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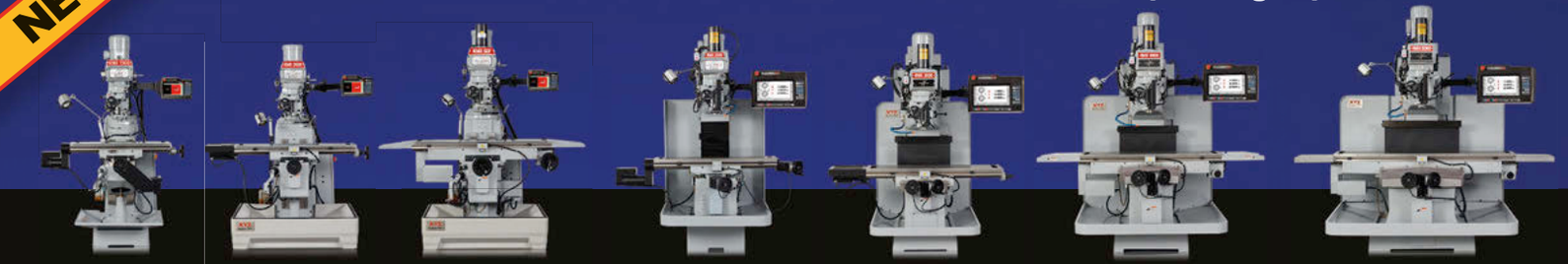

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this**issue**

Volume 300
Issue No. 7910
Established 1856

news

opinion

features

our**opinion**

Air time engineering

In a world where the rapid pace of technological change means that many engineered products are obsolete in the blink of an eye, the aviation industry occupies a curious position.

From the development of advanced propulsion technologies, to the deployment of a host of advanced manufacturing processes there's no doubt that the sector is at the absolute cutting edge of technological innovation. And yet its end products - whether they're military fighter jets or civil airliners – are typically expected to last for decades.

Indeed, with the exception of large chunks of infrastructure like bridges and power stations, it's hard to think of another area of engineering that presents such an extreme challenge in terms of complexity and longevity.

Against this backdrop, the aviation sector has been one of the pioneers of the concept of through-life engineering, the notion that a manufacturer doesn't wash its hands of a product once it rolls off the production line.

> "It's hard to think of any other field that presents such an extreme challenge"

The technology that enables existing aircraft to continue operating safely and to evolve to meet emerging efficiency and safety demands is a key part of delivering on this vision, and in this issue's cover story we take a look at how innovations from the often overlooked MRO (Maintenance, repair and overhaul (MRO) industry are at the heart of this approach.

As we report, it's a fertile area of technology innovation, with technologies ranging drone-mounted inspection systems cable of detecting defects invisible to the human eye; to AR devices able to guide technicians through complex inspection and processes; through to the development of robots that can crawl into the combustion chambers of jet engines and carry out repairs in-situ.

Elsewhere in this issue we take an in depth look at one of the most hotly anticipated car engines in recent years – the naturally aspirated V12 powerplant at the heart of Aston Martin's Valkyrie supercar - and present the first in a new series of articles profiling some of historical icons of engineering. This month it's the turn of the enigmatic Nikola Tesla – one of the founding fathers of modern electrical power (page 54).

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Cover Image: Aviation jet engine

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ISSN 0013-7758.
Printed by Pensord Press Ltd, Blackwood, NP12 2YA

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ENERGY

Danone plans biomass boiler

Food manufacturer invests in new plant to slash carbon emissions

HELEN KNIGHT REPORTS

Global food producer Danone is planning to cut carbon-dioxide emissions at one of its plants in New Zealand by 20,000 tonnes per year, with the installation of a new biomass boiler.

The €17.5m boiler, which is to be installed at the company's Nutricia spray-drying plant in Balclutha, on the country's South Island, is the first stage of Danone's plans to make the facility entirely carbon neutral by 2021.

The Balclutha plant processes raw milk sourced from 18 local farms into a powder that is used as the base for the production of its Infant Milk Formula (IMF) brands.

Spray-drying plants convert milk into a dry powder using heat from a boiler. As a result, around 85 per cent of the plant's energy consumption comes from steam production.

The new biomass facility will replace the gas or coal typically used as an energy source in boilers with sustainable, locally sourced wood fuels, according to Cyril Marniquet, Danone's New Zealand operations director.

'Biomass' is energy from plants or plant bi-products, in which solar energy is captured and stored via the process of photosynthesis. When biomass is burned, it releases CO2 and other by-products but this is largely offset by the CO2, which is absorbed in the growth of the plant.

"Danone's biomass boiler at the Balclutha facility will be fuelled by by-products or residue of forestry activity that may ordinarily go to waste," said Marniquet. "These lumber production by-products, while traditionally disposed of or burned, are valuable sources of heat, steam, and electricity when used in a biomass boiler system."

With four commercial forests within a 50km radius of the Balclutha plant, the facility will have a reliable source of biofuel, in addition to providing an economic benefit to the local forestry industry, Marniquet said.

"Danone will source fuel from local partners who participate in New Zealand's Forest Stewardship Council (FSC) certification scheme, to ensure fuel is being sourced from sustainably managed forests," he said. "Danone also plans to broaden its source of fuel to include urban wood waste."

The boiler is due to be installed by the end of 2020 and will be commissioned in 2021.

Danone will be investing approximately €25m in the Balclutha facility, which also includes the installation of a new water treatment plant to more efficiently treat water waste. It also plans to switch to renewable sources of electricity at the plant by 2020, which it claims will cut CO2 emissions by 96 per cent.

The remaining four per cent of CO2 emissions will be generated by the plant's gas consumption at times when the biomass boiler is undergoing maintenance. The company is also working towards finding a renewable source of energy to cover these maintenance periods, which it hopes to complete by 2021.

The development is part of Danone's 'One Planet. One Health' vision to be carbon neutral by 2050.

As part of this aim, the company has also set itself intermediate targets, in line with international efforts to meet the Paris Agreement objective of keeping global warming below 2°C. These targets include halving carbon emissions intensity across the company's full scope, which it dubs "from farm to family", by 2030. ■

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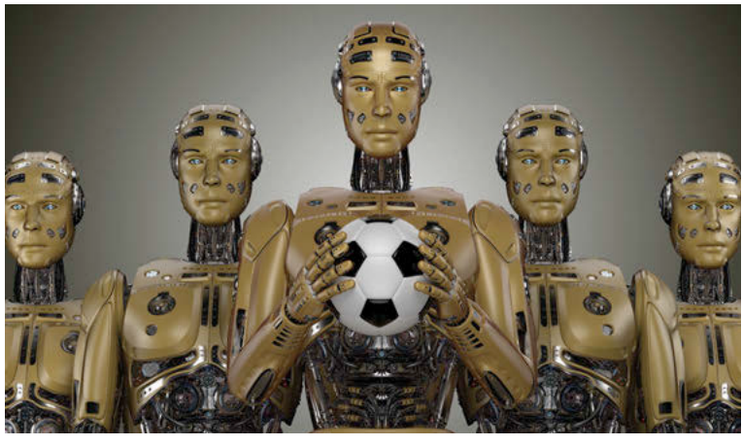
HELEN KNIGHT REPORTS



Robots look to humans for team skills

Driving on a busy road, or playing competitive team sports such as football, requires people to make split-second decisions based on an anticipation of what those around them will do next.

Now robots are set to be equipped with the skills needed to perform such real-world tasks, thanks to an EPSRC-funded project that aims to teach them to interact with and anticipate the actions of multiple other agents.

The project, which is led by Dr Varuna De Silva at Loughborough University London and also involves Chelsea Football Club Academy, will use an extensive dataset of player and ball tracking from football and basketball to train machine learning algorithms on what humans would do in such circumstances.

Existing artificial intelligence systems are often trained using a technique known as reinforcement learning, in which they are rewarded for making a desirable choice, and therefore learn the best course of action to take.

However, this training technique is less helpful in a multi-agent situation such as driving or playing football, where it is more difficult to identify an obvious reward for a given action.

So instead the researchers are using a technique known as imitation learning, in which the AI system is trained by observing the actions of experts, in the same way that humans learn new skills by imitating those who have already mastered them.

"What we are doing in this case is looking at years of football data, specifically player and ball tracking data, and using this to see how players behave on the field, and in this way to build a robotic model of a footballer," said De Silva. "Similarly, if we were to give autonomous vehicles the ability to drive in a situation that they are not used to, we will look at how humans have handled the same situation, to teach the robot a suitable and safe course of action."

Such AI systems could be used in autonomous vehicles and sports analytics, De Silva said. In sports analytics, the system could be used to measure players' skills, to identify particular talents. Players could be measured against the benchmark of the computational model, De Silva said.

In driverless vehicles, De Silva is investigating the possibility of using camera data road infrastructure to instruct autonomous vehicles in how the best human drivers tackle difficult scenarios. ■

MEDICAL

Fresh feel to prosthetics

STUART NATHAN REPORTS

For amputees who use prosthetics, control of their robotic limb is an important factor for their quality of life. The closer medical engineers can get to the function of a natural limb, the more comfortable the amputee tends to be, and comfort tends to correlate to confidence in using the prosthetic.

Now, bioengineers at Imperial College London, along with colleagues in the Medical University of Vienna, have carried out a small-scale test on a group of three amputees who had lost an arm above the elbow, and reported encouraging results in *Science Robotics*.

The research involved relocating nerves in the stumps of three patients, implanting wirelessly-chargeable electrodes and fitting new prostheses. The patients found that, in the two years after the surgery, they could move their arms more easily and with better accuracy.

Current prosthetic control works using sensors in the socket of the prosthetic to detect subtle movements in the muscles of the residual upper arm and convert these signals into the movements of the robotic arm and hand. However, slippage of the socket, sweat, and swelling of tissues can disrupt detection and pickup of signals between muscles and sensors.

The latest technique involves connecting electrodes directly to nerves and muscles in the arm stump, allowing the prosthetic to "feel" deeper muscles to get a better idea of the user's precise movements wanted by the user.

According to the group this led to improved control and the fitting of the prosthetic socket. ■

Newsinbrief

Fast-track visa plan

Government departments are to work with Britain's scientific community in developing a new fast-track visa system that 'attracts the very best minds from around the world'. Additional funding will be provided to scientists and researchers who have sought EU funding before the UK leaves the EU. In the event of a no-deal Brexit, the government will ensure that pending Horizon 2020 applications will be automatically reviewed by UKRI.

On track for new trains

Abellio UK has awarded Hitachi Rail £400m to build a new fleet of intercity trains. Set to operate from 2022, the new trains will be based on Japanese bullet train technology and will serve the main cities and towns on the Midland Main Line. Abellio has ordered 33 five-carriage trains, which will be operated in 10-carriage formations once delivered from Hitachi's factory in Newton Aycliffe, Co. Durham.

Fully-charged funding

An additional £2.5m has been made available by the government to fund the installation of over 1,000 new chargepoints for electric vehicles. The funding will support the on-street residential chargepoint scheme, launched in 2017, which helps drivers access suitable charging points near their homes when they don't have off-street parking. The scheme has already seen 16 local authorities ready to install 1,200 chargepoints in 2019.

UK first for 3D printing

The Manufacturing Technology Centre has become the UK's first research and development centre to install precision equipment for the 3D printing of small and complex electronic components. MTC has taken delivery of a Nano Dimension DragonFly LDM additive manufacturing system at its base in Coventry. The new equipment will allow the production of components used in smart connected devices, plus multi-layer printed circuit boards and sensors.

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AUTOMOTIVE

Going green with manual gearbox

Volkswagen to cut carbon with new transmission

HELEN KNIGHT REPORTS

A greener, more efficient manual gearbox that can reduce vehicle carbon-dioxide emissions has been developed by Volkswagen.

The MQ281 gearbox will be fitted to the new Passat, which is due to launch in September. It will later be added to almost all vehicle classes within the Volkswagen Group.

Depending on the engine and vehicle combination, the gearbox can save up to 5g of carbon dioxide per kilometre, according to Helmut Göbbels, head of manual gearbox and four-wheel-drivetrain development at Volkswagen.

This includes 'downspeeding', or driving in high gears at low engine speed in order to save fuel.

"The gearbox must play its part in the continuous improvement of the overall vehicle's fuel consumption," he said.

To develop the new gearbox, Volkswagen's engineers used computer modelling techniques, including simulating transmission fluid flow in order to ensure uniform and optimum lubrication of all necessary components under all operating conditions, said Göbbels.

"The delivery action as well as the turbulence generated by rotors such as gears were simulated with this method," he said. "The simulation focused particularly on operating ranges with a low engine speed, which pose particularly demanding requirements regarding transmission fluid delivery."

By improving the lubrication of all gear wheels and bearings, the company was able to reduce the amount of oil required by the gearbox over its lifetime to just 1.5 litres.

To reduce friction even further, a bearing concept adapted to the gearbox, using friction-minimised bearings with low-contact seals, was developed.

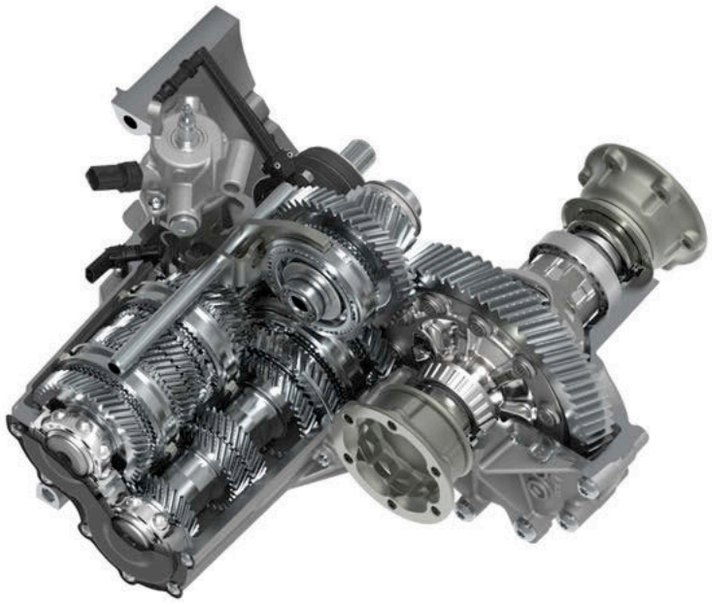
Using finite-element analysis, the team also optimised the use of materials and their distribution within the gearbox housing, said Göbbels. This allowed the maximum stiffness level for the structure, while minimising material use, he said.

The team also used a virtual 'acoustic fingerprint' development method to design the gearbox's acoustics.

"This method was used to simulate the sound radiation behaviour at the transmission's connection points under consideration of an optimal gear engagement behaviour," he said.

The new housing improves driving comfort by reducing the level of noise and vibration.

The new gearbox is being manufactured in house, with production being ramped up at Volkswagen's plants in Barcelona in Spain and Córdoba in Argentina. ■



The new gearbox will first be installed in the new Passat

SENSORS

Artificial tongue gets taste for whisky

An artificial tongue that detects subtle differences between different drams of whisky could help thwart the trade in counterfeit alcohol, according to a group at Glasgow University.

Described in a paper published in *Nanoscale*, the system uses a checkerboard arrangement of tiny gold and aluminium taste buds.

Statistical analysis of the subtle variations in how these tiny taste buds absorb light while submerged in different liquids allowed the team to identify different types of whiskies.

