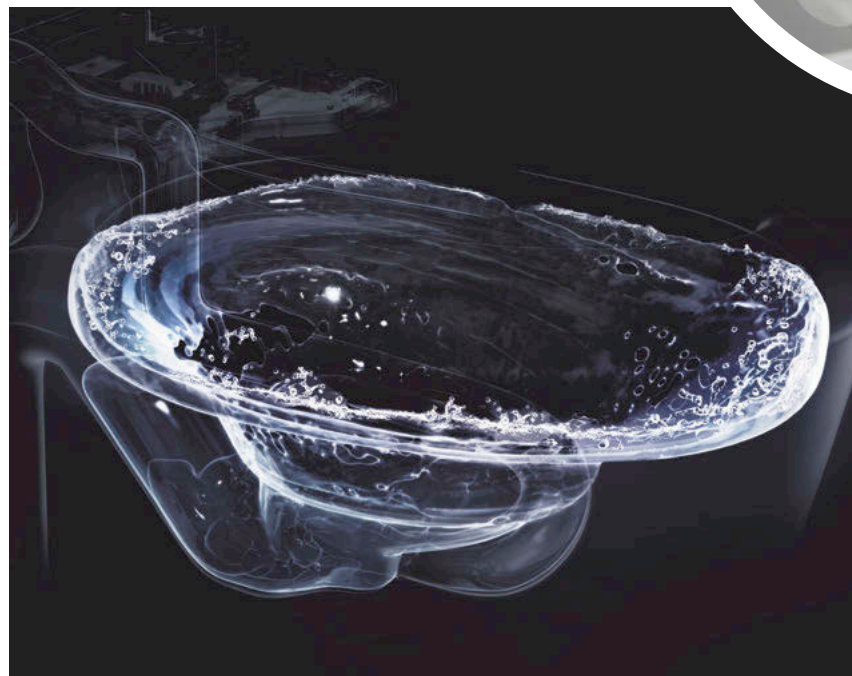
As well as front and back washes of varying pressures and temperatures, most models provide a pulsating function designed to help the user get down to business. Other standard features include automatically opening/closing and heated seats and built-in deodorisers.

“It has a deodoriser system built in,” said Case. “That’s extracting the air from within the bowl, sucking it out through a pre-filter and main filter. The main filter is a carbon filter, so it’s neutralising the odour and then putting the air back in the room.”

All these bells and whistles do require a dedicated power and water supply, which is easy to include off-plan but not so easy to retro-fit – one of the reasons shower toilets

have failed to penetrate western markets to anywhere near the same degree as Japan. But Toto’s products can increasingly be found in high-end London hotels and restaurants, as well as new apartment complexes. For the great unwashed to be converted, Case argues, they first have to experience the magic, and the same goes for builders and developers.

“The biggest challenge we have is getting people to think about the toilet,” he said. “I think a lot of design and construction is more or less cut and paste because people don’t consider the toilet as being a technology-driven area. It’s just a ceramic bowl. So, we still have that challenge.” #ENGINEER



← **TECH SPECS**
Using some of Japan’s most powerful supercomputers, Toto has optimised the ceramics of its bowls to create the ultra-efficient Tornado Flush. Its rimless bowls are also covered in a zirconium coating to minimise friction and reduce waste.



Energy storage is increasingly vital, both for the ongoing shift from fossil-fuel powered to electric vehicles and to bolster the grid to cope with generation from intermittent renewables. Batteries are a major focus for engineering research and a key part of UK industrial strategy. *The Engineer* quizzed UK-based and British experts on what's to come.

Meet the experts

Dr Amrit Chandan - chief executive of Aceleron, a clean technology company which builds lithium ion battery packs using recycled cells from automotive systems.

Dave Sandells, chief technology officer of Hyperdrive, a designer, developer and manufacturer of battery systems with a 9000 square foot, 30,000 unit/year factory in Northeast England

Scott McGregor, chief executive of RedT, a Jersey-based specialist in vanadium redox flow industrial energy storage systems

Alan Greenshields, chairman, Innolith, Switzerland-based innovative battery developer

Are you seeing new battery technologies (i.e. non-conventional lithium ion) getting close to the markets now?

AC: We're really excited about the future of battery chemistry development.

Q&A:

Battery technology and the future of electrification

Battery development is a key component of our electric future. The Engineer asked four leading figures in the battery sector how they see this important technology developing in the coming years.

STUART NATHAN REPORTS

Battery technologies are constantly improving and advancements, such as exploring graphene as an alternative to lithium-ion or ditching the precious metals entirely, are continually advancing the sector.

DS: There are a lot of developments happening at an R&D level right now, with people trying to overcome limitations of Li-ion batteries – increased life, increased energy density and improvements in safety being the main challenges that are being worked upon. It's worth remembering that Li-ion has been commercially available since the 1970s and it's taken 50 years to get to the stage that we're at now. New technologies will need to be revolutionary, rather than evolutionary, to effectively displace Li-ion in the near future.

AG: There is always a lot of innovation in battery research; the big question is which of the technologies will make it into a commercial product. Right now, the world's attention is on solid state batteries and the promise they have of higher energy densities and lower fire risk, but the jury is out on just how long these batteries will take to come to market (if ever). There has also been some interesting work on flow batteries and for some applications these could be very useful. I would, of course, also have to mention the rise of inorganic electrolyte systems and Innolith's



SCAN ME

// NEW TECHNOLOGIES WILL NEED TO BE REVOLUTIONARY RATHER THAN EVOLUTIONARY TO DISPLACE LITHIUM-ION IN THE NEAR FUTURE // Dave Sandells, Hyperdrive

development of new batteries with very interesting characteristics including exceptionally long cycle life, ultra-high energy densities and zero fire risk, as the electrolyte is non-flammable.

Will incremental development of current technology be sufficient for our needs in automotive and grid storage?

AC: There is a critical mass behind lithium-ion and incremental development in this established technology has the benefit of widespread innovation and progress. But a radical step change could address some of the current issues faced by the industry, such as cost, supply of components and waste.

A step change is certainly required in battery recycling to ensure all the parts and metals are captured. We don't want a new 'fossil fuels' situation when lithium reserves run low.

DS: I think that we do need a step change to make batteries the 'go-to' technology in applications such as grid storage. At present there are corner-cases where battery technology absolutely makes sense – but to become the de-facto standard more innovation is required.

SM: New technology in this sector is very difficult to take from research project through to a durable infrastructure application. There are now multiple mature storage technologies which are capable of meeting our needs.

AG: To truly cross the chasm to electrification of transport and renewable energy storage we need much higher energy densities as this would both enable applications and drastically cut costs. Traditional Li-ion using organic electrolyte is neither going to be able to reach the energy densities that will be needed nor usable life. It is widely accepted that there is a theoretical limit of 500 Wh/kg for traditional Li-ion, and a practical limit of 400 Wh/kg, the world needs batteries for cars and storage that can achieve 600 – 1000 Wh/kg. Concerns about safely

disposing of or recycling used batteries are growing – increasing usable life is probably the biggest lever to slow down exponential growth of scrap batteries.

Is the UK well-placed to make the advances needed in battery technologies?

AC: The UK is in a strong position. We have numerous pioneering individuals and organisations leading the advancement of battery storage technology, but we would like to see more support from the government. Energy storage technology will play an important role in mitigating the climate crisis. We would like to encourage the government to invest more in this technology to speed up innovation and maintain the UK's leading position in the global market.

DS: The UK is well placed with organisations such as the UK Battery Industrialisation Centre (UKBIC) and initiatives like the Faraday Battery Challenge and Driving the Electric Revolution (DER) ensuring that the UK takes a leading role in the battery industry. Finding truly compelling answers to questions surrounding battery manufacture, battery recycling and battery technologies will ensure the UK stays at the forefront of the industry.

SM: Our Prime Minister has proudly asserted the UK's leading role in the development of battery technology and there's definitely justification for his optimism. One example of that is a project we're a part of called Energy Superhub Oxford (ESO) – which aims to deploy one of the world's largest hybrid battery systems to support the acceleration of Oxford's electric vehicle charging capacity and power ground-



Dr Amrit Chandan
- chief executive of
Aceleron



Dave Sandells,
chief technology
officer of
Hyperdrive



Scott McGregor,
chief executive
of RedT



Alan Greenshields,
chairman, Innolith,

source heat pumps for residential properties.