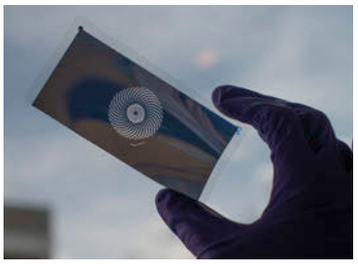
The team used the tongue to sample a selection of whiskies and was able to taste the differences between the drinks with greater than 99 per cent accuracy. It was also capable of picking up on the subtler distinctions between the same whisky aged in different barrels and tell the difference between the same whisky aged for 12, 15 and 18 years. **JE**

MATERIALS

New connections for electronics

Patterned metal made with greener technique

STUART NATHAN REPORTS



Warwick University chemists have created a new technique for making metal contact and connection pathways for electronics.

The method uses non-toxic chemicals and avoids metal wastage. Described in *Materials Horizons*, it is also compatible with continuous roll-to-roll processing methods.

Ross Hatton and Silvia Varagnolo received EPSRC funding for their project, which is based on their discovery that silver and copper do not condense onto extremely thin films of certain highly fluorinated compounds when the metal is deposited by simple thermal deposition. The organofluorine compounds are similar to those used to make non-stick coatings on cookware, and so are readily available..

The method involves printing the negative pattern where connections are not needed onto a polymer substrate, and then using thermal deposition to create a metal pattern where the coating is absent. The metal surface created is uncontaminated, which Hatton believes makes the technique very suitable for making next-generation sensors.

Another potentially important application is colour-tunable, flexible and lightweight photovoltaic cells. Perovskite minerals, organic semiconductors and nano crystals are all being investigated as possibilities for these, but they all require a low-cost, flexible organic electrode in order to function. The team used their methods to produce semi-transparent organic solar cells in which the top silver electrode is patterned with millions of tiny apertures per square centimetre. ■

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MEDICAL

Bionic system restores sight

Trials reverse effects of age-related macular degeneration HELEN KNIGHT REPORTS

Five people with age-related macular degeneration have been able to read letters again, following a successful feasibility study of a bionic vision system.

Pixium Vision's Prima system was trialled on five patients in France, all of whom had advanced dry age-related macular degeneration (AMD).

The system, which is designed to restore sight in patients blinded by retinal dystrophies, consists of a miniaturised, wireless sub-retinal implant, and augmented reality glasses, according to Guillaume Buc, chief technology officer at Paris-based Pixium Vision.

"We target diseases where the photoreceptors, the part of the retina that receives light and converts it into an initial signal for the brain, may have died," said Buc. "The idea is to replace the photoreceptors' function by electrical stimulation, using an implanted prosthesis."

While none of the patients had any remaining central vision at the start of the trial, after 12 months with the bionic implant most could identify letters, with some able to identify sequences of letters, he said.

The system consists of a 2mm-diameter photovoltaic chip, containing 378 electrodes, which is implanted under the retina where it acts like an array of solar panels.

These panels are powered by a pulsed beam of near-infrared light, transmitted by a miniature projector on the glasses. The light also acts as a signal, containing images captured by a mini-camera on the glasses, said Buc.

"The patterned light is projected through the pupil of the eye, and the implant at the back of the retina leverages that signal both as power and a signal," he said.

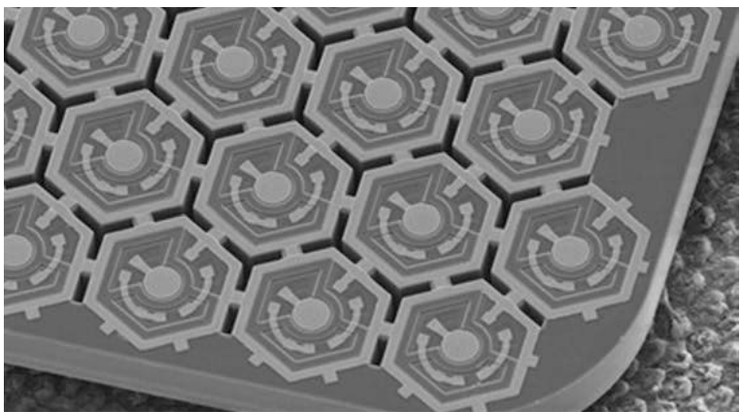
"There is a lot of intelligence inside the glasses themselves, which acquire the signal from the miniaturised camera and transform it into a simplified version of the digital scene in front of the patient."

AMD is the leading cause of severe vision loss and legal blindness in people over the age of 65 in Europe and the US.

While there are treatments to slow the progression of wet AMD, there is no cure available for the more frequent dry form of the disease.

Patients suffering with this form of retinal dystrophy gradually lose their central vision due to the loss of photoreceptors, said Buc. ■

Patterned light could help to restore sight



ROBOTICS

Robots need to get a grip

Study argues robotic systems will have to change STUART NATHAN REPORTS

Robots working alongside humans will need to understand the context of their tasks, according to a study from the National Centre for Nuclear Robotics at Birmingham University. Currently, industrial robots do what their controlling algorithms tell them to do with no understanding of why they are doing it. To work alongside humans safely, robotic systems will have to change.

A team led by Dr Valerio Ortenzi has looked at how robots grasp objects and the actions to which that grasping is linked, and as the team explains in Nature Machine Intelligence, it concludes that a drastic change in the philosophy of robotics may be needed to make the interaction between human and automated systems safe and effective.

Currently, a 'successful' grasp is one where the robotic gripper holds an object securely without causing damage. However, this may in fact be a real-world failure if, for example, the gripper is obscuring a barcode, which means that the object cannot be tracked. To be fully successful, the system has to understand the consequences of holding the item in the wrong way.

Credit: Lightfield Studios

"Imagine asking a robot to pass you a screwdriver," Ortenzi said. "Based on current conventions the best way for a robot to pick up the tool is by the handle. Unfortunately, that could mean that a hugely powerful machine then thrusts a potentially lethal blade towards you, at speed. Instead, the robot needs to know what the end goal is."

In another example, Ortenzi noted that if a robot was passing a glass of water to a resident in a care home, the action is successful if no water is spilled over the recipient and the glass could subsequently be taken from the robotic gripper.

Such criteria are currently not programmed into the control algorithms for robotic systems. "The traditional metrics used by researchers, over the past 20 years, to assess robotic manipulation, are not sufficient. In the most practical sense, robots need a new philosophy to get a grip," Ortenzi said. ■

MARINE

Auckland charges towards e-tug

Ports of Auckland has placed an order for the world's first full-size electric port tug, a green marine vessel predicted to save 465.31 tCO2e annually.

Set for delivery in 2021, the Damen RSD-E Tug 2513 – built by Gorinchem, Netherlands-based Damen Shipyards – will have a 70-tonne bollard pull, which matches Hauraki, the port's strongest diesel tug.

At 24.73m-long and with a 6m draft, the e-tug's 2,800kWh-rated battery pack will drive two azimuth thrusters with 3m diameter propellers to help the vessel carry out the same tasks as Hauraki, which consumes 120 litres of diesel an hour.

For redundancy, two 1,000kW back-up generator sets will allow the vessel to operate at 40 tonnes bollard pull if electrical systems fail.

"It was important to us that a new electric tug should be able to carry out normal port operations, just like our existing diesel tugs," said Tony Gibson, CEO of Ports of Auckland. "Our new e-tug will be able to do three to four shipping moves on a full charge, or around three to four hours work." **JF**

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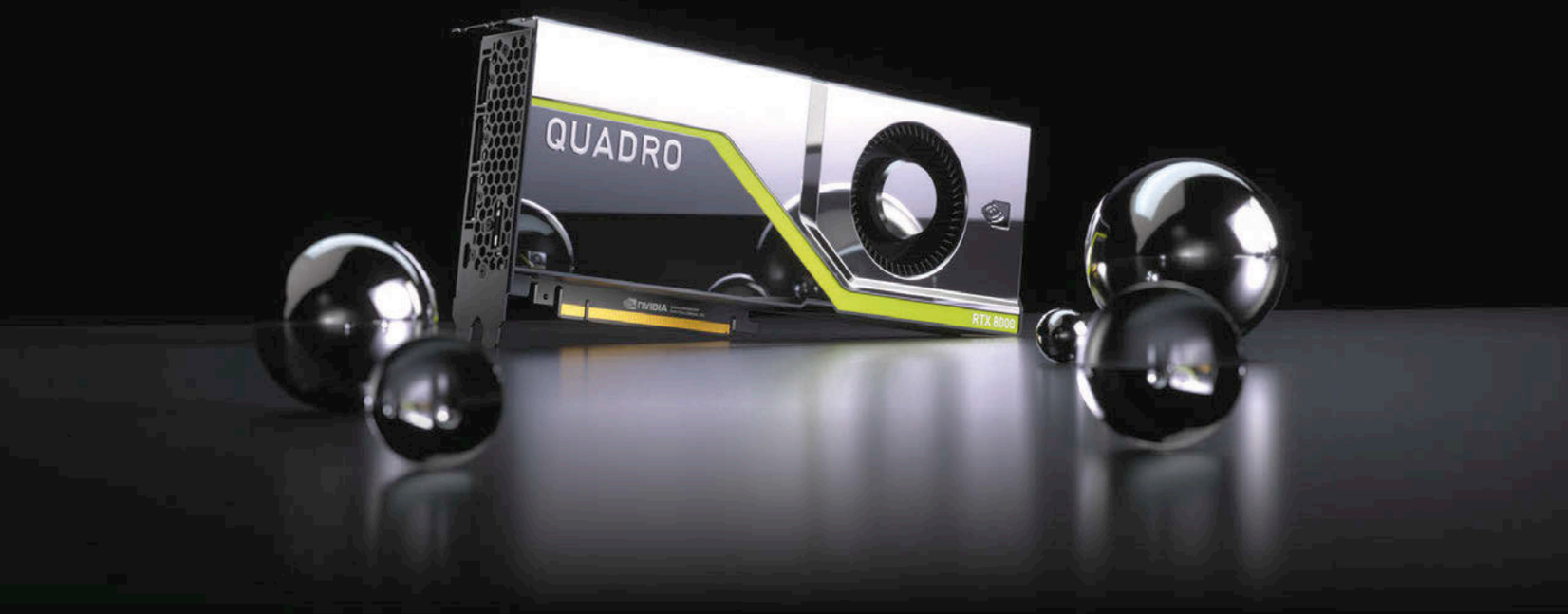

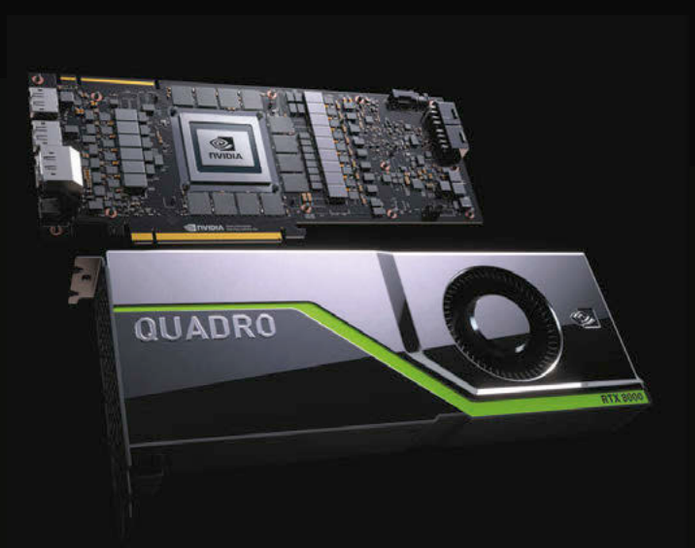

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ELECTRONICS

Sensor boost for 3D chip production

FBAR system is 1,000 times more accurate than existing sensors

HELEN KNIGHT REPORTS

Facial-recognition software is increasingly being used on smartphones such as the iPhone X for security and payment purposes.

The technology, which is based on a 3D camera chip known as an infra-red vertical cavity surface emitting laser (VCSEL), is expected to be used on one-billion smartphones within the next two years.

However, the technique typically used to produce these cameras is inaccurate, resulting in around 50 per cent of the chips being discarded and adding to their cost.

Now Sorex Sensors, a spin-out from Cambridge University, has developed a new sensor for use in the production process, which it claims is 1,000 times more accurate than existing sensors.

The FBAR (Film Bulk Acoustic Resonator) sensor, which will be launched this autumn, can help to improve the production process, significantly improving yields, according to CEO Michael LeGoff.

FBAR provides an atomic level of understanding

"Manufacturers are currently throwing half their material away, so if they can find a way to improve their yield, the economics are compelling," he said.

To build complex compound semiconductors such as Gallium Arsenide (GaAs) VCSELs, atomic layers of material are deposited onto a silicon wafer substrate under extreme temperatures and pressure within a chamber.

Within this chamber is a quartz crystal microbalance sensor to measure the material, which is not particularly accurate. Consequently, tool operators are forced to make educated assumptions about when to shut off the materials, and when to change temperatures and pressure.

"An atomic level understanding of what is going on throughout the process is critical to the performance of the device," said LeGoff.

The much higher accuracy of the FBAR sensor, in contrast, means it can be used to measure the deposition rates directly, said LeGoff.

The FBAR sensors, which are fabricated on a silicon wafer, consist of a thin film of resonating piezoelectric material. When a mass is attached to the surface it changes the resonant frequency, providing an extremely accurate measurement of the amount of mass on the sensor.

"Our sensor is much smaller [than a quartz crystal microbalance] and operates at much higher frequencies of between 2GHz and 2.6GHz," LeGoff said. "So, any tiny mass that lands on it has an immediate effect on its resonant frequency." ■

AEROSPACE

All a matter of thrust for US scramjet

An experimental Northrop Grumman scramjet has set a new US Air Force record for the highest thrust produced by an air-breathing hypersonic engine.

During ground tests conducted by the Air Force Research Laboratory (AFRL) and Air Force Test Centre, the engine delivered more than 13,000 pounds (57,850 Newtons) of thrust. The nine-month test programme at Arnold Air Force Base in Tennessee saw the 18ft scramjet deliver a combined 30 minutes of combustion time, performing in test conditions that simulated speeds in excess of Mach 4. Hypersonic flight is generally accepted as Mach 5 and above.

According to the AFRL, the new engine was born on the back of the X-51 Waverider programme, an experimental scramjet built by Boeing that launches from under the wing of a B-52 bomber. In May 2013, the X-51 exceeded Mach 5 for 210 seconds.

"A new engine with 10 times the flow of the X-51 would allow for a new class of scramjet vehicles," said AFRL's Todd Barhorst. **AW**

AUTOMOTIVE

UVeye out for inspections

Systems to be deployed in the automotive industry

JASON FORD REPORTS

An Israeli technology start-up has raised an additional $31m to expand the deployment of its external inspection systems for the automotive industry.

The latest investment in UVeye was led by Toyota Tsusho, Volvo Cars and WR Berkley Corporation with participation from partners, including FIT Ventures.

UVeye's technology carries out automatic vehicle inspections utilising artificial-intelligence purpose-built for vehicles.

"It's all based on the deep-learning engine and computer vision image-processing algorithms we developed in house to solve a very simple but hard problem," said David Oren, UVeye's chief strategy officer. "We are automatically detecting whatever you can see with your eyes. We are enhancing all the manual inspection with an automatic, objective and very efficient system." UVeye's drive-through systems can detect external and mechanical flaws and identify anomalies, modifications or foreign objects along the undercarriage and around the exterior of the vehicle. The scanning process completes within seconds and can be used throughout the entire lifecycle of the vehicle.

"Our cameras – our acquisition systems – take multiple images from around the object we are inspecting, then the deep-learning engine kicks in and does the analysis, which is based on segmentation, classification and some other very unique algorithms... we developed in house," Oren told The Engineer. ■

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MATERIALS

Leeds team strike gold in laboratory

Rich seam of applications for ultra-thin 2D material HELEN KNIGHT REPORTS

The thinnest unsupported form of gold ever created has been synthesised by researchers in the UK, an advance with applications in the medical device and electronics.