However, much more could be done when it comes to practical policy, allowing electricity network operators to contract more flexibly across the market and also offer more attractive long term ancillary service contracts which provide the right incentives to achieve the UK's decarbonisation goals.

AG: The UK has first class universities and a great track record in battery research. In fact, the pioneering work on organic Li-ion batteries was undertaken at Oxford University. What the UK lacks is the means to encourage and nurture the battery technology innovators it creates.

What role are automotive OEMs likely to play in battery development and testing?

DS: Automotive OEMs have the size and the power to help define the future of battery development and testing. A current strength of OEMs is their ability to optimise costs at high volume, which is key to widespread adoption of battery technologies in the future. A potential weakness of OEMs is their reluctance to invest for the very long-term future. To develop new technology takes significant time and investment before appreciable returns are seen.

SM: Automotive OEMs have played a major role in bringing the cost of conventional lithium and lead-acid batteries down significantly. It does however remain to be seen whether these technologies, originally designed for e-mobility and consumer electronics will prove to be the optimum choice for grid-scale applications in the future.

AG: The automotive manufacturers are undoubtedly going to be leaders in this movement, but they are aware that the partnerships with battery manufacturers and the battery innovators are going to be critically important to being new technologies to market. It can take 10-20 years for a battery technology to move from lab research to a commercial product, but the world is starting to rely on batteries in every facet of people's lives. We need to accelerate the time to market by a factor of three or four if we are truly going to make the transition to electrification happen. #ENGINEER

// WE WOULD LIKE TO ENCOURAGE THE GOVERNMENT TO INVEST MORE... TO SPEED INNOVATION // Amrit Chandan, Aceleron



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A CELEBRATION OF COLLABORATION

Winning projects in The Engineer's 2019 C2I awards embodied the very best of UK engineering collaboration

Modern engineering spans a dizzying and sometimes surprising range of application areas. But as the projects featured over the following pages highlight, the most successful engineering projects often have one common ingredient: they're the product of collaboration – the meeting of different mindsets, ideas and disciplines that so often provides the spark for innovation.

Now in its fourth year, The Engineer's Collaborate to Innovate awards was launched to celebrate this dynamic and uncover some of the

UK's most innovative and inspiring examples of engineering collaboration in action.

Over the following pages we spotlight the winners of this process, and examine how collaboration has been key to their success.

As well as demonstrating how engineers are applying emerging technologies to solve some of mankind's most pressing challenges, this year's finalists can also teach us some valuable lessons: not least the huge benefits of embracing a cross-disciplinary approach, and how ensuring that every member of a team is aware of the end goal is the most effective route to overcoming some of the challenges collaborative working presents. Many of our winning projects also highlight a particular strength for the UK, the richness and depth of its academic/industry collaboration and the incredible things that can be achieved when academia and industry are truly aligned.

As the stories over the following pages demonstrate, there are plenty of reasons to be positive about the state of UK innovation. But the conditions that sustain it shouldn't be taken for granted and it's important that industry academia and government work together to nurture and maintain this climate.

One key to this is ensuring that we have the skills base to continue to innovate in the future by inspiring and engaging the next generation of engineers, something that we celebrate in this year's Young Innovator award.

You can find out more about all of this year's winning projects at our website www.theengineer.co.uk

AUTOMOTIVE

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Project Name: Magnet Free Traction Motors for Commercial Vehicles: HDSRM

Team: Advanced Electric Machines Limited with Tevva Motors, Newcastle University, Motor Design Limited

Switched reluctance motors have existed for almost as long as the internal combustion engine, but have suffered from weaknesses in performance which have limited their use in electric vehicles.

Unlike common DC motor types, in

a switched reluctance motor power is delivered to windings in the stator rather than the rotor. This simplifies mechanical design because power does not have to be delivered to a moving part.

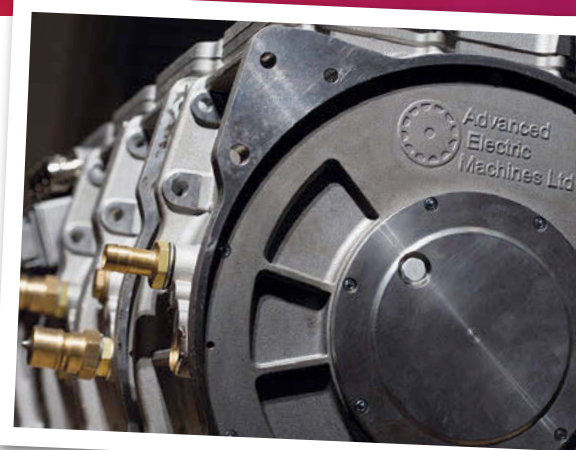
However, switched reluctance motors gained a reputation for being noisy. They also suffered from torque ripple – fluctuations in torque as the rotor rotates – which made them unsuitable for traction applications. They required different power electronics from permanent magnet machines to drive them, which, without economies of scale, were expensive.

The winning entry in this category – the product of a collaboration between Newcastle University spin-out Advanced Electric Machines Ltd; commercial vehicle maker Tevva Motors, Newcastle University,

and software specialist Motor Design – the High Density Switched Reluctance Motor (HDSRM), is claimed to overcome many of these problems.

AEM's breakthrough has been to make it possible to drive the SR motor using the same power electronics as a permanent magnet motor. And although it appears to the power electronics as a standard three-phase motor, it is in fact a six-phase design, which solves the torque ripple and noise problems.

Among the motor's main attributes is the elimination of rare earth permanent magnets and copper, both of which make end of life disposal more difficult.



AEM has also developed a patented manufacturing process that allows aluminium to be used for the windings. Aluminium is a tenth of the price of copper and easier to recycle – because it melts at a lower temperature than steel it can be recovered separately at the end of a motor's life, whereas copper contaminates the steel. →

UK engineering companies are potentially missing out on £10 billion of R&D funding each year

One in five (21%) eligible engineering companies aren't claiming the R&D funding potentially available to them

Eligible UK businesses are able to claim up to 33p of every pound invested in R&D activity

Engineering companies in the UK are potentially missing out on over £10 billion of R&D funding each year, new research has revealed.

The study, commissioned by innovation specialists MPA for Advanced Engineering 2019, found that one in five (21%) innovation active engineering firms are not taking advantage of the government's R&D Tax Credit scheme, which allows companies to claim back up to 33p for every £1 spent on R&D activity.

On average, engineering companies invest £386,000 a year on R&D activity, meaning they are potentially able to claim £100,360 in funding. With over 100,000 UK engineering firms not claiming, despite describing their company as innovation active, a staggering £10.2 billion is going unclaimed each year.

Reasons for not claiming the funding vary, but the most common answer given by engineers is that they don't believe their companies are eligible (10%).

However, the research revealed that many engineering companies probably qualify without them realising. Some examples of indicative qualifying activities are, if your company develops new processes to improve efficiency, quality or performance; overcome unplanned technical difficulties or create bespoke solutions for clients.

Two-thirds (67%) of workers think that

their firms are 'innovation active', which is the most accurate indicator that a company is eligible for the R&D Tax Credit scheme. Despite this, only a third (37%) say that their companies claim the available funding.

Another barrier blocking engineers from claiming is a lack of awareness about the initiative. Nearly a quarter (24%) of the surveyed engineers who aren't claiming admitted that they didn't even know that the scheme exists. Even among those who think they are innovation active, one in fourteen (7%) said that they were completely unaware of R&D tax credits.

While many are yet to take advantage of the scheme, engineering companies in the UK are planning on investing heavily in research and development. Over the next year, over one in five (22%) businesses in the industry are planning on spending over £1 million on innovative projects.

Nigel Urquhart, Senior Technical Analyst at MPA, said: "Engineering companies in the UK are respected all over the world for their quality and innovation, but a worryingly low number of them are claiming the R&D funding they are entitled to.

"Our research has highlighted that more work needs to be done to raise awareness of the R&D Tax Credit scheme, as these innovative companies

could save themselves hundreds of thousands of pounds. This money could then be reinvested to fund further innovation, which would ensure UK engineering stays at the forefront of the industry."

To see whether your company is eligible for the R&D Tax Credit scheme, visit: <https://mpa.co.uk/services/rd-tax-credits/>

About MPA: MPA help clients accelerate their innovation and business expansion. They help companies to capitalise on their research, innovation and development activities by maximising all the potential benefits from available HMRC tax concessions. MPA's experienced industry specialists and tax experts focus on maximising client value with high quality client service delivery. Working with them, their clients have received more than £180m of financial benefits for their business using the R&D tax credits and Patent Box concessions.