The 2D material, which consists of two layers of atoms sitting on top of each other in a sheet, has been developed at Leeds University.

The material could be used to create extremely sensitive home biomedical testing devices, as well as in pharmaceutical development and wastewater treatment, according to Dr Sunjie Ye, from Leeds' Molecular and Nanoscale Physics Group and the Leeds Institute of Medical Research. Ye is lead author of a paper describing the work in *Advanced Science*.

To synthesise the material, the researchers added chloroauric acid, an inorganic substance containing gold, and a reducing agent, sodium citrate acid aqueous solution, into a solution of a "confinement agent", methyl orange.

After being kept undisturbed for 12 hours at an ambient temperature, the chloroauric acid was reduced to its metallic form, with the confinement agent having encouraged the gold to form a two atom-thick sheet, said Ye.

The gold appears green in water, as a result of its nanoscale dimensions, so the researchers have dubbed it gold nanoseaweed.

When the researchers tested the ultra-thin gold, they found that it is 10 times more efficient as a catalytic substrate than existing 3D gold nanoparticles.

The researchers now plan to scale up the process to industrial levels.

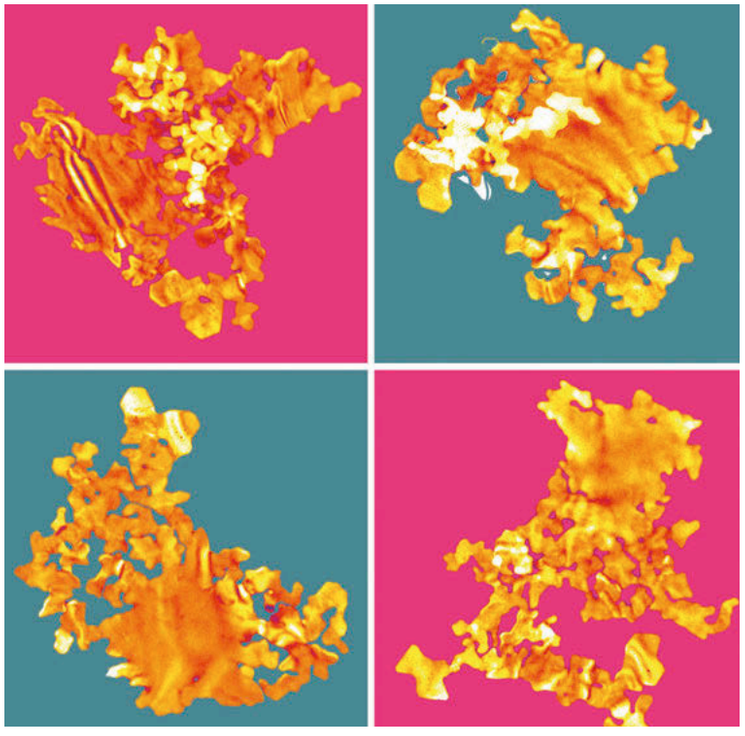
The material could be used for nanoenzyme-enabled ultra-sensitive bio-sensing devices that can be operated at home, in which the results can be observed through colour change.

"The ultra-sensitivity will enable the detection of analytes at very low concentration," said Ye. "This will facilitate the early detection of disease and also the monitoring of therapeutic effect, in particular cancer treatment after surgery."

The material's catalytic properties also means it could be used to transform some industrial waste into useful resources for synthesising pharmaceutical molecules, Ye said.

"It also has a potential application in water treatment, by providing an effective degradation of organic pollutants in wastewater," she said.

The flakes are also flexible, meaning they could form the basis of electronic components for bendable screens or electronic inks. ■



Synthesised gold could be used in transparent conducting displays

MEDICAL

Torso simulator braced for innovative back support

Engineers have for the first time created a simulator mimicking the mechanical behaviour of the human torso, an advance that could lead to innovations in the design of medical back supports.

The simuator will let researchers test different back brace designs and configurations without needing to test them on people.

The simulator was developed by a team from Lancaster University's Engineering Department and Dr Jane Martindale of the Wrightington, Wigan and Leigh NHS Foundation Trust and includes a male torso-shaped mechanical test rig, alongside computer simulation models. It also includes a 3D-printed spine and rib cage, created using modified CAD models derived from CT scans, and a torso with geometries and other properties that closely resemble and behave like human tissues.

The rig also allows for different spine configurations and deformities, such as scoliosis. **JF**

DEFENCE

Armed and unmanned RIB takes to sea

Demonstration vessel shows its capabilities

JON EXCELL REPORTS

An unmanned armed boat demonstrated by engineers at BAE Systems could pave the way for naval vessels able to travel further, faster, and into more dangerous environments than is currently possible.

Developed with engineers from L3Harris and MSI Defence Systems, BAE's autonomous Pacific 950 Rigid Inflatable Boat (RIB) demonstrator is able to operate and navigate autonomously whilst the weapons system remains firmly under a human operator's control.

According to BAE, the vessel can operate for up to 10 days at 'patrol speed' or 300 nautical miles in pursuit mode, reaching speeds of up to 45 knots, whilst either being remotely controlled or on a semi-autonomous mission.

BAE added that the vessel has potential applications across a range of missions, including anti-piracy operations, border control, persistent intelligence gathering, maritime security and force protection. The use of autonomous vessels in high-risk areas would allow operations to be conducted without endangering sailors.

Commenting on the trials Mike Woods, chief technologist for BAE Systems' Maritime Services business, said: "This technology represents a huge step forward in the interaction between human and machine, combining sophisticated autonomous technology with human capabilities to overcome many of the challenges faced in difficult conditions at sea." ■

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Let's get ethical

Does engineering need to do more to embed ethics at the heart of the profession? Dr Jim Baxter, an ethicist at the University of Leeds, thinks so

Engineers make the seemingly impossible, possible.

They fired the Industrial Revolution. They landed a man on the Moon. They've built the world's great megacities.

And they will shape the future. They will find ways to help the world feed itself, keep vast populations on the move, and protect people from climate change.

But the challenges to come are more complex than those faced by the engineers of the past.

Emerging technologies that promise good also pose threats to our well-being, privacy and human rights – and inappropriately-used technology could further damage a stressed global ecosystem.

Faced with all of this, engineers can draw on ethics and values to help them make day-to-day judgements; to reach balanced decisions amid competing demands and pressures.

But is the system in the UK for ensuring engineers are applying those values robust enough?

Back in 2005, the Royal Academy of Engineering – Engineering Council jointly published its Statement of Ethical Principles. Those obliged all engineers to act with honesty and integrity, to challenge unethical behaviour and to hold paramount the health and safety of others.

What is fundamentally expected of engineers is no different from other professionals, such as doctors. But in engineering there is a weakness: the system for ensuring that ethical values are followed and applied is fractured.

It is the 36 professional engineering institutions (PEIs), working with the Engineering Council, that provide oversight of an engineer's professional conduct. However, there is no requirement for a practising UK engineer to be a member of a PEI.

As an outsider, when I first started working with the engineering profession, I was somewhat taken aback by the extremely low number of engineers who are professionally registered.

The engineer and lawyer John Uff QC conducted a major review into the structure of the engineering profession: UK Engineering 2016. In that review, he quoted estimates that only 15 per cent of engineers were members of a professional body.

In consequence of this, the vast majority of engineers fall outside professional oversight.

Do engineers have a responsibility to help ensure that emerging technologies such as AI don't undermine our well-being, privacy and human rights? *Image credit: sdecoret via stock.adobe*

There is no assurance that they are keeping up to date through continuing professional development.

The serious implications of this weakness emerged with the inquiry into building regulations and fire safety following the Grenfell Tower blaze. Dame Judith Hackitt, who chaired the enquiry, *Building a Safer Future*, identified "... a lack of skills, knowledge and experience and a lack of any formal process of assuring the skills of those engaged at every stage of the life cycle of higher-risk residential buildings as a major flaw in the current regulatory system".

The inquiry also noted the importance of continuing professional development, particularly in fire safety. In other countries, it noted, people who work on complex buildings require certification and registration.

I am involved with a 10-year plan to root ethics at the heart of the profession, and for it to become a tool to guide and inform day-to-day decisions.

The plan was written following consultation with the leaders of the profession, including the Royal Academy of Engineering, the Engineering Council, Engineers Without Borders and the Engineering Professors' Council.

Called Engineering Ethics 2028, it is not proposing a new ethical code. The values established 14 years ago still hold true.

It aims to establish an ethical framework. The first objective is to bring more engineers within the scope of professional oversight.

Engineers also need to think about ethical competence. How good are they at applying ethical principles, are they comfortable speaking about decisions that are being made, and can employers support staff who challenge corporate decisions?

Engineering Ethics 2028 calls for responsible innovation where practitioners play a part in the public debate around new technologies.

And, of course, engineers have to consider the impact of their work on a fragile world and to work in a way that is sustainable. If the profession achieves this, it will fulfill what is the over-arching duty of engineers: to serve the public good.

Engineering Ethics 2028 was written to provoke a debate about how ethics should operate in engineering. As the profession moves into a world that is increasingly dominated by technology, it has to show that decisions are ethically sound.

Failure to do so risks eroding the standing of engineers at a time when they can grab an opportunity to establish a role as stewards of a future shaped by technological advances. ■

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Thehottopic

Getting to grips with HS2

Our online poll on how the UK's new government should tackle HS2 provoked a debate on UK 5G infrastructure

The large companies involved so far have not shown their best side; it's already out of control. We still have to establish when Crossrail will be completed. Not a good position. Do that many people need high-speed rail compared to their need for reliable broadband, 3G or 4G? Even in the middle of our major cities you often can't get 4G. The future is digital communication and a reliable service everywhere is what people seek. This will enable flexible working, especially in rural communities. I am a regular rail user; let's make the current system more reliable.
Declan Flynn

Upgrade existing lines only. Our existing railway infrastructure is falling apart and suffers through lack of investment, so if we have £100bn to spare (because that is the current HS2 cost guesstimate) it would be better spent on upgrading the existing infrastructure. Also, I would suggest that 'any' work on improving/upgrading the railways should always start with the northern sections and only complete the London sections last. This would ensure the north is not short changed and would provide the requisite pressure on schedules from London (and, for the record, I'm a southerner).
Another Steve

Since Beeching took his axe to the rail network in the 1960s the population of the UK has more than doubled. To expect the existing lines to cope with additional demand with the greater population and a push to get us to use public transport is pure fantasy. More capacity is needed; anyone who has used the vastly over-crowded network will have noticed. Using air travel on this island demonstrates how far behind French, German and Spanish railways we are.
Malcolm Jennings

Why are these projects being considered using 1950s pantograph technology? Surely, we need to develop train systems with integrated clean power sources such as hydrogen. Fahrzeugmanagement Region Frankfurt RheinMain, a rail operator in the Frankfurt Rhine-Main Metropolitan Area, has ordered 27 hydrogen-powered trains of the Coradia iLint type. The vehicles will be delivered by the end of 2022. The supply costs around €500m. Our government will spend at least that long deciding what colour the meeting room chairs should be; then the project will take twice as long and cost three times as much as budgeted.

So where is this new vibrant, thrusting government going to put its new Trans-Pennine track? Has Boris even considered that pantographs don't fit into Victorian tunnels? If they don't cut a new tunnel, they will have to go around, via Burnley or Woodhead, defeating the object of making it faster.

The whole system needs to be massively upgraded, otherwise it will be like a motorway, never fully open from end to end because of rolling minor improvements.
Sandy

We don't need high speed as much as we need high capacity. Door-to-door total time means that high speed doesn't give much gain, especially over the relatively short distances between Liverpool and Doncaster. But frequent high-capacity trains would make a difference... after we've sorted out the roads first, of course!
Tim

Unlike the major airports, where landings and take-off slots are at capacity, rail lines can easily accommodate more trains per hour. The rail infrastructure could and should be upgraded to reflect this obvious fact. I agree that high speed is less important in a country of our size than the capacity to travel in comfort and at a frequency conducive to both business and leisure activities.
Mike Blamey

Crossrail ran into troubles trying to complete too many new technologies in one project simultaneously. The existing infrastructure, although very stressed, evolved to its current situation, which is why it just about copes, most of the time. The chaos that Crossrail is trapped in is likely for whichever flavour of HS2 is imposed on the country. There are too many new features in a mix that has too many problems already. Cancel the London-to-Birmingham section. It's the wrong route and the wrong solution.
The Colonel

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Variety is the spice of an engineering life

A new role working on an unfamiliar product prompts our anonymous blogger to reflect on the value of working in a wide range of sectors

I can now reveal that the Secret Engineer is moving jobs once more. Hardly unexpected this time as I've been working as a sub-contractor and, as such, this has been of an intrinsically temporary nature. I have been both a 'permie' and a 'subby' regularly throughout my career, having found there are advantages and disadvantages with each role. What I have always looked for is a change from what I have done before. There are industries I'd like to go back to given the chance but even then I hope that there would be some new challenge involved.

My own approach to seeking variety within my career became crystallised early on. I was working on space-related gubbins when myself and a much more experienced and senior colleague were called into the boss's office. He was looking for someone to work on a new and revolutionary propulsion system. However, where I was immediately enthusiastic at being involved in something cutting edge and new to me, m'learned colleague simply replied: "I only do waveguides." I'm still quite shocked at him having such a limited outlook even now, about 30 years later.

I can understand the mentality of wanting to be very good, or comfortable within your own specialisation but to not even consider the occasional diversion is surely both limiting and potentially tedious? It also seems to reduce options in personal development. To be the best within such a closely defined field should be

achievable for most of us but where do we go from there? Where is the challenge and excitement that is at the core of engineering?

Worse for me – and I believe I have touched on this before – is how companies seem to restrict the scope of fresh-faced graduates. I feel very lucky to have worked on a wide variety of products within a range of companies, but rather than 'lucky' I would prefer to feel that I had simply followed a path that is still readily available to those currently joining our ranks. Of course, back in the day, with apprentices at least, such peripatetic tenancies were positively encouraged. Once you received your papers that was it, you were off and away. Times may have changed, along with the jobs market, but the loss of this early personal diversification – whether by design or happen-stance – feels like something of an own goal for industry.

People still move about between companies; if anything, we have seen a marked reduction in the 'job-for-life' paradigm but my focus here is towards the youngsters and how they accumulate a broad working knowledge as quickly as possible. After all, what is 'experience' other than being exposed to multiple influences and finding out for yourself what works and what doesn't in various situations?

As regards the latest stage in my own adventure within the realms of engineering, I am (ironically) currently at the slightly apprehensive 'should I have stayed where I was comfortable' phase. The new position is below heights I have scaled before and involves manufacturing techniques I am entirely familiar with, yet I still worry that I will find some aspects difficult to master. Look at it another way. I will be working on a product I have not worked on before, for a new company, and I will have the chance to learn something new. I will of course be absolutely committed in my approach and I hope that this will be the start of a lengthy and mutually fruitful association. In fact, I would go so far as to say, at this early stage, that the signs are good for settling in for the long haul. If it doesn't work out though, there are plenty more opportunities to learn and flourish. ■

Inyouropinion

Engineering on television

I see the imperative behind 'dumbing down' but suspect that those for whom it is dumbed down will not be watching anyway. I don't believe that engineering qualifications are essential for the presenters, but a thorough understanding of the technology and enthusiasm most definitely is.
Richard Jenvey

There are not enough engineers involved in television. Some years ago, the Royal Academy of Engineering (RAEng) ran media fellowship competitions for rising young engineering stars. We had several winners. They were so good in the role that the media (BBC etc) wanted to keep them. But they were smart enough to recognise that television was not the best route to a high-flying engineering career. The RAEng would be most willing to help.
Prof Terry Wilkins

The problem I have with most of the 'engineering'-based coverage is that it has to repeat the last three minutes after every ad break. I may be advancing in years, but I am not in the goldfish category yet. By the time the repeated bits are edited out, that '30-minute' programme contains barely five minutes of actual data and most of that is so lightweight that it becomes tedious to watch.
Pete

UK car production declines

Cars now have a longer life of five-plus years. People and companies keep them longer. The internal combustion engine is fading and no one knows when or what the replacement might be. So the number of new cars sold drops. We do not cope well with negative growth, but we ought to get used to it as it will be a feature of the future.
Oliver Dunthorne

Car production has obviously been hit by the diesel problem, but investment confidence is obviously going to be hit by Brexit, because no one told people this was going to happen three years ago. What do you expect when you intend to kick out your best customer and when the few motor manufacturers in the UK have alternative production sites?
Sandy

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Repairs on high

How are aircraft returned to active service as soon as possible? The answer lies with the MRO industry. Stuart Nathan reports.