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¹ Survey of 250 UK engineers conducted by The Engineer on behalf of MPA in September 2019

² R&D tax credits calculator: <https://mpa.co.uk/services/rd-tax-credits/>

³ Office for National Statistics: 'Engineering Industry in the UK' (December 2018) - there are 721,940 active engineering enterprises in the UK. 485,143 (67%) of these are innovation active. 101,880 (21%) of these innovation active companies are not claiming R&D funding: [//www.ons.gov.uk/businessindustryandtrade/business/activitysizeandlocation/adhocs/009383engineeringindustryintheuk](https://www.ons.gov.uk/businessindustryandtrade/business/activitysizeandlocation/adhocs/009383engineeringindustryintheuk)

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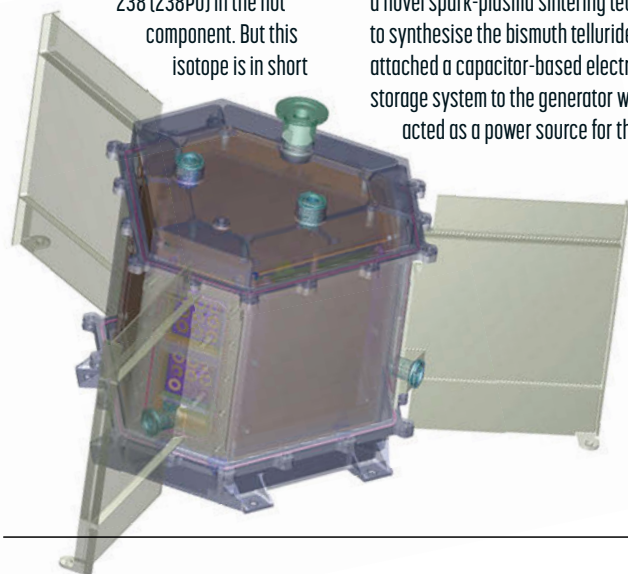
Project name: UK Scientists generate electricity from rare element to power future space missions

Team: University of Leicester, National Nuclear Laboratory & European Thermodynamics Ltd

The winner trophy for this year's aerospace category has gone to Richard Ambrosi from the University of Leicester, who led a collaboration with the UK National Nuclear Laboratory (NNL) to extract a fuel from stockpiled plutonium that could power humanity's exploration of the distant solar system.

Radioisotope thermoelectric generators (RTGs) have been powering the US Voyager probes for decades, and NASA's Curiosity rover contains one that allows the vehicle to operate during the Martian night. They typically consist of a chunk of a radioactive material which gets hot as a result of nuclear decomposition. One end of a thermocouple is attached to the hot material, while the other is kept at the much colder temperature of the spacecraft's environment. The temperature difference forces a current to flow from hot to cold.

They generally use plutonium 238 (238Pu) in the hot component. But this isotope is in short



supply, and is only produced in specialist nuclear reactors. The European Space Agency (ESA), which currently does not operate any RTG-powered spacecraft, decided in 2009 that it would develop its own capability so that it could consider deep space exploration missions, and as part of this effort, NNL contacted Ambrosi's team at Leicester, who are specialists in RTG technology.

Ambrosi explained to The Engineer that the plutonium stockpile, a result of reprocessing nuclear fuel, was an obvious choice of source for an RTG fuel. "The plutonium isotope it contains is not in itself suitable, but as it is stored its natural decomposition contaminates it with americium 241 (241Am). If you want to then utilize the plutonium in a nuclear power plant, you have to extract the americium anyway to clean up the plutonium."

The Leicester team developed a thermoelectric conversion technology specifically for this project, with a special geometry for the thermoelectric modules designed to maximise the temperature difference between the 241Am pellet and the exterior environment. The element that converted temperature difference into electric current was a semiconductor based on bismuth telluride, and earlier this year the team demonstrated that this could produce enough current to operate an electric light. The Leicester team developed a novel spark-plasma sintering technology to synthesise the bismuth telluride, and attached a capacitor-based electricity storage system to the generator which acted as a power source for the light.



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Project name: SCENe (Sustainable Community Energy Networks)

Team: University of Nottingham with Loughborough University, Igloo Blueprint, Urbed, Siemens, Solar Ready and Confers

Project SCENe is a working partnership between engineers at the University of Nottingham, the local authority and experts from the housing and energy sectors that's transforming local energy infrastructure and could be rolled out across the UK.

The project applies multi-vector energy systems, including solar power and localised energy storage, combined with carbon neutral housing technology, to create what the partners say is the first robust and "smart" business model for sustainable community energy.

A team led by Professor Mark Gillott, Chair in Sustainable Building Design at the university and the academic lead for project SCENe, built an early demonstrator living lab at the university campus, using smart technology to monitor and record energy shared usage, which gave

commercial partners the reassurance to scale it up.

The model was transferred into Trent Basin where 42 homes are already inhabited and plugged in to the system, another 31 sustainable homes are being built and 500 homes are planned. Trent Basin is the first ever new-build residential site to generate, store and use this electrical power for community benefit.

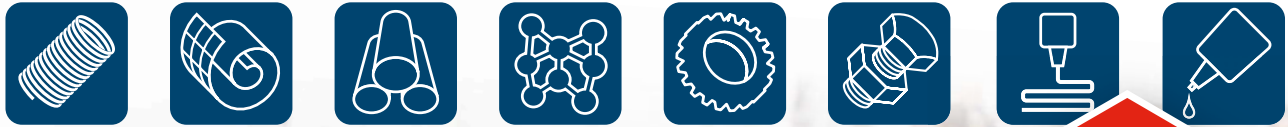
Since May 2018 when the system went online, SCENe has saved 110 tonnes of CO₂, generated over 310,000 kW/hours of renewable energy, offset energy costs by 25% and created a new company and business model that is attracting interest from more developers.

SCENe generates its own renewable energy from solar panels fitted on the homes. These feed a community battery - claimed to be the largest in Europe - supplied by Tesla, that stores power locally and is connected to the national grid. The battery can store 2.1MWh of energy that delivers 500kW of power, enough to power 167 electric kettles simultaneously for over four hours. →

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HEALTHCARE & MEDICAL

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Project Name: Laparoscopic molecular probe for prostate cancer surgery

Team: Lightpoint Medical with National Physical Laboratory

In cancer surgery one of the main difficulties for surgeons lies in distinguishing between cancerous and healthy tissue. The risk is twofold: cancer cells can be missed so the patient requires further treatment, or healthy tissue is unnecessarily removed, which can lead to other health consequences and complications.

Lightpoint Medical's Sensei probe aims to address this problem by making it possible to identify cancer cells during laparoscopic (keyhole) surgery in real time.

Developed in partnership with the National Physical Laboratory, the probe is able to detect radiopharmaceuticals (radioactive drugs widely used in pre-operative diagnostic imaging of cancer) interoperatively and give live feedback to the surgeon, so they can target the

cancerous tissue while sparing healthy tissue.

The device has almost completed its product development phase and Lightpoint's team is preparing for clinical trials, which are expected to start early next year.

Key innovations include miniaturisation (the probe must fit through a 12 mm portal in the abdomen) and the probes tethered format. The probe is a small instrument on a flexible cable. A nodule behind the probe head allows it to be grasped by a manual or robotic surgical grasping tool operated by the surgeon from outside the patient's body. "This allows them to articulate our probe through the full six degrees of freedom," Dr Vyas said.

Several surgical specialists used the model to evaluate different grip designs and to demonstrate that they could successfully manipulate the probe and detect the radioactive capsules.

The probe is now ready for clinical trials. The first application will be to detect sentinel lymph nodes for sentinel lymph node biopsy, in prostate cancer surgery.

INFORMATION, DATA AND CONNECTIVITY

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Project Name: GeoSHM

Team: University of Nottingham with UbiPOS, BRDI, Leica Geosystems, GVL & Transport Scotland

GeoSHM (GNSS and Earth Observation for Structural Health Monitoring) uses multiple space technologies combined with in-situ sensors to provide a real-time picture of bridge movement and stresses.

At the core of the system are GNSS (Global Navigation Satellite System) receivers that pick up positional data via the GPS, Galileo and BeiDou Navigation Satellite (BDS) constellations. This real-time monitoring is complemented by interferometric synthetic-aperture radar (InSAR) data provided by Earth Observation (EO) satellites that can track potential ground subsidence of the structure.

The technology is being brought to market by UbiPOS UK, a spinout from the University of Nottingham. Collaborating partners include Leica Geosystems, Geomatic Ventures Limited and China Railway Major Bridge Reconnaissance

& Design Institute (BRDI). Various incarnations of the system have been deployed on the Forth Road Bridge (FRB) for over a decade, in partnership with Transport Scotland and current FRB operator, Amey.

In November 2018, the consortium deployed its first all-in-one monitoring suite on the FRB, combining GNSS receivers with an accelerometer, antenna and communications module. The patent-pending kit sends real-time data back to users via the GeoSHM Analyst Toolbox, where AI and analytics help evaluate the overall structural health of the bridge.

Away from the UK, collaboration partner BRDI in China has deployed a prototype system on two of its long-span rail bridges that cross the Yangtze river. China Railway operates more than 1,000 long bridges across the country, presenting a huge market opportunity for the technology. In 2020, GeoSHM will be installed on the Hutong Yangtze River Bridge, which will be the world's largest cable-stayed road-rail bridge, reaching 1,092 metres with its main span. →



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MANUFACTURING TECHNOLOGY

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Project name: SHYMAN - Sustainable Hydrothermal Manufacturing of Nanomaterials
Team: Promethean Particles with University of Nottingham and others

Radio frequency identification (RFID) tags are a key underpinning technology for the so-called Internet of Things.

But the high cost of producing one of the key raw materials for these tags, silver nano-particles, is holding back the full potential of the technology.

University of Nottingham spin out Promethean Particles hopes to change this.

Promethean is the outcome of a consortium of 18 industry and academic partners across Europe that developed the SHYMAN project (Sustainable Hydrothermal Manufacturing of Nanomaterials) winning a €10 million EU Framework 7 grant to develop a cleaner process to manufacture nanomaterials in large volumes.

These tiny particles, that can measure less than one billionth of a metre, are used in the manufacture of inorganic and organic pigments and metal nanomaterials, which are used in industrial applications including printed electronics, Metal Organic Frameworks (MOF), catalysts, healthcare and nanocomposites, including plastics and coatings.

SHYMAN has led to Promethean building the largest multi-material nanoparticle plant in the world, in Nottingham. The process - a continuous, sustainable hydrothermal synthesis of high-quality inorganic nanoparticles - uses hot water rather than potentially hazardous chemicals to fabricate the nanoparticles.

Crucially, the process has been successfully scaled up, and the working plant is able to produce up to 200 kg of nanoparticles per hour. It now produces 1,000 tonnes of nanomaterials a year, making it viable for commercial supply to chemical and industrial companies including Solvay, Fiat and Repsol.

Continuous hydrothermal synthesis produces nanoparticulate materials by mixing superheated or supercritical water flow with an aqueous flow containing a dissolved metal salt. So rather than slowly heating the entire contents of a batch vessel (called batch hydrothermal synthesis), two fluids are continuously mixed together.

The problems around this process were solved during years of research at The University of Nottingham and the reactor configuration necessary for continuous production was demonstrated at bench (g/hr) and pilot scale (kg/day) before the SHYMAN project began.

Continuous hydrothermal synthesis offers a true alternative to other, chemical-intensive production methods because it is a genuinely continuous process and is chemically more benign.

YOUNG INNOVATOR

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SOLIDWORKS

Project name: Facial Recognition Door Entry System and Home Monitoring System for the Elderly
List of collaborating partners: Freddie Howells, CETEC - Centre for Excellence in Technology Enhanced Care

The winning entry to this year's Young Innovator category - a system aimed at vulnerable elderly people live safely and independently in their own homes - provided the C21 judging panel with plenty of reasons to be optimistic about the future pipeline of engineering talent.

Inspired by the challenges facing his great Aunt Pat, who lives alone at home with dementia, Freddie Howells developed a facial recognition door entry system and a suite of home monitoring technologies to protect her from unwanted visitors and to check up on her welfare.

Developed by Freddie when he was just 12 years old (he's just turned 14) the system was created using a Raspberry Pi microcomputer.

For the entry system a PIR motion sensor attached to the front door triggers a camera to take an image when motion is

detected.

This is compared against a database of known faces and if the face is recognised, the visitor is prompted to scan their ID tag for 2 factor authentication. If the face and ID tag match, the door is opened via means of a 5V single channel relay attached to a 12V electric door strike. If they're not recognised or do not match, the user is prompted to call a number to gain access.

When the visitor gains access, a text is sent to the family alerting them to who has visited and when. At the same time an audio recording of the visitor's voice is played in the elderly person's room so they know who is visiting.

Freddie has also installed various monitoring devices around the home including a motion sensor which triggers a text alert if there is no motion for a period of time, and temperature and humidity sensors which will automatically turn on a fan if the temperature gets too hot. He's also installed a webcam which can be used for remote monitoring and a voice-activated intercom system that enables two-way communication without the need for the phone.





PRODUCT DETAILS

PTS's Vuforia augmented reality technology is helping improve a host of shop floor processes

Q&A:

Simulation innovations

Experts from some of the world's leading software suppliers offer their perspectives on the trends and solutions that are shaping their field

JASON FORD REPORTS

Digitalisation and vehicular autonomy are just two arenas in which software will be the leading driver of innovation, but what do leaders in some of the most influential software companies make of current and emerging trends, and what solutions will they offer to stay ahead of the game?

The Engineer has sought the opinions of Olivier Roll, Lead Solutions Engineer for Europe at ANSYS, Alan Prior, Senior Director, Technical Sales, Dassault Systèmes, and Paul Haimes, VP Europe Technical Sales at PTC to discuss the ways in which their solutions are driving product innovation and the changes taking place in industry that are accelerating innovation and growth.

What trends / customer requirements are driving developments in your area?

Paul Haimes (PH): We see many manufacturing organisations revisiting OEE (overall equipment effectiveness) and the need to better understand

factory performance. We see PTC customers' looking at IoT technologies, such as PTC's ThingWorx Industrial Internet of Things (IIoT) platform, as a way to improve OEE calculations – not by replacing existing OT infrastructure, but by connecting it to our IoT platform via our Kepware technology. Deployment of ThingWorx as part of a Smart Factory infrastructure captures a more detailed understanding of equipment availability, performance and quality through existing and secondary instrumentation - enabling OEE comparison between cells, between lines or between a global network of factories. These insights are the first step towards realising better performance and unlocking other Industry 4.0 use-cases such as Predictive Maintenance and Connected Workers.

Alan Prior (AP): Functionality is always a key topic for clients in the simulation domain, and we continue to see a demand for technical advances across all the main areas – structures, fluids, electromagnetics, etc. However, there is a strong emerging requirement for rapid improvements in productivity and effectiveness of teams working in product development. Firms need to develop products faster, in the face of competitive pressure on time-to-market; they need to develop products in a more holistic manner, taking into account supply chain, manufacturing and distribution; and they must also demonstrate a sustainable approach to product innovation, through the use of advanced materials.

Olivier Roll (OR): Megatrends such as electrification, 5G and autonomous vehicle engineering are revolutionising products and processes across many industries. Take vehicle autonomy, where car manufacturers now need cost-effective solutions that are accurate and ensure vehicle safety. Using physics-based simulations, we are able to simulate real world accuracy for autonomous vehicles. For example, one particular challenge for autonomous vehicle manufacturers is harsh weather conditions. Rather than waiting for a foggy day for road-testing, they can use ANSYS simulation to test vehicle sensor technology in foggy conditions, virtually. This means that the testing time before an autonomous vehicle is judged safe and roadworthy can be dramatically accelerated.

Give one or two examples of how your products are helping customers meet the challenges that they are facing?

PH: Augmented Reality (AR), through PTC's Vuforia technology, is improving



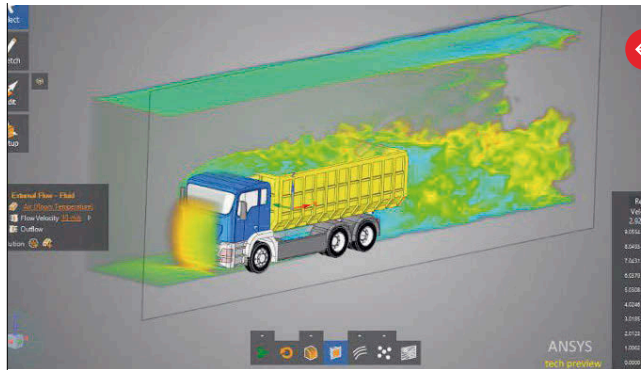
manufacturing, quality control or repair processes performed by operators on the shop floor. An operator can perform his or her tasks faster and with better consistency by overlaying their view with relevant 2D and 3D information. It's also important to add that AR now has the ability to meet the challenge of the ageing manufacturing workforce. PTC's Vuforia Expert Capture solution allows experienced operators to capture and document each step of their manufacturing, assembly or repair process. This first-hand information, often from retiring, ageing personnel, can be delivered to the younger workforce using technologies they are happy to adopt.