Drones are particularly useful for inspecting parts of aircraft that are difficult for maintenance staff to access, such as the tailfin

Image: Lufthansa Teknik

While much of *The Engineer*'s coverage of the aerospace sector involves the research, development and manufacture of new aircraft, this is hardly the whole story of engineering in aerospace. The average lifetime of any aircraft can be measured in decades, and the effort – and innovation – that goes into keeping them in the air is considerable. And like so many aspects of the engineering world, it has its own set of acronyms.

The most important of these is MRO – maintenance, repair and overhaul – which refers to the activity and the companies that provide this service. The MRO industry is as varied as any other part of the engineering landscape, consisting of companies both large and small. At the top end of the spectrum, many of the large airlines run MRO operations on behalf of smaller players, something that has grown with the increasing prevalence of low-cost airlines that find it cheaper to contract in services than to provide their own. At the small end of the market are operations that tend to service 'executive airlines' that run a few business jets.

It would be fair to say that virtually all innovation in the aerospace sector is driven by efficiency, although different parts of the sector attach their own meaning to this. For aircraft manufacturers, efficiency means extracting the maximum possible performance from their vehicles for the minimum input of fuel: flying further for less cost and producing low emissions of greenhouse gas and noise. The obvious consequence of this is aircraft becoming lighter and using composites in place of heavier metals.

For MROs, efficiency has a slightly different meaning. It's to do with the most efficient use of the aircraft in service of its owner: in practical terms making sure it is earning money for the largest-possible fraction of its working life. An aircraft being maintained is not carrying passengers and therefore not earning fares – so in almost all cases, innovation in MRO is to do with making the process faster and returning the aircraft to active service in the air as soon as possible, rather than it being stuck in a hangar with components strewn over the floor.

Prof Ian Jennions, director of the IVHM (integrated vehicle health management) centre at Cranfield University, explained that airlines have scheduled maintenance, where the aircraft comes in for various kinds of checks at set periods, and unscheduled maintenance, which is fixing things that have gone wrong. "That's the expensive stuff, where the pilot comes into the cockpit turns the key [figuratively] and nothing happens. For the airlines, it's a case of how long will it take for us to turn that around? And because they don't know what's wrong, they don't know how long the plane will be the ground or how much it will cost. So, increasingly, the goal of scheduled maintenance is to, as far as possible, stop that from happening. When you ask airlines what they want from maintenance, the answer is that they want 100 per cent availability of their asset. Of course, that's not really possible: what they want is to be able to use their aircraft when they need it. And that means 'no surprises'."

In common with many sectors of industry, that means preventative maintenance is the priority during those scheduled maintenance periods. "Scheduled maintenance is called A, B, and C checks," Jennions explained. "A checks are like 'check the oil and the tyres'. Bs are where you might also check the batteries and things like that. C is more the heavy maintenance where you strip the aircraft down,

as far as taking the engines and even wings off, and checking for corrosion. During those periods, a lot of activity is about playing safe. If you have a component that you know will last for about 1,000 hours of flying time, you'll give it 950 hours and then pull it for replacement. That's simple, of course, but the area I work in is moving towards condition monitoring. And that's to do with informing maintainers how components are behaving. So, we fit sensors, we take data, we perform algorithms, and look at how those different parts are degrading to avoid this unscheduled maintenance.

"One kind of algorithm is a diagnostic; that will tell you what has gone wrong with something. The other is a prognostic, which is saying, 'something is not quite right and it will ultimately fail in the future'. It's giving you a time, saying that if you continue to use this vehicle in this way, you have a month, two months, three months in which to repair it before it can fail. That's kind of where it's at. So, you can inform the airline that they need to take action. They can arrange that with their maintenance staff, so they do it when they want to rather than when the plane breaks."

A variety of sensors are used for these purposes, Jennions said. Depending on the type of component or subsystem in question, they might be temperature or vibration sensors, for example. And this is bringing about a change in the way that maintenance is carried out, he added. "Aircraft have a maintenance computer and when they land, a first-line maintenance engineer will go into the cockpit and it will tell them what to do. That's quite a big change in culture, and you often get a response of 'that's not gone wrong, it's never gone wrong before.' But once people check and see that it's right, they quickly start taking the systems much more seriously."

Such scenarios are likely to be familiar to engineers in manufacturing sectors, where factories are also becoming increasingly sensor-equipped and oriented towards condition monitoring and preventative maintenance. But the MRO sector is also turning towards new technologies to help maintenance engineers do their job more effectively. For one of the biggest MROs, Lufthansa Technik, which provides services for many smaller and budget airlines, there is a dedicated business function for developing, assessing and forming usage procedures for such new technologies. Kevin Guelck, who works in the base maintenance product division (which handles mainly what Jennions referred to as C checks, the large-scale strip-down activities that occur at relatively long periods in the aircraft's duty cycle, typically every three years or so depending on the aircraft's flight hours), explained what happens in Lufthansa Teknik's Innovation Bay.

The bay is a hangar at the business's base in Malta, he explained. "We came up with the idea in 2018," he said. "It's a lot about internal process optimisation and improvements. We are not aiming for a theoretical improvement idea. It's really practical, next to the aircraft, interacting with the customer, interacting with the experts on site and

Image: :Lufthansa Teknik

Image:Lufthansa Teknik

01 Exoskeletons can help operators peform repeatetive tasks, but may limit flexibility
02 3D printing speeds up production of tooling

> "You often get a response of 'that's not gone wrong, it's never gone wrong before.' But once people check and see it's correct, they start taking maintenance computer systems more seriously"
>
> Prof Ian Jennions, Cranfield

prtrying to get things moved there." Some of the technologies being tested are on the cutting edge of engineering techniques, said Guelck. "One very good example is 3D printing, which we are using to make small tools and fixtures. It's a very fast way for us to prototype these tools, and we'll work up towards printing them on demand to be used during actual operations, rather than having to have them manufactured off site."

Another technology that has been trialled in the Innovation Bay is the use of drones in aircraft inspection. "Today, that's all done by the human eye. A maintenance engineer inspects the surface of the aircraft for scratches, corrosion and dents. A camera mounted on a drone system with machine vision checking the camera output is potentially faster and more able to reach some of the difficult areas, such as the vertical tail fin, which can be very high off the ground, so getting a person up there on a gantry and getting them close enough to inspect properly can be a problem."

UK company Blue Bear is among those developing drones for this activity. Operations director Gavin Goudie told The Engineer that drone inspections are intended to supplement rather than replace altogether visual inspections by maintenance engineers. "However, we are looking at installing different types of sensor on the drone that could potentially detect the kind of defects that would not be visible even to the experienced human eye," he said. "As with all technology in this space, the goal is to improve the thoroughness of the inspection and to reduce the time it takes."

Guelck also explained how Lufthansa Technik is looking at the introduction of augmented reality systems to help maintenance engineers perform their role. "We've looked at one system that helps the operator to get a direct visual feedback on the dimensions of a dent or scratch. The more 'classical applications' of augmented reality, with systems such as Google Glass or Microsoft HoloLens, have

03 Augmented reality rig to help scan for supeficial damage

different options where they are used in training or to help guide people through the various steps of inspection or repair processes."

Aircraft manufacturers are looking at ways of augmenting engineers themselves to help with their jobs. For example, Airbus now uses partial exoskeletons to help engineers perform repetitive operations that require awkward physical positioning, such as lifting heavy tools many times to fix fasteners in position. Lufthansa Technik is also looking at exoskeleton usage, said Guelck. "Base maintenance is very man-hour intensive. The people working on the aircraft have to carry out tasks that are sometimes very, very heavy and take a lot of energy. And that gave us the idea to bring the problem side and the technology side together and trial exoskeleton systems in the Innovation Bay."

Two different types of exoskeleton have been tested, said Guelck. One of these is a 'chairless chair', a device that supports operators in a relaxed sitting position when they have to work on something at a lower level. Another is a device called the Airframe, which supports the operator's arms when they lift heavy items. Eventually, the company decided not to implement either solution. "We got some positive feedback in that they do help with support, but operators also found that they limited flexibility of movements. We continue to work closely with suppliers to develop such systems – in these cases they came from the medical sector to help people rehabilitating from injury and from prosthetic technology, but we decided they weren't for us in routine operations."

Much of Guelck's work is with airframe maintenance; for Lufthansa Technik, at least, engine maintenance comes under a different division. But here, new technology is again developing, with the aim of making engine maintenance faster. At Rolls-Royce, a suite of robotic systems is being developed to maintain engines without having to take them off the wing of the aircraft.

Rolls-Royce joining and addition specialist Chris Heason explained that taking an engine off a wing makes working on it much easier, as all the systems are more accessible, but it means that the aircraft will be out of operation for weeks. If the maintenance and repair operations can be carried out with the engine in place, that could potentially be shortened to days. "We only make an engine once, but it will be fully serviced four or five times, and that tends to be every 10 million miles of flight service – that's equivalent of flying to the Moon and back 20 times. When they come in for overhaul, many if not most of the parts look misshapen compared to when they came out of the factory."

> "An engine will be serviced every 10 million miles of flight service - that's the equivalent of flying to the moon and back 20 times"
>
> Chris Heason, Rolls-Royce

Rolls-Royce is developing three different on-wing robotic maintenance systems. Flare is a snake-robot-based system that can go inside engine combustion chambers and carry out in-situ repairs. The interiors of combustion chambers are coated with a specialist ceramic that helps them resist the high temperatures of burning fuel, but these coatings can, over time, flake and expose the underlying metal. The flare system uses a pair of snake robots, the diameter of a pen, one of which is

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accrued with cameras and the other with a flame-spray nozzle that melts powdered ceramic at around 3,000°C and fires it at a damaged area. "When we find a bit of coating that's flaked off, we can go inside the engine and put a patch back on; rather like a high-tech sticking plaster, to make sure that the engine gets back to base when it's scheduled to," Heason explained. This system is being developed in partnership with Nottingham University and Dudley-based company Metallisation, which specialises in flame-spray technology.

Another system, Cobra, is a 5m-long, 8mm diameter, highly manoeuvrable snake robot that would be used in conjunction with augmented reality technology to inspect the interior of a jet engine to diagnose any problems it might have. Cobra can also carry tools to melt, for example, cracked turbine blades so that the crack is replaced by a scallop shape that cannot propagate and break off the blade while the engine is in service. This system is being developed in association with RACE (Remote Applications in Challenging Environments), the UK Atomic Energy Authority robot development organisation, as it may also have applications in inspecting the interiors of nuclear reactors, said Heason.

The third system is called Swarm and, as the name implies, it consists of very small bug-like robots. These are based on a chassis developed by Harvard University, which would explore the interior of an engine combustion chamber. "A range of these beetles would be introduced into the engine using a snake-like robot. Each of them is looking at a feature within the engine and it is sending its position, as well as what it is seeing, back to a centralised location. That enables you to complete a scan of what you're seeing. And once you've finished, all of those little devices are then collected back by the same snake robot and taken out of the engine." Although the swarm beetles would not themselves carry out any repairs, their data would help a system such as Cobra or Flare to be deployed more quickly and effectively, Heason explained. Currently, the beetles use electrostatic forces around their feet to enable them to walk upside down inside the complex shaped spaces of the combustion chamber.

Another system that Rolls-Royce is working on, although not this time in the on-wing paradigm, is the automated repair of blisks: bladed discs that make up part of the compressor section of a gas turbine engine. Blisks are lighter and stronger than discs onto which blades have been welded, but they are high-value components that are difficult to repair, Heason said. The company has been working with Swansea and Birmingham universities on a system that uses relative layer manufacturing to repair damaged blisks.

It's a multistage process. First, the blisk is sprayed with a thin coating of a white paint so that a visual scanning system is not confused by reflections from the highly polished metal of the blisk. Then, a camera system mounted on a robot arm is used to inspect blisks from all angles to build up a detailed three-dimensional scan of its geometry, including any damaged or snapped blades. "They may have picked up a lot of damage. They might have bent a little bit slightly. The point is they don't look like the CAD model that we sent out the door. They have to be digitised first. Every repair that we make in that cell is highly adaptive and unique to that damage feature. We need to have some kind of digital twin to make sure that that adaptive repair takes place."

The scanned blade is then put into a laser additive layer manufacturing cell under a carefully controlled argon atmosphere, where a metal powder jet is used to repair any defects. "There aren't any other laser cells like that in the world that enable you to have such a control of the atmospheric conditions, so the resulting repaired blade is as good as it would be when it leaves the factory floor. So, we don't have any kind of fatigue life loss within this component after its repair." The final stage of the process is re-machining the repaired blisks on a six-axis machine-tool so they conform precisely to the original design specifications.

The MRO business is currently undergoing significant changes, according to Cranfield's Ian Jennions. This, he explained, comes from the airlines realising that the profit margins in MRO are considerably higher than those for operators: 25 to 30 per cent compared with 10 to 15 per cent. This has led to companies such as Delta Air Lines moving aggressively into the MRO market, he said. "They overhaul engines; they overhaul everything. They recognised very early that the money was in the parts, not just in attached labour. So, they reverse-engineered the entire structure of the blades, for example, got them approved, and then they do their own blade repairs."

But this is not the case everywhere, he added. In Europe, KLM, Air France and Lufthansa also offer similar services, but Middle East carriers such as Etihad and Emirates prefer the OEMs to carry out their own MRO activities, Jennions explained "It's a fascinating space because on one side, you've got the MRO organisations of airlines like Delta saying, 'we have all this operational data on how to fly Boeings. Would you like it and how much are you going to pay for it?'. On the other hand, you've got equally large airlines like Emirates saying, 'okay, Mr Boeing or Mr Airbus, you arrange the maintenance for us. Just take care of it." ■

> "Every blisk repair we make in the cell is hughly adaptive and unique. We need to have a digital twin to make sure it takes place."
>
> Chris Heason, Rolls-Royce

04 Rolls-Royce's maintenance innovations, clockwise from top left: Cobra, being controlled by AR; Swarm; FLARE, flame-spraying; and FLARE, exploring

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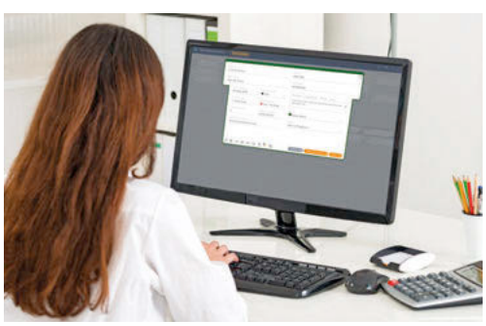

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Sustainababble and the circular economy

What might the future look like for manufacturing when we have to take sustainability more seriously? Stuart Nathan puts on his thinking cap

Is sustainability sustainable? I don't mean the concept itself. At a time when we are supposed to be on the lookout for runaway growth in all sorts of environmental markers, one thing that is growing exponentially is the use of buzzwords, and that threatens to rob them of their meaning and their force.