AP: Society's focus on sustainability is driving rapid development in the simulation capabilities for electric vehicles, alternative power generation and use of advanced materials. The simulation portfolio from the SIMULIA brand of Dassault Systèmes is advancing in all these areas. The multi-physics simulation of batteries, for example, involves a wide range of advanced capabilities in electro-thermal, mechanical and systems simulation.

OR: Last year, Volkswagen Motorsport broke the time record at Pikes Peak International Hill Climb. Finishing in 7.57.148 minutes. Volkswagen driver Romain Dumas crossed the finish line in Volkswagen's first-ever fully-electric race car - thanks to ANSYS' technology. Using ANSYS solutions, the car had been engineered to meet the extreme conditions of the race, with the ideal balance of cooling airflow and aerodynamic loss to determine the optimal performance of the vehicle.

What's the key product for you currently and how is it being applied?

PH: PTC's ThingWorx Industrial Internet of Things (IIoT) platform is established as the IIoT platform of choice for industrial companies around the world, enabling thousands of



← **PRODUCT DETAILS**
Ansys physics based simulation technology enables engineers to predict how a variety of products will behave in real-world environments

companies to realise the promise of a connected enterprise through digital transformation objectives. For instance, as of September 2019, approximately 2,000 global customers are using ThingWorx to connect their products, factories, processes, and people.

AP: While we continue to develop our various simulation technologies at pace, the major value for our clients comes from the 3DEXPERIENCE platform, which allows businesses to collaborate across their simulation, design, manufacturing and distribution functions, using a single source of the product definition, and minimising the siloed approach that has been so prevalent in the past. Rapid product innovation can only be achieved with multiple stakeholders all having access to a common, consistent, up-to-date definition of the product and supporting business operations.

OR: Physics-based simulation is becoming crucial in the design and development process. Engineers are now able to accurately predict how products will behave in real-world environments and using the ANSYS simulation platform enables them to couple multiple types of physics while building the virtual prototype of any product or system. ANSYS Workbench allows engineers to couple simulation across different physics in one simple environment. ANSYS' multiphysics solutions let engineers examine various effects - such as electromagnetic radiation or fluid forces - in any combination, allowing them to meet today's demanding product development requirements.

What products do you see changing your sector in the future?

PH: Factory connectivity as a technology is evolving at pace with the ability to connect wirelessly on the shop floor already in place in some leading manufacturers. Allied to this is the concept of self-provisioning equipment - where assets are

able to self-register on a network and automatically adopt connectivity and security templates. Linked to this is the adoption of Cloud technology. Companies are embedding hybrid enterprise architectures which accommodate both on-premise and cloud environments. This recognises the need to keep localised asset data within the factory while still benefitting from the scalability of Cloud environments.

AP: We see three trends that are changing the approach to simulation within the broader business framework. Firstly, the use of the cloud for large volume computation, with all of the associated benefits of accessing a highly scalable compute resource while reducing IT overhead. Secondly, the increasing use of a systems approach to product development, and the subsequent acceleration of the innovation process. And thirdly, the increasing acceptance of the power of machine learning to help guide innovative solutions.

OR: As the demand for autonomous vehicles grows, we have seen an increased appetite for AI technology and AI-enabled solutions. In the aerospace sector, we're currently working with Airbus on AI-enabled flight control software. Using our embedded software solution, Airbus is developing unmanned aerial vehicles that will be engineered for speed, safety and affordability. Developing these platforms creates a huge engineering challenge as advanced, safety-critical, AI-driven flight control software will be required to perform highly sophisticated decision making with unprecedented speed and accuracy. Using our embedded software flagship product, ANSYS SCADe, will deliver an exponential leap to Airbus' autonomous capabilities and will empower them to cost-effectively deploy AI-driven flight controls in safety-critical functions. #ENGINEER

➔ **PRODUCT DETAILS**
Dassault's SIMULIA portfolio is helping to drive advances in the development of alternative powertrain technologies





GUSTAVE EIFFEL: TOWERING AMBITIONS

Best known for his eponymous tower in Paris and the Statue of Liberty in New York, Gustave Eiffel's career was a mixture of technical achievement, public scandal and obscurity.

WRITTEN BY NICK SMITH

Despite being one of the most important engineers and aerodynamicists of his age, Gustave Eiffel's reputation ultimately rests on two instantly recognisable landmarks: the Eiffel Tower and the Statue of Liberty. His monumental career spanned seven decades, from his early civil projects such as the Bordeaux bridge to his later scientific research into air resistance. Living well into his nineties, Eiffel is remembered the greatest engineer France has ever produced.

Alexandre Gustave Bonickhausen dit Eiffel was born in Burgundy in 1832 at a time when France, under the rule of Louis Philippe I, was in a period of rapid industrial, economic and colonial expansion. His mother had a successful charcoal business and his uncle distilled vinegar: the former providing the undistinguished school student with a stable financial background, while the latter supplied an improvised education, teaching the young Gustave the rudiments of an eclectic set of disciplines that included chemistry, mining, theology and philosophy. This unorthodox background bore fruit to a degree when he was accepted by the École Centrale des Arts et Manufactures in Paris, where we know he specialised in chemistry and we think developed his passion for engineering. His enthusiasm for technology was nurtured by the fact that in 1855 Paris played host to the second World's Fair, for which his mother supplied him with a season



GUSTAVE EIFFEL 1832-1923

ticket. A quarter of a century later his famous tower would be the centrepiece of another technology showcase, the 1889 Exposition Universelle.

Eiffel's career got off to an uncertain start, with family disputes and employer bankruptcies obstructing his path. But eventually he fell into the orbit of railway engineer Charles Nepveu, managing director of two factories in Paris owned by the Compagnie Belge de Matériels de Chemin de Fer, and an influence on Eiffel's initial success. His first significant project under Nepveu was assisting on a 500m iron girder railway bridge over the river Garonne at Bordeaux. Following his boss's resignation, Eiffel was promoted to manage the entire project, subsequently rising to become principal engineer of the Compagnie Belge. By 1865 dwindling market conditions meant that Eiffel had little choice but to go it alone as an independent engineering consultant. It was a move that would see him

building locomotives for the Egyptian government and assisting with the design of the exhibition hall of the 1867 Exposition Universelle, which would lead him into researching the structural properties of cast iron. By 1868 he was sufficiently established to form 'Eiffel et Cie' (Eiffel & Co) in partnership with his fellow École Centrale graduate and bridge builder Théophile Seyrig.

Their first projects were a railway terminus for the line from Vienna to Budapest, and a bridge over the river Douro in Portugal. At the time, this bridge represented the longest arch span (160m) ever built, and was finished in less than two years for just under a million French francs. Within a decade, Eiffel was France's most famous engineer, and by 1879 he had parted company with Seyrig, and was trading under the



Eiffel's Maria Pia bridge spans the river Douro in Porto, Portugal

name Compagnie des Établissements Eiffel. Such was his reputation that he was routinely commissioned for major works without having to go through the process of competitive tendering. Eiffel

also started to introduce his concept of exporting prefabricated bridges as far afield as China that could be assembled by bolting them together rather than riveting. At the same time Eiffel took on key personnel – including Franco-Swiss structural engineer Maurice Koechlin and French civil engineer Émile Nouguier – who were to play vital roles in the design of the Eiffel Tower.

In 1881 Eiffel became involved in a project to build a neo-classical monument that was to be a gift from France to America to commemorate the centenary of American Independence. The Statue of Liberty (more correctly 'Liberty Enlightening the World') in New York Harbor was the brainchild of French sculptor Frédéric Auguste Bartholdi who had conceived of the Roman goddess Libertas bearing a torch in her right hand, while in her left, a tablet inscribed with "JULY IV MDCCLXXVI" (July 4, 1776). Bartholdi required an engineer to help him bring his design to fruition and Eiffel, duly enlisted because of his vast knowledge of wind stresses acquired during a career designing bridges, created the four-legged pylon that supports Liberty's copper sheet exterior. Eiffel built the statue at his works in Paris before shipping it in boxes to America for reassembly on Bedoe's Island, where it was dedicated by President Grover Cleveland on 26 October 1886, a decade after the actual centenary.

When the idea for erecting a tower in central Paris that would be a focus for the 1889 Exposition Universelle was first floated, Eiffel showed no interest other than to tolerate Koechlin and Nouguier working on plans for 'a great pylon' in their own time. But, as the concept gathered momentum – Eiffel displayed more enthusiasm, delivering a paper on the project's technical challenges to the Société des Ingénieurs Civils. Political inertia at government level put the idea on hold until a budget for the exposition was eventually passed by Minister for Trade, Edouard Lockroy, who then released a schedule of regulations for what was officially an 'open' competition but was transparently biased in favour of Eiffel's pre-existing design.

At this point Eiffel pricked up his ears and started to enter into contracts for the proposed 6.5 million-franc tower



/// CAN ONE THINK THAT BECAUSE WE ARE ENGINEERS, BEAUTY DOES NOT PREOCCUPY US, OR THAT WE DO NOT TRY TO BUILD BEAUTIFUL, AS WELL AS SOLID AND LONG-LASTING STRUCTURES? ///

GUSTAVE EIFFEL



as a private individual, rather than as a representative of his own company. As construction got underway the artistic community mobilised a protest against this "ridiculous tower dominating Paris like a gigantic smokestack" by way of a petition from the Committee of Three Hundred published in *Le Temps* newspaper. Eiffel retaliated by comparing his oeuvre to the Pyramids: "Why should that which is admirable in Egypt become hideous in Paris?" He also declared his tower would be the highest structure ever built, which remained true from its inauguration in 1889 until 1929, when it was overtaken by New York's Chrysler Building.

Reaction to the tower was mixed. While Thomas Edison gushed over "Monsieur Eiffel the Engineer, who has the greatest respect and admiration for all Engineers including the Great Engineer the Bon Dieu," man of letters Guy de Maupassant showed his displeasure at a vulgar edifice he regarded as his

'arch nemesis' by dining at the restaurant on the deuxième étage every day, famously claiming: "inside the restaurant was one of the few places where I could sit and not actually see the Tower."

If the tower had been a cause célèbre, what followed was nothing less than an outright public scandal. Eiffel became embroiled in the French attempt to build a canal crossing across the Panama isthmus

in Central America. His involvement was as a sub-contractor in charge of designing and manufacturing the canal locks. But when the French Panama Canal Company went into liquidation, he was caught up in a political and financial melee, with the result that in 1893 he was charged along with the directors of the company with misuse of funds. Eiffel was found guilty, fined 20,000 francs and sentenced to two years imprisonment. Although acquitted on appeal, his reputation was in tatters, leading to his resignation from the Board of Directors of Compagnie des Établissements Eiffel.

The remainder of Eiffel's career was spent in the relative obscurity of scientific research in the field of aerodynamics. He had a laboratory at the foot of the tower that bore his name and, by experimenting with dropping objects from his tower, proved that the air resistance of a body is related to the square of the airspeed. In 1909, he built a wind tunnel to investigate the characteristics of aerofoils that were finding their way into technology and in 1913 he was presented with a medal by the Smithsonian Institution for his work in aerodynamics, with Alexander Graham Bell stating that Eiffel's writings on the subject were 'classical' and had "given engineers the data for designing and constructing flying machines upon sound, scientific principles."

Gustave Eiffel died in 1923 while listening to Beethoven's 5th symphony. #ENGINEER



MAY 1937

Hyperbole and awe

Hercules - the most powerful warship in the British navy

Portsmouth's Historic Dockyard is home to a technology first that was once the toast of the nation but would be obsolete a decade after she was launched.

HMS Warrior was built in response to developments in France where La Gloire, the first armoured wooden-hulled ship, was launched in 1859. La Gloire was the result of lessons learned during the Crimean War, a conflict in which the Russian navy made short work of wooden hulls with shell-fired guns.

From a seagoing and military viewpoint La Gloire was something of a disaster - she was only effective as an offensive force in calm seas - but her construction is said to have caused enough panic across the English Channel to start a naval arms race, which resulted in Warrior, the first of the Royal Navy's sail- and steam-propelled Ironclads.

Warrior was, however, built at a time when the punching power of ordnance was improving rapidly and it wasn't long before she was superseded by Hercules, a vessel described in detail by The Engineer in 1867, but seemingly - and perhaps unfairly - at the expense of Warrior.

Reflecting on Warrior, The Engineer said: "No addition had previously been made to our naval power which attracted much attention as this vessel, justly so; she forced herself upon the notice of the world, not only by reason of her enormous dimensions, her then impregnability, and her great speed, but as the embodiment of a new principle of construction. As an armoured frigate the world had not up to the time she was launched, seen anything like her."

However, when she was commissioned "no one could assert positively that she was then impregnable to heavy guns, or that granting her armoured sides could then keep out the shot."

The Engineer added: "The Warrior was the most powerful ship for the moment but even as she was launched men felt her reign of empire might be short."

Today's Royal Navy is undergoing a fleet renewal that includes the first tranche of adaptable, multi-role Type 26 City Class frigates, which are expected to be in service for

at least 25 years. Over 150 years previously, the Royal Navy was keen for Hercules to have a similarly lengthy service life, so the ship was designed to withstand emerging, as well as contemporary, artillery threats.

"The Hercules is a ship whose value will probably remain unimpaired for years to come," The Engineer said. "In one word, she will not only be the most powerful warship in the British navy, but in the whole world. She will be able with ease to sink any vessel now afloat... in the navy of any other power."

In a final patriotic flurry, The Engineer took aim at developments across the Atlantic where the US Navy was adding turret ships to its fleet, an advance that gave commanders an arc of fire and greater offensive flexibility when engaging an adversary.

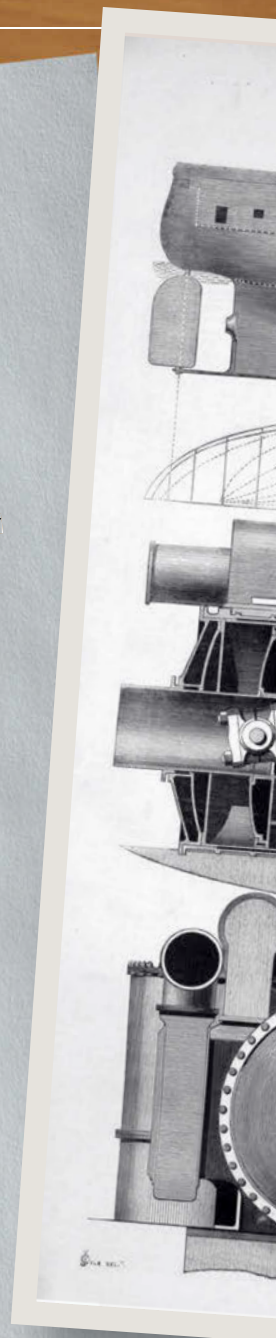
"It is still clear that in the weight of ordnance and number of guns [Hercules] will carry... no turret ship has ever been built which will bear a moment's comparison with her," The Engineer said.

The Hercules was laid down at Chatham in 1886 and emerged 337ft long with a 70ft 6in beam and a displacement of 5,226 tons.

"Her engines are of 1,200-horsepower, expected to work up to 7,200 indicated horsepower, and to propel the ship at 14 knots per hour," The Engineer said. "She will carry an enormous spread of canvas, and much is hoped from her as a sailing vessel."