An event organised by Dassault Systemes in July was concerned with sustainable industry and explored the implications of the term. The changes that true sustainability will require from industry are profound. While talk of "sustainable people" might be pure 'sustainababble', to borrow an irresistible term from keynote speaker James Woudhuysen, it's worth thinking about what a truly sustainable vision of industry would be.

It would take product stewardship to a level so far unseen. If we are to think sustainably – that is, ensuring that the pool of usable raw materials is not permanently depleted – then we will have to adapt our business models so that manufacturers can still make a profit when they return the materials to the supply chain.

It might be that the recycling aspect of the 'circular economy' would fall to a new industrial sector, but that sector would still have to generate a profit for its investors. s the feeling at a political and public level is that the manufacturer should take responsibility for recycling, there would have to be some sort of transaction between manufacturer and recycler.

This raises an interesting question. Who is the manufacturer? If Jaguar Land Rover (JLR) builds a car, it's made mainly from aluminium and steel, which are highly recyclable. At the end of its life, having passed through the hands of several owners, it needs to be recycled. Many of its components will have been made by companies in JLR's supply chain, and that origin will have been captured as part of its business processes. Will JLR have to become a reverse distributor, taking responsibility somehow for returning those components back to their origin for disposal and recycling?

This is even more complex than it seems. I'm indebted to friend of *The Engineer* Prof Mark Miodownik of UCL for a couple of thought-provoking examples. The touchscreen devices that so many of us have incorporated into our everyday lives depend for their function on the unique properties of one element: indium. Touchscreens will not work without indium tin oxide, a transparent conductor. And indium is quite scarce.

That's a lot of rhenium. Are we going to need to recycle it?
Image: Rolls-Royce

Most of it comes from China as a byproduct of zinc mining, and at the rates we are producing touchscreen electronic devices we only have enough for the next couple of decades. Somebody is going to have to seriously work on a process for recovering indium from end-of-life touchscreens.

The aerospace industry is one that is probably more familiar to most *Engineer* readers, and it has a similar problem. Low-cost flying is a result of the development of more fuel-efficient engines that operate at high temperatures. That is a direct result of the heat-resistant properties of rhenium, a component of the alloys from which jet engine turbine blades are made. Rhenium is one of the rarest elements on Earth; 70 per cent of all annual production goes into turbine blades and we're going to run out of it at current rates of production. Are jet-engine manufacturers going to have to build rhenium recovery into their business models?

Questions such as these are one reason that some people are thinking about space mining. Elements are produced in supernovas. There might be deposits on the Moon and they will exist inside asteroids. But the cost and complexity of finding, extracting and bringing them back to Earth is not going to be economic soon, and so turning the industries that use them into part of the circular economy is probably the only practical solution.

So, what is a sustainable person? Is it somebody who can work out how industry can continue to operate? Is it somebody who can adapt and learn new skills that don't currently exist to handle such processes? Is it somebody who can cope with the changes to a way of life we have come to take for granted as the iron laws of elemental properties and abundance in the Earth's crust take hold? Or is that so much 'sustainababble'?

Comments on p32

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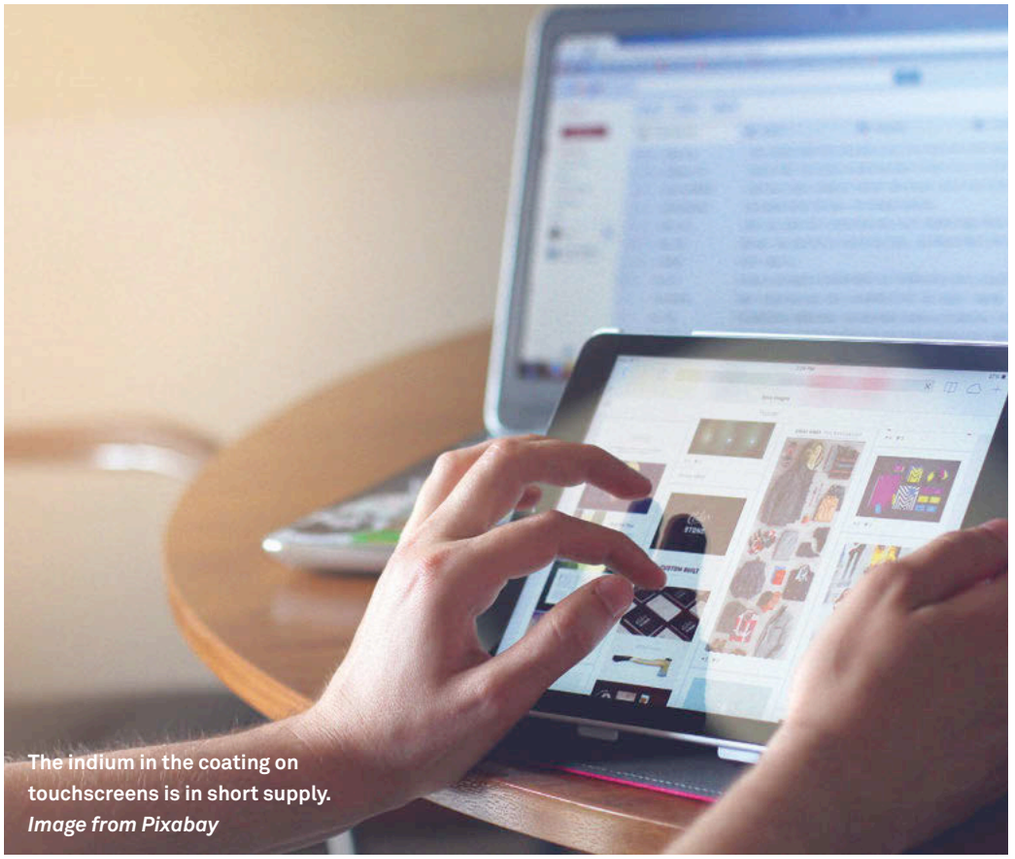
"Perhaps the circle is more of a helix with different options - such as repair and reusability or repurposing. Car spare parts could be made cheaper and easier to fix"

Julian Spence



The indium in the coating on touchscreens is in short supply. ***Image from Pixabay***

I find this opportunity really exciting. More and more of my students are engaging in these conversations, which I love to see. I'm going to use this in my classes. A question for you and your readers. From a supply chain perspective, and in the main, do you think we will have to create brand-new supply chains to move successfully into the circular economy? Or can we adapt existing supply chains?

Chuck Nemer

The circular economy requires new mindsets at every level. If we look at the JLR and aerospace cases being at the more complex end of the spectrum, this topic has to become a central part of the management process, but governments will also have to be seriously involved.

At the product-owner level (JLR, Airbus), every component will have to be designed for a high level of re-cycling with the responsibility of each member of the supply chain identified and signed up to the re-manufacturing process as an integral part of the supply contract.

If the re-manufacture of a components cannot be guaranteed, the design should be changed even if this might mean reduced performance or increased cost. End-of-product life will also need to be handled.

The greenhouse-gas emissions for the complete manufacturing and distribution process will need to be continuously monitored with point-of-sale tax added for goods for which appropriate documentation and guarantees are not available.

This may well reduce the demand or change the supply chain: for instance, local supply may become more competitive.

Sound drastic? Perhaps, but with good PLM, manufacturing and maintenance systems this is achievable, but the design process has to be seriously re-thought.

Ian Duncan

I think this is a good article that gets the ball rolling.

People are already looking to replace indium tin oxide because of its cost and toxicity, and zinc oxide looks a good bet. However, the point is well made about resource scarcity and resource limits.

The point about the costs of recycling (money, pollution and so on) has been well made.

However, perhaps the circle is more of a helix with different options – such as repair and re-usability and re-purposing. I'm not sure how this could be encouraged. Perhaps, for example, car spare parts could be made cheaper and easier to fix. This would reduce insurance costs and could encourage the birth of small local 'fixit' companies (and could also apply to other electronic goods).

In addition, lightweighting, by design (including multi-functionality) has a part to play in increasing material efficiency. As cost is often 'designed in' it is perhaps worth considering affordable manufacturing technologies and then get designers to consider manufacturing opportunities

Julian Spence

"There really isn't anything to compete with neodymium for magnets". This according to a mines expert in 2019.

In November 2018, a 3.6MW wind turbine in Denmark had its permanent magnet generator replaced by a high-temperature superconducting ceramic as part of the EU-funded EcoSwing project. The superconductor reduces the size of the generator and replaces about 1t of neodymium (Nd) used in NdFeB permanent magnets with about 1kg of the rare earth gadolinium used in the superconducting composite tape: gadolinium–barium–copper oxide (GdBaCuO).

How much funding is the EU prepared to put into a sea change in marine RE design, to make all these electrical components redundant? Install integral energy storage too. Then you'll have sustainable, dispatchable electricity around the globe.

David Smart

I have long seen the word "Sustainability" as an excuse for lazy thinking, as noted in the article it is used in the media to justify anything. The natural supply/demand side of sustainability should be able to cope but needs regulations to ensure that the right costs are applied to the right wastage stream. Thus, the disposable food wrapping (and even wasted food therein) are taxed very lightly at present and there is little incentive to recycle or avoid wastage.

The real implication of wastage is litter, increased waste treatment and disposal costs and sometimes loss of a valuable asset. "Sustainability" is used instead of "good-housekeeping" and "common sense" to try to make reducing wastage and poor economic evaluation of this seem scientifically based. Look at the reduction in plastic bag usage since charges were imposed: this simple, sensible bit of conservation took years longer than it ought to have taken.

Jack Boughton

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Charting a course for autonomy

Thales UK chief executive Victor Chavez spoke to Andrew Wade **about maritime autonomy, cybersecurity, skills and Brexit**

Given Victor Chavez's background, it's perhaps no surprise that he ended up at the helm of one of the UK's biggest naval contactors.

"You might not get it from my surname, but I was born in Barrow-in-Furness in Cumbria," Chavez told The Engineer. "My father ran off to join the Chilean Navy at the age of 15. My mother was British and they met when Vickers in Barrow was building ships for the Chilean Navy. So I am the product of a defence exports sale, which seems entirely appropriate!"

Chavez was speaking on the back of a Thales UK roundtable on maritime autonomy that the chief executive had chaired himself. Having joined the company in 1999, he graduated to the top job in 2011. Thales today counts more than 50 of the world's navies as customers, many of whom view autonomy as a growing priority.

"Maritime defence is basically our biggest sector as Thales UK, so maritime autonomy is naturally an area that we're gravitating to and it's a huge opportunity for navies around the world," Chavez said.

He points to the dominance of Predator drones in the unmanned aerial market when they arrived more than 20 years ago. By comparison, no such hegemony exists in the maritime world, giving space for a broader ecosystem to evolve. Thales UK's expertise in mine clearance puts it in prime position to be part of that ecosystem, according to the CEO.

"Not only is maritime our major sector, but mine countermeasures and mine hunting is an export product and capability that we've been providing for decades to the Royal Navy. And mine clearance is one of the most obvious use cases for autonomy," he said.

"We're at that transition where navies around the world will start buying autonomous systems and phasing out historic mine countermeasures vessels. So, for us it's existential that Thales UK succeeds in this market."

Mine hunters may be the obvious entry point for autonomous naval vessels, but there is a much wider maritime market on the horizon. This raises the question of data and communications. In a future where fleets of autonomous or unmanned vessels rule the waves, will satcoms be capable of relaying all that data? Chavez, whose academic background is in physics and satellite engineering, says the current infrastructure is sufficient but that defence systems are rarely built to rely on satcoms alone.

"As we all know with bandwidth, the more you give the more we use," he said. "For defence autonomous systems, we design them to be robust in the face of a hostile RF [radio-frequency] environment as well."

01 With more than 50 of the world's navies as customers, maritime defence is Thales UK's biggest sector

02 Both surface and subsea autonomy are major priorities for Thales

In many instances, this means redundancy that allows platforms to operate in the complete absence of satcoms.

"You can use satellite if it's there. If it's not there, then you have to make do with something else. So, it teaches us to be very meagre in terms of our data rates; we really will compress everything down as far as humanly possible.

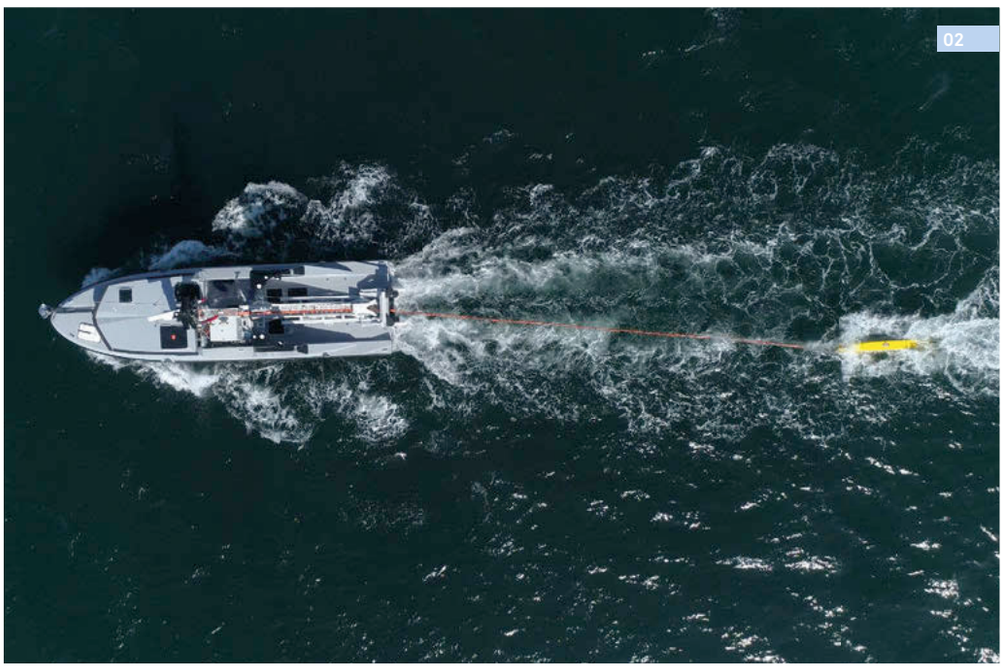
"As capacity increases, it gives us the opportunity for ever-richer analysis, because we'll have a richer data set to look at. At the moment, we have to rely on smarter algorithms on board to compress data sets in certain scenarios."

Satcoms for surface vessels may not be a problem, but subsea communications remain a stubborn conundrum. To reach submarines or unmanned underwater vehicles (UUVs) at significant depths, radio signals need to be in the extremely low frequency (ELF) range, generally considered to be between 0-300Hz.

Creating these mega longwave transmissions requires grounded wire antennas up to 60km long that use huge amounts of energy, sometimes requiring their own power stations. Even then, communication is limited to just a few characters per minute, with submarines often simply instructed to climb to periscope depth so that more detailed orders can be given via traditional RF methods.

"It's a little bit specialised," Chavez joked. "Whales seem to be quite good at it."

Although research is ongoing, the Thales UK



chief admits that subsea comms is a technical issue that may never be solved.

"The laws of physics tend to be fairly immutable in that respect."

Tomorrow's engineers may not be expected to solve the problem of subsea communication, but skills around autonomy will be a prerequisite for many. Indeed, Thales sees unmanned vessels as something of a honeypot for the maritime sector. Where the brightest and best may once have been lost to the 'sexier' disciplines of aerospace and automotive, the rapid advances in maritime autonomy could help redress the balance.