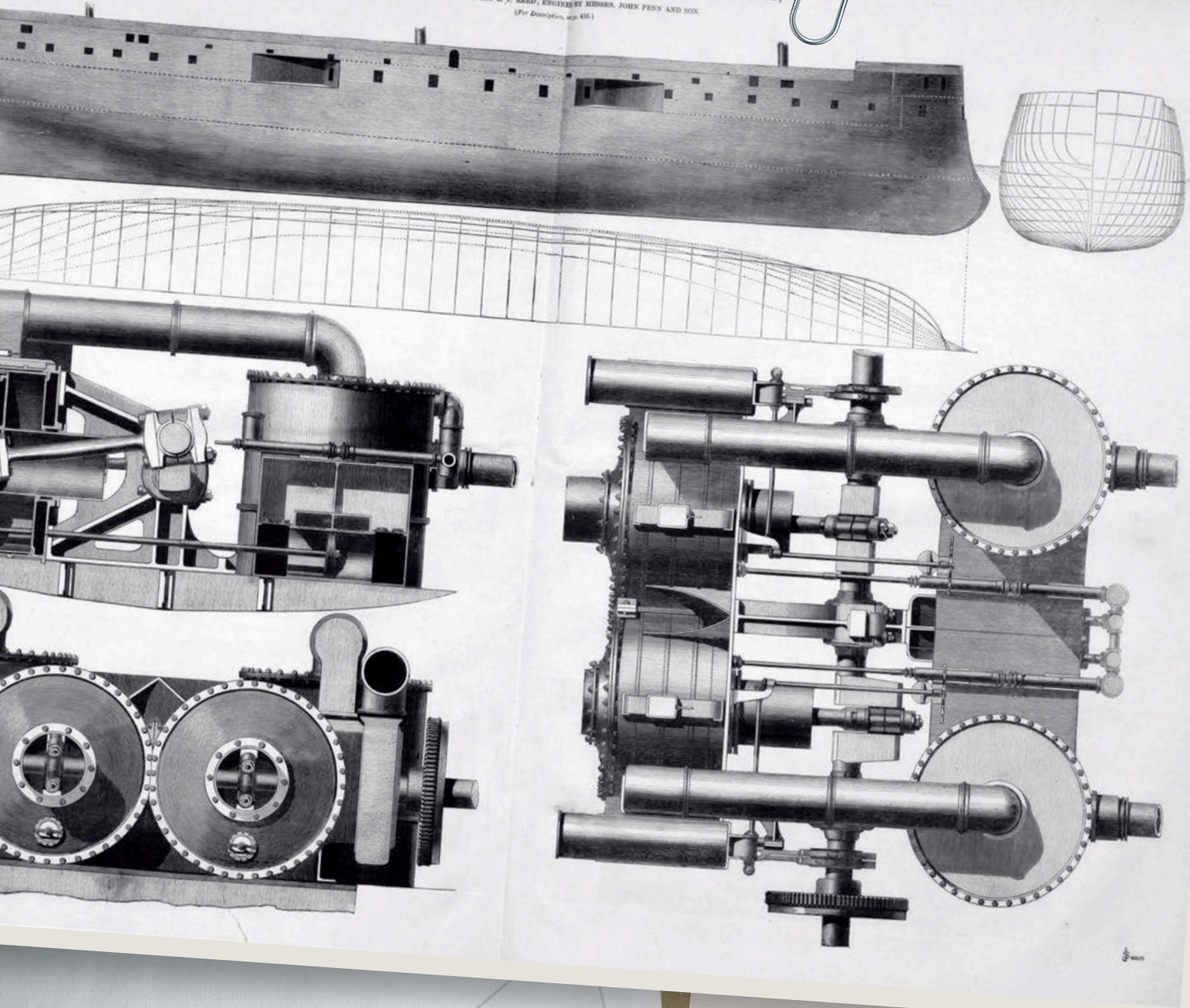
As with Warrior, Hercules' trunk engines were supplied by John Penn & Sons and The Engineer, working with the illustration with which it had been provided, drew attention to small subsidiary side valves fitted on the tops of the cylinders.

"These are intended to admit steam so that the engines may be started whether the valves are or are not open," The Engineer said. "They can be worked by one man, and the engines thus kept slowly turning while the main links are in mid-gear. Messrs Penn and Son inform us that they have never had the smallest difficulty in handling by their aid engines of 1350-horsepower. The cylinders are fitted



HER MAJESTY'S IRONCLAD SHIP HERCULES.

DESIGNED BY MR. E. J. REED, ENGINEER BY MESSRS. JOHN PENN AND SON.
(For Description, see p. 435.)



with relief valves - Penn's patent - which materially lessen the risk of injury from priming or any other cause which may bring water into the cylinders."

As might be deduced, The Engineer's ongoing coverage of Hercules came with lashings of hyperbole and awe, as the final words reveal.

"Nothing will give a better idea of the magnitude of these magnificent engines than the following statement of the weights and dimensions of some of the principal portions of the machinery: weight of crankshaft, 34 tons 16cwt; ditto of screw shaft, 24 tons; ditto of cylinder (each), 32 tons 17cwt; ditto of screw propeller, 23 tons 10cwt." THE ENGINEER

The rise of the ironclads

The Hercules was laid down at Chatham in 1886 and emerged 337ft long with a 70ft 6in beam and a displacement of 5,226 tons. The vessel was propelled at speeds up 14 knots per hour by its giant 1,200-horsepower engines.



GARETH L. POWELL

Who Goes There?

If you're scared now just wait till you see the future of facial recognition technology

selection of music from your online playlists. Smart panels on the walls of shopping centres, offices and hotels will change not only the advertisements they display for you, but also the entire décor of the space you're in.

But what happens if this technology gets abused? I'm not talking about a kind of Big Brother state panopticon, as that appears inevitable. Rather, I'm talking about more unscrupulous adaptations.

What if neighbourhoods and shopping malls refuse entry to

known or suspected offenders?

What if airlines deny service to customers they consider 'high risk' based on their ethnicity?

Journalists and stalkers could easily track the movements of celebrities using drones able to scan and recognise faces. On a more disturbing note, this technology could be used for assassinations, allowing a drone carrying a few grams of high explosive to select and pursue a target.

Of course, the deployment of LFR technology will lead to the

development of countermeasures. The most basic of these might be as simple as a large parka hood maybe paired with mirrored sunglasses or contact lenses that change the colour of the eyes, while more sophisticated methods could employ dazzle camouflage, using make-up to create optical illusions on the face, obscuring its exact proportions, or patterns that present as interference when viewed through a camera. One can also picture backstreet surgeons altering a person's facial appearance in order to supply them with a new identity in a world where your face is your passport.

With the rise of deep-fake technology, it's also not unreasonable to imagine the ability for members of the public to 3-D print masks in the exact likeness of celebrities or politicians, in order to obscure their own movements or frame those individuals for crimes or infidelities. If identity theft in 2019 is a problem, imagine how much worse it would be if a criminal stole your face and used it to access your bank account, cast fraudulent votes, and maybe even place you at the scene of a murder.

Looking further into the future, we might consider the development of a self-aware artificial intelligence. What might such a creature do if it recognised the technicians who were coming to shut it down? Perhaps it might use some of the methods mentioned above to track down and eliminate those opposed to its existence, or those involved in competing projects. It might even seek out and kill its designers in order to ensure it remains one of a kind, unchallenged in its digital existence. #ENGINEER

October's issue of The Engineer featured an article discussing the controversy surrounding trials of live facial recognition (LFR) technology by South Wales Police and the Metropolitan Police.

Put simply, LFR technology enables a computer connected to a surveillance system to recognise individuals in real-time, which could allow those individuals to be tracked and behavioural profiles compiled. But while this kind of state scrutiny might set off alarm bells in those of us who have read 1984, there are implications to this technology that not even George Orwell could have foreseen.

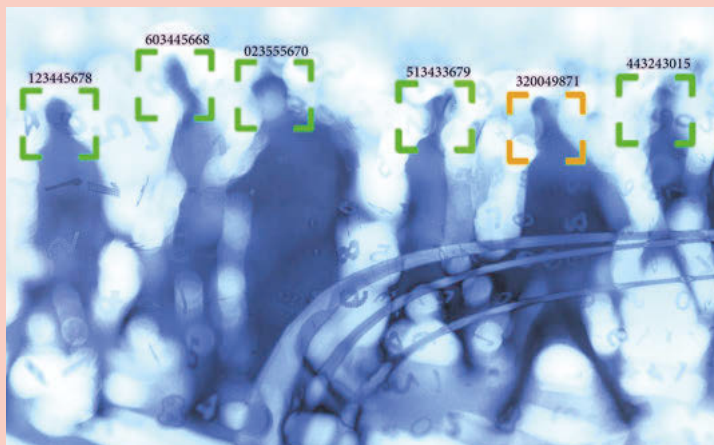
As a science fiction writer, my job is to look not at how people will be using a piece of technology tomorrow, but to imagine what they might be doing with it ten, fifty, even a hundred years from now.

So, what might the world look like by the end of the next decade if we assume that we'll have LFR technology that's sophisticated enough not to be easily fooled by sunglasses or beards, and cheap enough to be accessed by most organisations and even some individuals?