"We do really see things such as autonomy and robotics as exciting the next generation of talent in engineering, and people who are interested in STEM want to work on new technologies and capabilities," said Chavez.

"At Thales we're currently working on unmanned air vehicles, unmanned surface vehicles, unmanned underwater vehicles, autonomous trains, unmanned air traffic management, and satellites, which are pretty autonomous once you put them up there."

Autonomy in the maritime segment – particularly in commercial shipping – could also help substantially reduce emissions, striking a chord with climate-conscious millennial engineers.

"There's no doubt that maritime autonomy has a good potential in exciting people and, as with all autonomous systems, they actually require a wide range of engineering disciplines," said Chavez.

> "We're at that transition where navies around the world will start buying autonomous systems"

One of those disciplines will be cybersecurity and the area of digital trust. In April, Thales completed the €4.8bn acquisition of Dutch software firm Gemalto, specialists in digital identity and biometrics. The company will become Thales's seventh global division, named Digital Identity and Security (DIS). According to Chavez, Gemalto's capabilities will benefit the entire Thales Group.

"They are at the heart of all of the digital identity and security that you touch and use every day of your lives, whether it's SIM cards in your mobile phone or the security for the banking and payment card in your wallet," he explained.

"It's quite a different sector for us. It's a much more 'civil' sector, a more mobile tech sector. And that's really exciting because we will transform all of our businesses using these technologies, regardless of which sector it is. Digital trust is at the heart of securing all of those autonomous systems, for example... and as we become more and more dependent on these capabilities, advanced trust architectures are the answer to how we can trust these systems with our lives."

With Brexit looming, Thales is again preparing for possible disruption to its supply chains. It's a worry, but not one that Chavez seems to be losing sleep over. Having ramped up preparations in March, the company will be doing similar ahead of the 31 October deadline. As for any skills squeeze, Thales should be insulated from the worst of it by the nature of its business.

"Because we do a significant element of defence work in the UK, the vast majority of our people are UK nationals, but as you'd expect we do have some non-UK EU nationals as well," said Chavez. "And it's really important that we retain access to this sort of talent."

Key to that, according to Chavez, will be a responsive visa regime that enables swift access to overseas engineers. Boris Johnson's recent announcement for just such a system will no doubt be welcomed by the Thales UK chief. As always, however, the devil will be in the detail. The future of the high seas may well be unmanned, but the human skills required to build that future have never been more in demand. ■

Standing out from the rest

Maintec, the longest standing event dedicated to the maintenance and reliability in the UK is back. And it's bigger and bolder than ever...

Maintec is somewhat an outlier in the world of engineering exhibitions in the UK. As the longest-standing event dedicated to the maintenance industry, which this year will be celebrating 44 years, it has stood the test of time – evolving and adapting to the changing profession and becoming the only annual event of its kind.

When the event returns to The NEC, Birmingham on the 30-31 October 2019, it will be third edition of Maintec under the steerage of Western Business Exhibitions, part of the Nineteen Group, who have invested significant time and resources into revolutionising the event to ensure it remains pertinent to the maintenance and reliability engineering professionals operating in the UK today.

In 2018, Maintec was delivered under the theme 'The future of maintenance and reliability', and was described by Jos Diamond, Event Manager, "a new direction" with organisers moving to a new date line of November and reducing the show down to two more impactful days. These major changes to the event format were hailed as a success with 65% of exhibitors

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confirming their participation for 2019 before the show doors had closed.

Details of its success has since caught the attention of a breadth of new exhibiting companies participating this year including global manufacturer and automation solution specialist, Emerson who announced their headline event partnership back in May.

Gary Ingram, Sales Manager UK & Ireland – Reliability Solution at Emerson Automation Solutions said of the partnership: "We are delighted to be attending Maintec 2019 as Event Partner. The event will provide a fantastic forum to share our latest digital technologies with the industry."

Platform to Launch

Its high-level seminar content and breadth of exhibitor base attracts maintenance, reliability and asset professionals from across UK industry and as such is seen by many exhibitors as the best platform to launch their brand new technology and equipment to the UK market.

Over a fifth of exhibitors used the event as a platform to launch their new technologies and services for the first time in the UK in 2018 and while many exhibitors are still keeping the details of their launches for this year close to their chest, they are promising to bring their very latest products, equipment and software to the event allowing visitors to see and experience the cutting-edge technology live and exclusively on the show floor.

Digitalisation to the fore

Education has always been part of the WBE format of Maintec. The new-look programme will feature a variety of different session formats including; keynote presentations, in-depth case study reviews of active maintenance projects, technical sessions, and panel discussions.

Each day begins with a keynote presentation, both of which emphasise the role of digitalisation in modern maintenance. Today, digitalisation offers wide-ranging potential for long-term and predictive maintenance.

A company's digital transformation journey can start small to address a single issue, such as pump health or personnel safety and build from there. Or it can explore company-wide programmes across a full impact area, such as reliability. On an even larger scale, it can mean an enterprise-wide strategy across all manufacturing and operations areas, with a view to enabling true business transformation.

IIoT uses network-enabled intelligent sensing devices and applications to collect, analyse and act upon huge amounts of plant data. Companies in process and manufacturing have for many years been using connected sensors to feed data into computers to control their processes. The IIoT uses connectivity to extend this methodology, so that real-time data can be accessed and interpreted by experts

> **"Companies that have invested in IIoT are now achieving quantifiable business value through a significant reduction in maintenance costs.**

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anywhere in the world. They can then provide actionable insights that can lead to significant improvements in core areas such as energy consumption and equipment reliability.

Companies that have invested in IIoT are now achieving quantifiable business value through a significant reduction in maintenance costs. The technology can warn that a piece of critical equipment is about to fail, enabling them to repair or replace it before it does so.

But how do we that ensure the data needed for planning, processing and documenting maintenance measures is exchanged reliably? On day one (30 October), Gary Ingram from Emerson Automation Solutions will talk on 'Accelerating the Digitalisation Journey with Operational Certainty'. Emerson studies suggest that a company can save around £40 million on their ongoing maintenance budget for every £1 billion of capital that they already have deployed in their plant.

On day two (31 October), Martin Walder, Chairman of the Engineering and Machinery Alliance (EAMA) and Vice President Industry, Schneider UK, will talk on 'Merging IT (Information Technology) and OT (Operational Technology) to Maximise the Potential of Digitalisation'. Information Technology (IT) teams that are accustomed to working in spotless data centres now need to collaborate with Operations Technology (OT) colleagues who often work in dangerous industrial settings. What happens when OT and IT collide? If not managed well, the result can be a clash of cultures and a potential crisis.

One Schneider case study talks of an instance where IT and OT were not working well together so the manufacturer sent both IT and OT to school to learn about each other's area of expertise!

Raising the standard

After the extremely successful partnership in 2018, Society of Operations Engineers (SOE), the professional engineering membership organisation, has once again confirmed that it will be partnering with Maintec for 2019.

SOE promotes efficient, safe and environmentally sustainable Operations Engineering for the betterment of the community at large, with the view of also promoting public safety by supporting and encouraging the standards of competence when contributing to the society.

All of the Maintec seminar sessions will be CPD accredited and approved by the Society of Operations Engineers, who review each session prior to the event to ensure the highest level of educational quality.

In an open letter to the industry, Bruce McGill, CEO at SOE states: "Last year the Society of Operations Engineers partnered with Maintec to approve its CPD programme for the two-day event in Birmingham. It was an easy decision given that the show has a reputation for attracting a high-quality line-up of guest speakers, while fulfilling CPD requirements which have now become mandatory. As there are many shows in the calendar throughout the year, it is reassuring to know that this one is the only one dedicated to the maintenance engineering community.

"The quality on offer at Maintec is why we approved this CPD programme last year and will do so again in October. So, what can visitors of the show expect from the programme? We have all now heard about elements of Industry 4.0, predictive maintenance, The Internet of Things, AI and big data, but what is the significance of this technology, how will it be integrated, and what are the repercussions for engineering maintenance teams? What will its impact be on education and skills, strategy and policy? Two or three years ago we were looking ahead at how this technology would change our working lives. Would it render some of us obsolete in the workplace? Now it has begun, we are asking different questions about what it means - to what extent can it improve efficiency, flexibility and productivity? Speakers and expert panels at Maintec will tell you how, exactly, it will affect maintenance engineers and what it means for the future of the sector."

> **The quality on offer at Maintec is why we approved this CPD programme last year and will do so again in October.**

PROGRAMME HIGHLIGHTS

This year's Maintec seminar programme features some of the UK's leadning engineering voices.

Highlights include:

KEYNOTE SESSION - Accelerating the Digitalisation Journey with Operational Certainty
Speaker: Gary Ingram, Sales Manager UK&I, Emerson Automation Solutions
Gary Ingram, Sales Manager UK&I at Emerson Automation Solutions speaks about the increasing significance of digitalisation in the maintenance function.

Maintec Insights Deep Dive session: Improved reliability and productivity at oil storage and offloading facilities
Speaker: Dr Bassey O Bassey, Cranfield University
A balance needs to be struck between meeting production targets and minimising breakdowns. This case study looks at a petroleum transportation and storage facility in the Eastern Niger Delta area of Nigeria. Your guide is Dr Bassey Bassey, who studies Energy and Power at Cranfield University. He was previously the flow assurance team deputy lead and facilities inspection coordinator for Northwest Petroleum and Gas Company Limited, Calabar, Nigeria.

Active Maintenance Case Study: Building a Predictive Maintenance Program from scratch in the pharmaceutical industry
Speaker: Chris Hallum, Technical Support Engineer, UE Systems
Ultrasound technology offers a wide range of application areas, notably in the pharmaceutical industry. It can be effectively applied in maintenance activities, and UE Systems Technical Support Engineer Chris Hallum leads a presentation with Ipsen Biopharma, for whom the UK is one of three global hubs.

Reliability Dialogue Panel Discussion: Asset Maintenance Strategies
Back by popular demand, the Reliability Dialogue panel discussion on Asset Maintenance Strategies which had visitors standing in the aisles last year. This lively Q&A session will give visitors to put forward their questions on any aspect of asset maintenance to professional panel.

All sessions are CPD accredited and approved by the Society of Operations Engineers.

Free visitor registration for Maintec is now open at www.maintec.co.uk. Follow @UKMAINTEC on Twitter for show news.

Force to be reckoned with

Aston Martin's Valkyrie is one of the most hotly anticipated supercars of the decade, and its V12 powerplant has been hailed as the ultimate expression of the internal combustion engine. Jon Excell reports

Even behind two hermetically sealed doors, three layers of bullet-proof glass, and several layers of acoustic damping, the scream of the chunk of precision-engineered metal strapped to a dynamometer deep inside the HQ of UK powertrain specialist Cosworth is frighteningly impressive. We're reliably assured that were we standing next to it we wouldn't be able to hear ourselves think.

This is the engine for the Aston Martin Valkyrie, the long-awaited £2.5m hypercar jointly developed with Red Bull Racing, which made its first public appearance at Silverstone during the British Grand Prix earlier this summer.

Developed by Cosworth in close collaboration with Valkyrie's chief designer, Red Bull CTO Adrian Newey, this 6.5-litre V12 boasts the highest specific power of any normally aspirated production road engine in the world, producing 1,000bhp at 11,100rpm, and is key to the performance of what is claimed to be the fastest street-legal vehicle in the world.

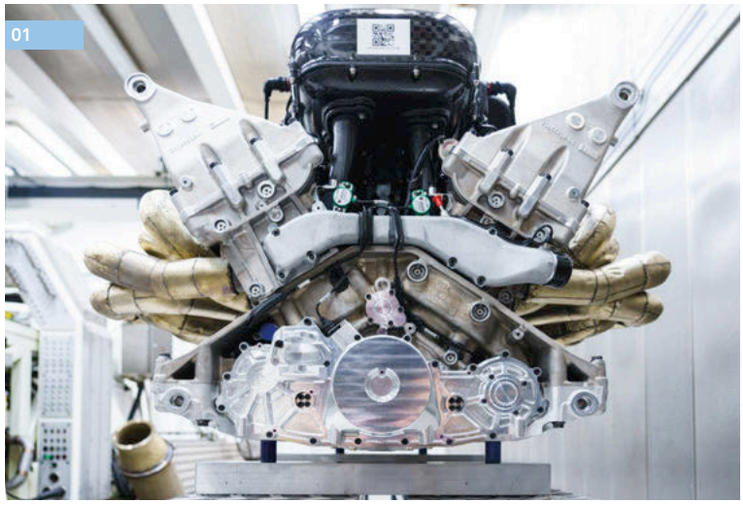
Cosworth, which celebrated its 60th anniversary in 2018, is the natural choice for such a project. Best known for its long association with motorsport – its legendary DFV (Double Four Valve) V8 engine remains the most successful prime mover in racing history – the Northampton firm has been expanding into other areas in recent years, and as MD Bruce Wood told *The Engineer*, the lucrative and growing market for high-end production engines is a logical outlet for its expertise.

"All the skills we've learned in motor racing are absolutely applicable in the road-car world," he said, "because motor racing really is just about efficiency, whether it's power-to-weight ratio, fuel consumption in F1; they're all efficiency by another name."

Nevertheless, the Valkyrie engine pushes this dynamic to its limits. "It's a combination of everything we've learned in the last 30 years both in terms of the engineering design and manufacturing excellence. This is not just some track-day special, this is Aston's flagship car, and it's a production vehicle."

Indeed, while Aston may only be making 150 cars, the fact that it is technically a road car and has to meet the same regulations as other road cars is key. And balancing the demands for high power and low emissions without using a turbo charger was, said Wood, the core challenge of the project. "To make a 1,000hp, 6.5-litre engine, while a challenge in itself, is what we've done for our entire lives. The real challenge is to make a 1,000hp, 6.5-litre engine that meets Euro 6 emissions standards, because those two things, if not mutually exclusive, drive you in different directions."

> "You start with the combustion system and clothe it with an engine"



The key problem here is one of airflow: while high power requires lots of laminar flow into the engine, reduced emissions require turbulence. And with Adrian Newey adamant that the Valkyrie couldn't simply use a turbocharger, Wood's team had to come up with a different approach.

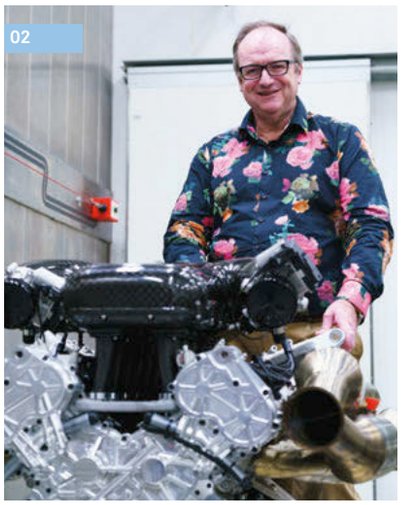
While Wood wouldn't be drawn on precisely how his team pulled off this tricky balancing act, the story of how it got to this point is fascinating. And it began with the design and simulation of the combustion system. "It all comes down to the combustion system," he explained. "You start with the combustion system and clothe it with the architecture of an engine."

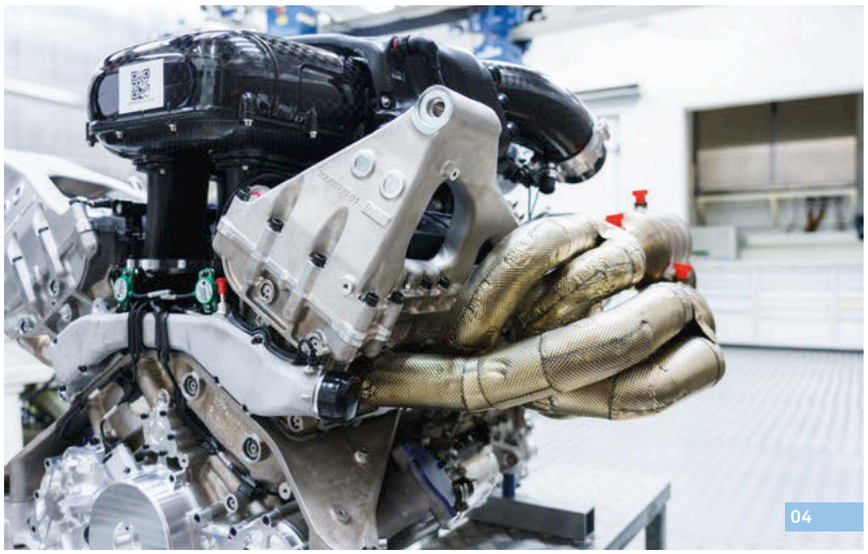
Within six weeks of kicking off the project, before any hardware had been developed, Wood's team was confident that it could meet the emissions targets and get the airflow.

The next step was the development of a mule engine: a scaled-down three-cylinder version of the full engine. "We didn't want to wait 12 months [the design time for the entire engine] to find out whether we were right about our combustion simulation, so we set out to make a quarter of an engine," explained Wood. This three-cylinder model was up and running on the dynamometer within five months, and after just a couple of weeks of running, the team was confident that the final engine would deliver.

Beyond the combustion system, another major innovation in the design of the engine is the fact that it's also a full structural element: remove the engine and there's nothing connecting the front and rear wheels. Cosworth introduced structural engines to F1 in 1967, but it has never before featured on a production vehicle.

This means that the engine has had to be designed to withstand some





01 The Valkyrie V12 has the highest specific power of any normally aspirated road engine

02 Bruce Wood with his V12 brainchild ©DEAN SMITH

03 The Valkyrie is Aston's flagship car

04 All parts of the engine were machined in-house

05 The engine is a structural component, connecting the front and back wheels of the car

pretty ferocious loads: "The forces are absolutely enormous," said Wood, "which is why most people don't do it – we're quite used to designing engines as structural elements of a car but even for us this was very difficult."

One of the reasons for this is that the car is a two-seater, and the engine mounts are therefore much further apart than in an F1 car. "To drive the weight out but to have the stiffness to take all of those loads and transmit them down to the only stiff bit of the engine was very, very difficult," said Wood.

Another challenge has been integrating the Valkyrie engine with the car's hybrid element, its 160hp electric motor, which was developed by Milton Keynes-based Integral Powertrain. Largely used to drive the car in reverse and to help with the gear shifting, this system – which is integrated into the gearbox – doesn't come into physical contact with the engine. However, Wood said that a lot of the calibration strategy for the engine has revolved around the hybrid elements.

In terms of manufacturing, pretty much every part of the engine (from the cam covers, block and sump to the cranks, cylinder heads and pumps) were machined in house. The pistons were made on the firm's own piston forge, while the cranks were painstakingly machined from a single billet of triple vacuum re-melted steel. Cosworth has been producing engines at a rate of about two per week since March 2019.

In the meantime, the engine continues to be put through its paces in the firm's state-of-the-art Dynamometer facility.

Originally built to test F1 engines, the facility – one of the most advanced of its kind in the UK – enables Cosworth's technicians to replicate anything from the Nürburgring to a sedate trip to the supermarket, and to expose the engine to the full range of conditions that it will meet in the real world. "We can create anything from 10-degree air inlet to 45-degree air inlet, with anything from 0-100 per cent humidity," explained lead dyno technician Liam Gorton.

While Valkyrie is going to keep Cosworth's engineers busy for some time yet, the firm already has another supercar in its sights: the Gordon Murray T50, for which it will be making what's expected to be the highest-revving engine ever used in a road car.

In the age of electrification, its perhaps surprising to see the V12 engine at the heart of any automotive firm's plans for the future, but Wood is in no doubt that the market for high-end engines is growing and will form a significant part of the company's future.

And while acknowledging the need to diversify – somewhat surprisingly, aerospace and marine projects now account for around 50 per cent of Cosworth's revenues – he rejects the notion that the high-end space represents some rarefied final bastion for the internal combustion engine. "In 20 years, every vehicle will have some form of electrification, but I don't subscribe to the view that that's the death of the IC engine, and I don't see anything on the horizon that will change that. The future is hybridisation. Electrification and the internal combustion engine have a happy life together for at least the next 10 to 15 years." ■

Q&A: Ian Warhurst on rescuing Bloodhound

The Engineer speaks to the Yorkshire businessman who rescued Bloodhound from the scrapheap

As reported earlier this summer, Bloodhound, the car designed for Britain's next assault on the world land speed record, is set for high-speed tests in South Africa this autumn.

The news is a welcome sign that the project is back on track following its rescue late last year by Yorkshire businessman Ian Warhurst.

Earlier this summer The Engineer spoke to Warhurst about his involvement in the project and his plans for the future.

How did you end up buying Bloodhound?

I thought I'd retired. I've been running my own business for the last 16 years [turbocharger specialist Melett]. I sold the business in 2017 and retired officially at the end of November. I had no plans to do anything other than take it easy and enjoy life.

I'd been following the Thrust SSC project back in the 1990s and thought it was fantastic, and I'd been following Bloodhound. I became a member of the 1k Club [the supporters' club] in 2009. My son came here to the NEC to do a STEM rocket-car challenge and he thought it was great, so I knew the project was doing a really good job of inspiring new engineers.

When I heard the project had gone into administration in October I was very disappointed like everybody but I also thought "well, it's gone under covers, it needs a bit of a break to get more sponsorship, I'm sure it'll reappear and carry on".

Then I was sitting at home one Friday night in December and my son Charlie sent me a text and said: "Hey dad, have you seen the Bloodhound car's for sale? Why don't you go and buy it?" So, I Googled Richard Noble and sent him an email saying: "Hi Richard. You don't know me, but I've got a few quid, can I help?" and he came straight back.

I spoke to the administrators on the Monday, went down on the Tuesday and I realised that the problem was that the car has some military-controlled equipment in it and that had to come out because the MoD had got wind of the fact that the administrators were going to cut up the car and sell it off.

The MoD was banging the door down trying to get in to take its stuff out, and the administrators couldn't get it out because it was very deep inside the car so they came to the conclusion the only way of getting this thing out was getting an angle grinder and cutting the car in half.

I knew when I left that building that if I hadn't done a deal the next man in that building was the man with the angle grinder coming to break it all up, so I did a deal.

On Wednesday, we were talking to each other; on Thursday I was confirming the contract and on Friday morning I signed up, job done. I then owned this massive long car.

What's your role in the project?

I initially thought I'd buy the car, ring-fence the assets and hold it together in one place so that no one bit could disappear, and the project could rebuild and regroup.

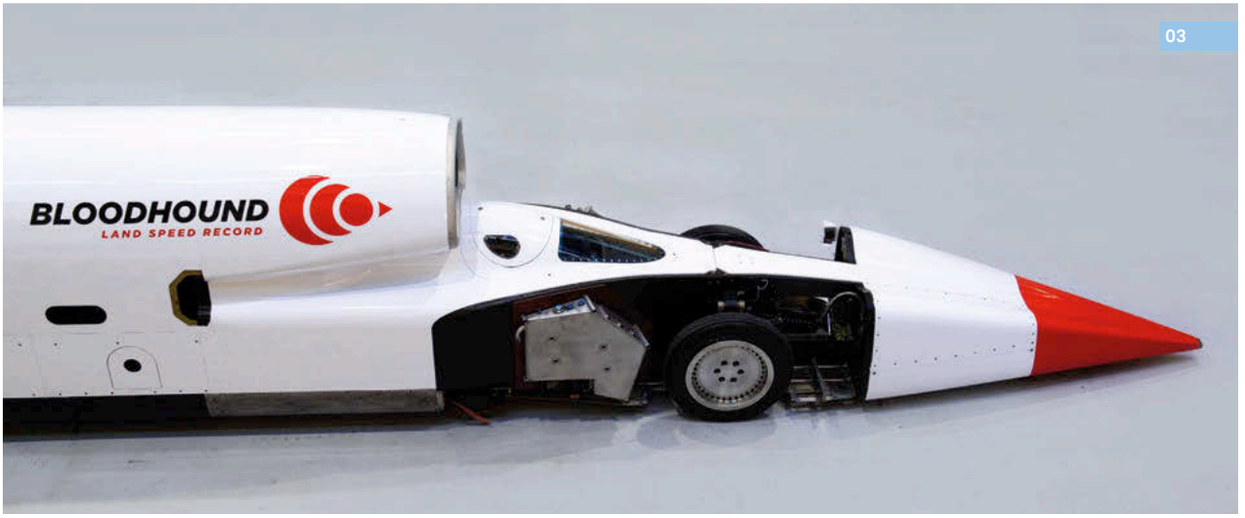
I was supposed to be the man with the money helping out not running the project but the more I got involved the more I found myself having to get the team together; having to find out more about the car; having to find a building to put it in. And because it was my money I was spending, I felt I'd like to look after what I was spending so I ended up almost naturally stepping into the role and I'm now running the project.

While I'm CEO the key people are also still in

01 Bloodhound's new owner, Ian Warhurst with new acquisition

02 Revitalised Bloodhound LSR sporting its brand new livery

place: Andy Green is still driving the car; Mark Chapman is still the chief engineer and he knows the car inside out. Everybody's getting on with the job now and I'm just overseeing the project and giving them some direction and some money.



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What's the economic mode for the project now that you're running it?

The problem the project had in the past was it was not supposed to take 10 years, it was supposed to take three or four. It ended up costing huge amounts more than we first anticipated and when you're trying to sell sponsorship you can only sell the space on a car once. It got to the point where there was no space left to sell and because it kept not hitting deadlines people were less and less interested in sponsoring it, so it went into a bit of a downward spiral.

Having effectively bought the car out of a skip I've got a new company, and all the original sponsor deals were with the original company. We like to the think the original sponsorship was for the design and build phase of the project.

What we're looking at now is the running phase of the project, which is a different part. To commercialise this I want to be able to find new sponsors.

The question is what's it going to cost to get to the desert and do something and what do we think the value of sponsorship is worth on the car? After we did some analysis, we estimated the value to run the car to the land speed record would be covered by the cost of sponsoring the car.

I'm 100 per cent committed to get this car to the desert for the high-speed testing. We're already having great conversations with sponsors – existing and new – and I'm very comfortable this will become sponsored. The most important thing my money is doing is providing cashflow and that gives certainty to sponsors.

Are you proposing any fundamental changes to the core technology?

Fundamentally it's still an EJ200 jet engine with a monopropellant rocket. The one thing that is changing is that the rocket motor was originally run with a JLR V8 engine, and we're looking to electrify that. From a safety point of view, you don't want to mix hydrogen peroxide with anything organic such as oil. At the time when it was designed the technology didn't exist to electrify the motors but because it's gone on for 10 years the technology now exists.

> "I'm 100 per cent committed to get this car to the desert for the high-speed testing"

When will the rocket be integrated?

That ties in with what we're doing at the moment. I've split the project into two parts: land speed record and maximum design speed.

Everyone bills this as the 1,000mph car, but that's the second phase. That allows us to focus clearly on the land speed record, understand the costs involved in that and focus on that part of the project.

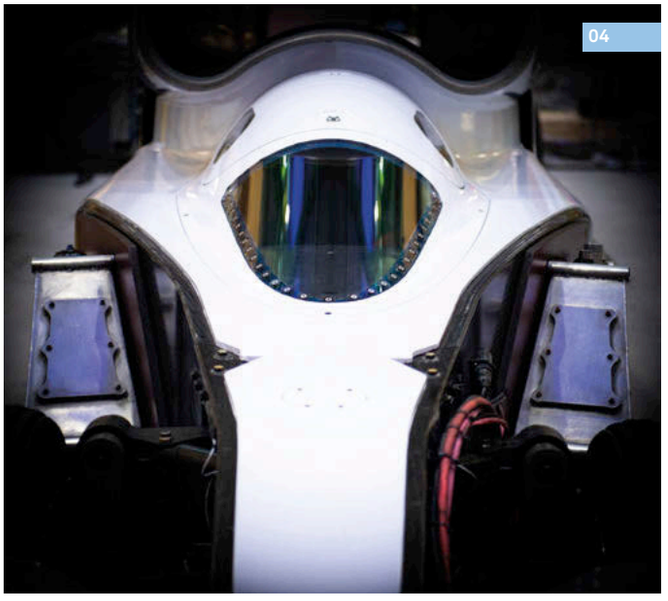
That's because the rocket required to get to maximum design speed needs a big redesign of the back end of the car. It doesn't fit in the current configuration.

When do you hope to go for the record?

One of the problems the project had last time was they kept making dates in the hope it would happen to try and bring sponsors on board but then didn't hit the date. I prefer the 'under-promise and over-deliver' approach, but, at the moment, our plan is to get to the desert this year.

Is STEM engagement still an important part of the project?

I got involved in this because of the STEM aspect. Britain needs more engineers. What's been fantastic about this project is the inspiration it gives to people to get into engineering. Because it's been going 10 years there are people inspired back in 2010 who are now engineers.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03 Bloodhound has three brakes: air, parachute and disc

04 Outside view of the cockpit Andy Green will occupy

Bloodhound Education [the STEM arm of the project] never stopped; it was carrying on through the administration and we're continuing with it.

Apart from STEM Impact, will Bloodhound have any technological spin-off projects?

Clearly, no one wants to go to the shops in a 1,000mph car, but the technology behind it is pushing the boundaries and taking us to places we don't go. The great thing about that is you don't do these things, you don't go there, you won't find out what happens when you do get there,

Will you have a ride in it yourself?

I don't want to go in it myself. It's really scary! ■

And then there was Li-Fi

Wireless technology that enables users to send and receive data in beams of LED light will help overcome the limitations of radio frequency communications. Jon Excell reports.

In today's connected world, wireless data has become a critical utility: an invisible element of our modern infrastructure that increasingly underpins many of the services upon which we rely.

And as we deploy connected devices in ever-greater numbers, and embrace emerging technologies such as autonomous systems, the internet of things and virtual reality (VR), the demand for wireless connectivity is expected to increase exponentially.

But there's a problem. The radio spectrum upon which much of our connectivity depends is getting crowded and some fear that our insatiable appetite for data will ultimately lead to a 'spectrum crunch' that will soon crash our communications networks, rendering many of our fancy new technologies useless.

Against this backdrop, unlocking new levels of data and bandwidth is a priority, and one area of technology that looks set to play a major role in addressing this challenge is Li-Fi, an emerging wireless optical networking technology that enables data to be transmitted over short distances via the rapid and imperceptible (to the human eye) modulation of LED light bulbs.

Pioneered almost a decade ago by Edinburgh University's Prof Harald Haas, the technology has some compelling advantages. For a start, the data spectrum for visible light is 1,000 times greater than the RF spectrum so there's more capacity to drive bigger bandwidths and higher data rates. Li-Fi developers have already demonstrated speeds of 224Gbps in laboratory conditions and expect 1Gbps or above – around 100 times faster than conventional Wi-Fi – to become the norm.

What's more, because data can be contained within a tight area of illumination, there's little risk of interference and it's also highly secure: while radio waves penetrate through walls and can be intercepted, a beam of light is confined.

Haas first caught the headlines with the technology following a 2011 TED talk in which he demonstrated how a standard LED lamp could be used to transmit high-resolution video directly to a receiver placed just beneath the bulb.