Perhaps your employer will require you to spend a certain amount of time at the gym each week in order to retain your health benefits. They will also know which shops you frequent and probably what you buy there, as well as how many times a week you visit a bar.

Investigators will be able to track the movements of cheating spouses. Self-driving taxis will recognise you and allow you to choose a destination from your 'favourites' list, while playing you a

// THERE ARE IMPLICATIONS TO THIS TECHNOLOGY THAT NOT EVEN GEORGE ORWELL COULD HAVE FORESEEN //





PLANNED OBSOLESCENCE VERSUS SAVING THE PLANET

An entrenched need to regularly replace and renew the products upon which we rely is damaging our planet, and engineers must take some responsibility for this, writes our anonymous blogger.

As warnings become ever more alarming and predicted timescales to irreversible crashing of the planet ever shorter, I'm surprised by the widespread response to climate change. I'm not talking about politicians or big business, well not directly, but rather the man and woman in the street. There's plenty of angst about the amount of packaging used by companies and even calls to give up meat due to its ecological impact. However, these always strike me as being window dressing at best and conscious self-delusion at worst. Never mind the amount of plastic cradling your new smartastic-phone-3000, why are you buying a new one in the first place? I'd bet that mostly its because "its the latest thing" rather than the old one being broken or compromised beyond usefulness.

This is no new phenomenon. A friend of Mrs Secret-Engineer's has regularly renewed the contents of her wardrobe every couple of years since adolescence - whether the garments were worn out or just barely worn. She, and those who queue through the night for the latest big thing are the cornerstone of the conspicuous consumption that the first world, and increasingly the whole world, rely on to create power and wealth. The rather worrying downside is that its killing the planet. As ever, we need only turn to the motoring sector for clear examples of how this mindset is created and exploited.

The pre-war years saw cars as either luxury items or minimal requirement runabouts, the emerging comfortable family car being temporarily postponed by hostilities. As the 50s hit their



stride though car companies had already established the idea of regular new models and updates to entice the newly affluent buyer into parting with their cash. The car had become fashion statement and status symbol, so long as you kept up with the Joneses. The double whammy came with the scruffy, cast-off cars being bought by those who couldn't afford better, but crucially aspired to. Where to after this? The introduction of planned obsolescence. I clearly remember

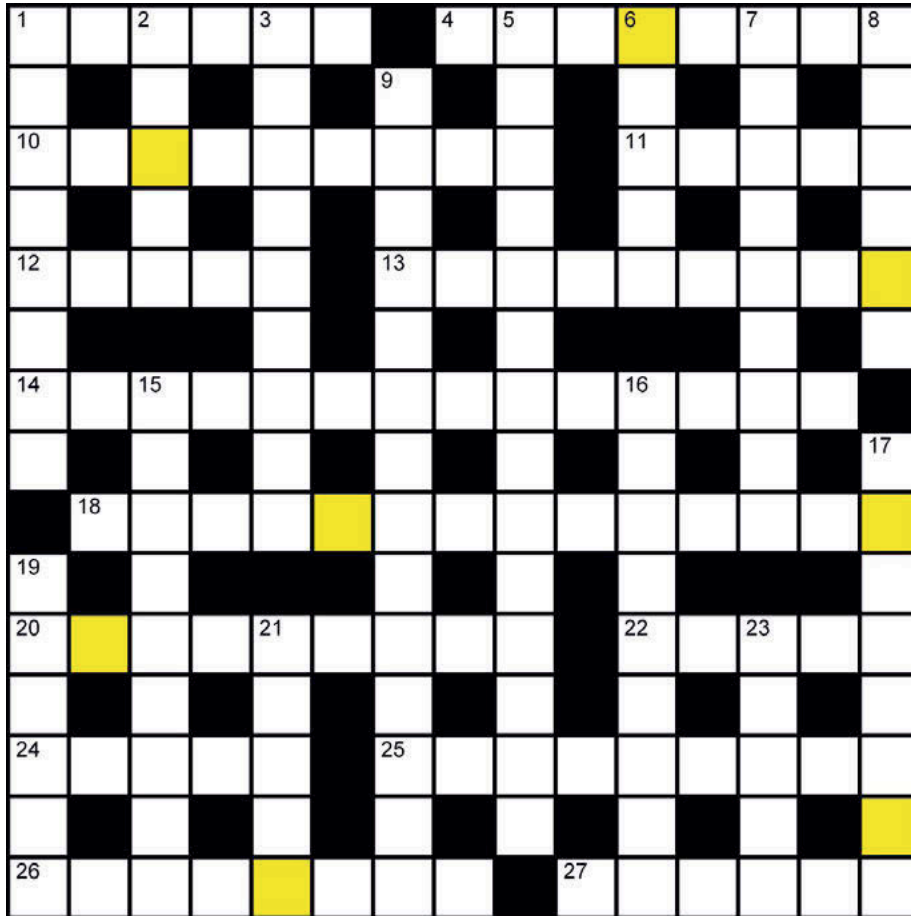
a consultant at one place proudly claiming he'd introduced a small recess under the crown of a certain manufacturer's pistons. An additional machining operation on a car component is not something undertaken lightly, but this one virtually guaranteed failure after a known life. Chances are the car would subsequently be scrapped, meaning somewhere in the food chain a replacement would have to be bought new.

Look to the future and Tesla may well be leading the

way, however not in the way its advocates would suggest. Increased complexity and integrated computing has been seen as the way forward for a while and Tesla has taken this to heart. All well and good but what happens when sub-systems go down or, as with your home PC, the software becomes unsupported? Whether intentional or not this is another way that a car can be forced into obsolescence, although it is too soon to see if this is a planned strategy. Regarding the present, I was surprised to see a fairly forthright environmental-change pundit on television suggesting, amongst other things, "if you buy a new car buy an electric one." I remain highly sceptical regarding the potential ecological benefits, cradle to grave, of electric cars but this was not the main issue for me. It was that he missed the opportunity of questioning whether we should be buying new cars at all.

The chance of a sudden radical change in our buying habits and coping with the seismic socio-economic upheaval this would trigger seems as close to zero as makes no odds. However, against this there is the reportedly large probability of extinction. As a significant number of engineers rely directly on the perpetuation of the status quo for their livelihoods, any move to a reduction in consumerism is likely to critically affect us all. Equally though we cannot help but also be at the heart of enabling solutions. Whatever happens we are obliged to fulfil the requirements of our employers, but perhaps it is time some of us were a little less proud of our role in creating this mess? #ENGINEER

CROSSWORD



Across

- 1 Remove impurities from (6)
- 4 Put in motion (8)
- 10 German physicist born in 1929 (9)
- 11 Diminish gradually (5)
- 12 Synthetic silklike fabric (5)
- 13 Branch of social science (9)
- 14 Removal of ore from close to the surface (8,6)
- 18 Quality of being without sharp outlines (14)
- 20 Old type of computer printer (3,6)
- 22 Equip with new parts (5)
- 24 Formal or authoritative proclamation (5)
- 25 Wave formed along a narrow estuary (5,4)
- 26 Code of letters and digits added to a postal address (8)
- 27 Hydrated calcium sulphate (6)

Down

- 1 Medicinal area at a spa (4,4)
- 2 Covered in corrosion (5)
- 3 Series of increasing numbers (9)
- 5 Odourless very poisonous gas (6,8)
- 6 Formally making a person known to another (5)
- 7 Durable goods for home or office use (9)
- 8 Becoming visible (6)
- 9 Being more concentrated than normally possible (14)
- 15 Exceptional intellectuals (9)
- 16 As might be expected (9)
- 17 Line connecting points having the same temperature (8)
- 19 Push one's way into (4,2)
- 21 Ancient Mexican engineer (5)
- 23 Falls loosely (5)



When completed rearrange the highlighted squares to spell out a cutting tool. The first correct answer received will win a £20 Amazon voucher. Email your answer to jon.excell@markallengroup.com

September's highlighted solution was Handspike. Winner Gavin McCarthy



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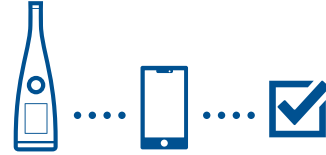
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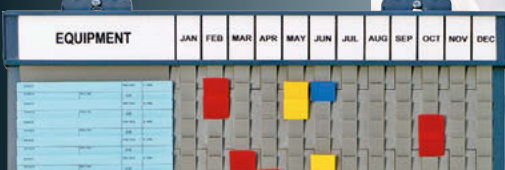
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