In the years following this jaw-dropping illustration of the technology in action, Li-Fi has begun making waves beyond the academic research space, with a number of organisations already commercialising the technology, and a growing number of companies supporting research into what is increasingly being viewed as a key emerging sector. Indeed, according to a recent report from Global Market Insights, the Li-Fi industry is expected to be worth $75.5bn by 2023.

Unsurprisingly, one of the main players is the firm spun-out of Haas's research, Pure LiFi, which, since its launch in 2012 has developed a number of Li-Fi-based hardware peripherals that can be used to upload and download data.

As the market has evolved, Pure LiFi has shifted its focus to refining the Li-Fi specific components that could be integrated into next-generation smartphones and other connected devices. It used this year's Mobile World Congress in Barcelona (March 2019) to demonstrate its burgeoning capabilities in this area using a modified laptop with a 1Gbps Li-Fi system. "We're focusing on developing the Li-Fi components that will enable anything to talk to everything else," Pure LiFi CEO Alistair Banham told The Engineer. "Our goal has always been to develop the components to enable these big companies to design their own Li-Fi systems around our light antenna device."

Banham said that there are now around 189 deployments of the firm's technology worldwide and that it's working with a range of customers, including smartphone firms and major lighting companies – such as Lucibel, Zumtobel and Signify (formerly Philips Lighting) – who view Li-Fi as an exciting new market opportunity.

Banham identified a range of potential applications for the technology: from its use in smart office spaces, to domestic and consumer applications either for high-bandwidth machine-to-machine communications or, ultimately, to provide domestic 'hotspots' in high-bandwidth areas such as living rooms and bedrooms.

He added that the technology also has great potential for location-based services. Indeed, in a separate development, Signify has been working with French supermarket chain Carrefour on a Li-Fi-based indoor-positioning systems, whereby each LED has a distinct location code and is able to interact with a smartphone app to help users locate products and promotions.

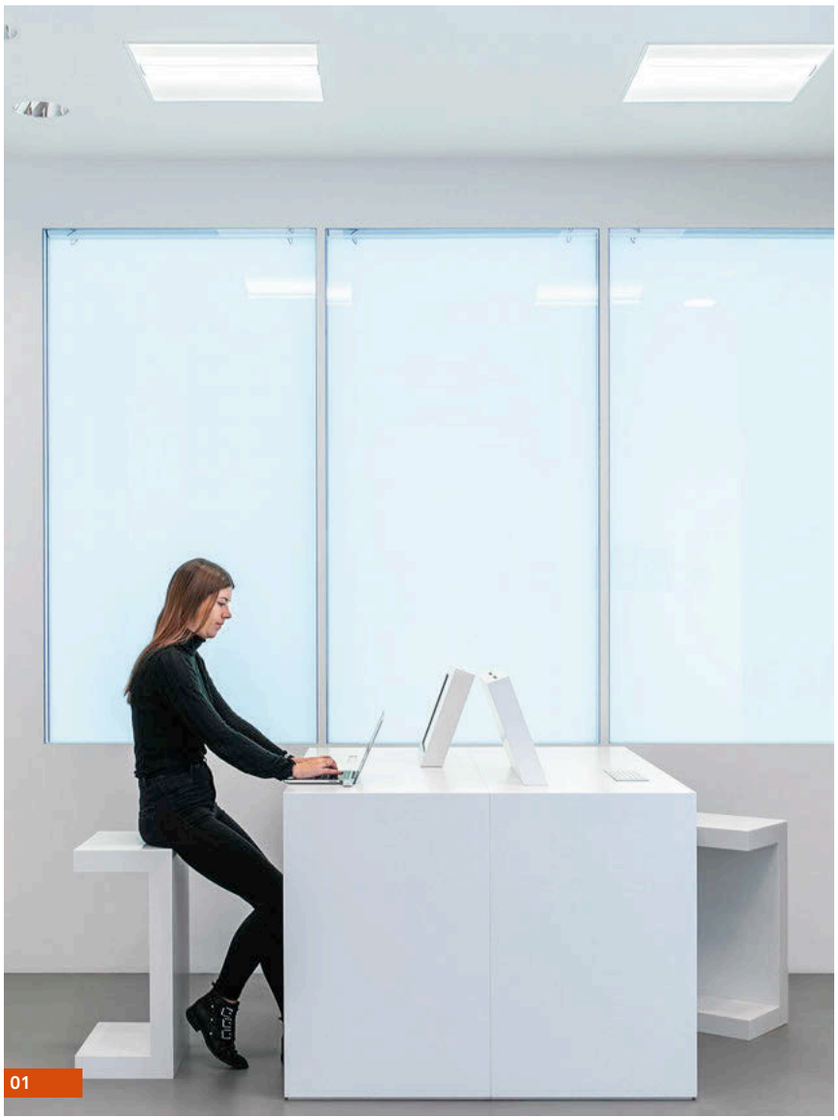
Clearly, despite all of its many advantages, light-based communication relies on line of sight to work, and for this reason it's viewed as a complementary technology to existing wireless solutions rather than a replacement.

"Where we can really bring a benefit is in the crowded radio spectrum where we see the launch of a new wireless LAN standard pretty much every year but fail to deliver those data rates in practice because there's just so much RF noise and interference out there," explained Pure LiFi co-founder and CTO Mostafa Afgani. "By offering to shift that communication to a different band – the light band – we can now provide another wireless channel that can deliver those data rates over a medium that is much more reliable and can actually deliver the quoted data rates."

> "Where we can really bring a benefit is in the crowded radio spectrum"

While refining its own technology, Pure LiFi is also playing an active role in developing what it terms the Li-Fi ecosystem and it recently joined forces with organisations including Nokia, Emirates Integrated Telecommunications Company, Liberty Global and Lucibel to set up the Light Communications Alliance, which aims to ensure collaboration to help stimulate the market for the technology.

A key member of the wider Li-Fi community is Oxford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01 & 02 Pure LiFi has been working with lighting specialist Zumtobel on applications of its technology

03 Pure LiFi's ultimate goal is to see its technology incorporated into mobile devices

University photonics specialist Prof Dominic O'Brien, who has discerned a growing commercial interest in the academic research base in recent years. "There's a lot more interest and the interest is at a higher level of commitment, with companies such as Signify committing a considerable amount of resources to bringing this stuff to market," he told The Engineer.

One example of this growing appetite for collaboration is the recently announced ELiot (Enhance Lighting for the Internet of Things) project, a €6 million EU-funded effort involving, among others, the University of Oxford, Signify, Nokia and Deutsche Telekom, which is looking at developing mass-market applications for Li-Fi technology.

Speaking at the launch of the project in July 2019, Prof Jean-Paul Linnartz, who's leading Signify's research into Li-Fi, said: "Li-Fi can deliver high-speed communication, interference-free with high reliability. The available spectrum can be fully reused in every room. The lighting infrastructure is in an excellent position to provide wireless connectivity for the rapidly increasing number of wireless devices in every room."

Signify is at the forefront of efforts to commercialise Li-Fi technology. In June 2019 it announced the launch of its Truelifi product range, which it claims can be used to give 150Mbps connectivity to its lighting units.

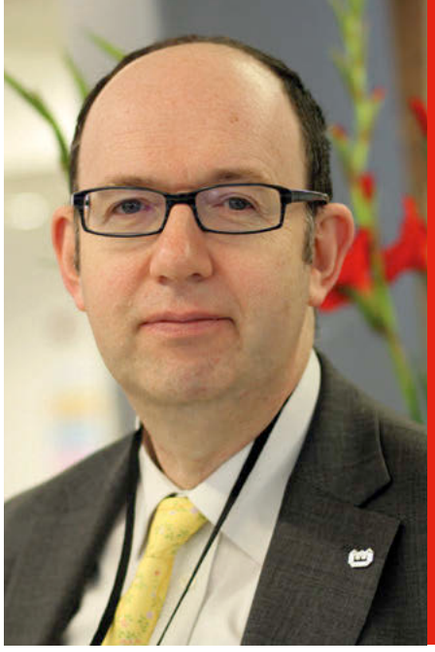
Another initiative singled out by O'Brien is the EU-funded WORTECS (Wireless Optical/Radio TErabit Communications) project, which is exploring how a combination of high-frequency mm-wave radio communications and Li-Fi technology could be used to meet the incredibly high data rate demands of virtual-reality technology.

O'Brien said that the project – which involves, among others Pure LiFi and Orange – is working on a concept in which separate branches of optical fibre would be taken into each room of a house and used to direct a narrow beam of light at a terminal. "We can get very high data rates from that, because we're essentially using the data directly from the fibre, which is transmitting at 100Gbps," he said.

With the technology progressing rapidly, and the weight of real-world commercial applications and trials providing compelling evidence of its advantages, it seems inevitable that Li-Fi will one day be as widespread as the other wireless technologies we now take for granted. But despite the wow factor of Prof Haas's 2011 TED talk, it's entirely possible that when it does arrive, we won't notice it. It may simply become another technology that creeps into the mix by stealth, humming away quietly in the background, its success predicated on its complete invisibility to those it serves.

"It might be one of those things that actually the average user doesn't really know about because it's just another wireless technology integrated with the RF technologies that are available already," said O'Brien.

"Together they provide some augmented service. But are users going to know it's light and not radio?" ■



An Ingenious mission for engineers

The Royal Academy of Engineering's Ingenious awards programme is playing a vital role in taking engineering to a wider audience

What inspired you to be an engineer? Taking an old record player apart? Adapting some code from a magazine so you could play 'pong' on your Sinclair Spectrum? A craft project that unexpectedly took a technical turn? A copy of World Engineering Marvels from the local library? Meccano? Maybe even school science lessons... hold it in your mind as you read this.

For me, it started at The Molecule Club, sometime in the late 1960s, early 1970s. The Molecule Club was basically a science pantomime. It took place at the Mermaid Theatre near Blackfriars, London. I was taken by my mother from my home in suburban Hendon.

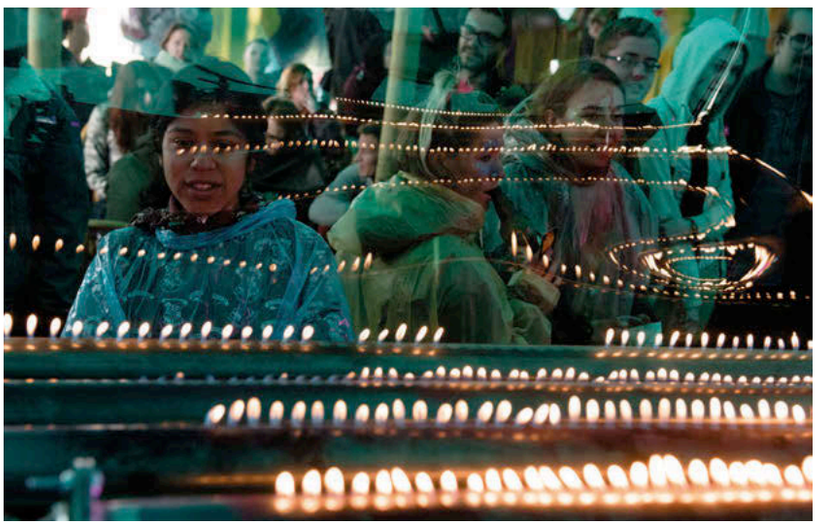
I went to several different performances, each themed around different physical principles. There were bangs, songs, Heath Robinson devices, mild peril and audience participation. There were quiz sheets to complete in the interval. I was captivated as were the many tens of thousands of children who experienced performances over the years.

I now suspect that the theatre company and my mother had educational intent, but fortunately I was blissfully unaware of this, otherwise I might have resisted. Their stratagem was successful, I was bitten by the bug and a career in engineering has followed. This career has given me many opportunities, and much to engage me, but I would put high on that list that I now chair the Royal Academy of Engineering Ingenious awards panel.

The Ingenious awards support innovative public engagement to promote engineering. A major goal of Ingenious is to give people from a wide variety of backgrounds a real experience of engineering. In the STEM (science, technology, engineering and maths) world, we call this science capital.

Science capital can be likened to a holdall that carries a person's the science-related experiences. A person who has parents employed in science will have high exposure to the sciences, and hence, that person would have high science capital. Equally, the Molecule Club gave me some science capital. Each bit of capital adds up, and people with high capital tend to go on to work in the sciences.

Beyond careers, science capital contributes to science literacy, attitudes and values. It empowers citizens and communities.



STEM engagement in action with the Guerilla Science Fire Organ ©Richard Eaton

Of course, I was a boy from the middle-class London suburbs. Ingenious aims to reach beyond this to women, still underrepresented in our profession (only 12 per cent of UK engineers are female), and to disadvantaged and underserved groups (fewer than 8 per cent of UK engineers are from black and minority ethnic backgrounds).

Ingenious awardees develop amazing programmes harnessing museums, theatres, festivals, to make people excited about STEM and get engaged with its possibilities. Across the UK they get involved with cities and with local communities to reach out and present engineering in new contexts. Activities include space camps, interactive problem solving and experimentation. Engineering is mixed in with music making, model building and community action. Many programmes use local schools and colleges, supporting teachers with high-value resources.

I would be misrepresenting Ingenious if I focused only on the 'audience'. Although many of the awardees are professional communicators, most of the content is delivered by practising engineers and engineering students. Indeed, Ingenious is the only UK grant scheme specifically aimed at building capacity and enabling more engineers to do public engagement. Their enthusiasm accounts for the high degree of success enjoyed by the programme. They gain skills and networks, but this is a small part of the return. Public engagement is enormous fun. To see a child's eyes light up; or, to see an adult about to turn away and start back, startled by a demonstration of some physical effect. Each reignites the pleasure of our early engagement or reminds us not to take things for granted.

So, if you see an Ingenious event in your local area, make a point of going. Take some children... daughters would be good. Sign up to participate in delivering Ingenious content. I absolutely guarantee you will enjoy it. Persuade your employer and colleagues to participate. Ask yourself if your organisation, dependent upon engineering talent, is doing enough to prime the pipeline that feeds its future. Finally, having primed your energy and enthusiasm as well as built your skills, you could apply for an award yourself.

In opening, I asked you to hold your engineering inspiration in mind, now I want you to take a little piece of it and share it. A legacy of the Molecule Club and the mission of the Ingenious Awards.

For more information and to apply for an Ingenious grant, see

www.raeng.org.uk/grants-and-prizes/grants/ingenious-grant

Prof Anthony Finkelstein CBE FREng DSc is chair of the Royal Academy of Engineering Ingenious awards panel

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EDF uses ThingWorx for remote monitoring

Platform will allow EDF business customers to flexibly manage capacity and generate revenue Supplier: PTC

Energy company EDF is deploying PTCS's ThingWorx IoT platform to help its customers monitor and control energy usage. ThingWorx is supporting EDF's Powershift, a cloud-based energy trading, monitoring and control system that provides businesses with a flexible way to manage how and when their energy is consumed. The tool will enable EDF customers to generate revenue by selling spare capacity back to the UK grid. The integration was facilitated by PTC partner Capula, an integration specialist for control, automation and operational IT systems.

"PowerShift enables customers to both save and make money, allowing them to optimise energy, as part of a wider distributed power network," said Chris Regan, EDF's head of energy trading services.

"Having utilised our significant experience in the energy trading element of PowerShift, we then partnered with technology experts to enhance the monitoring and control aspect for PowerShift users. Capula's OPUS tool, which is built on PTC's ThingWorx IoT platform, is now a core component of PowerShift.

ThingWorx will enable EDF customers to manage power efficiently

"ThingWorx's role is to drive efficiencies and cost reduction by monitoring, collecting and analysing energy data. By using Powershift, EDF Energy customers can drive savings and revenue from their flexible assets by making capacity available for the National Grid."

The deal marks a significant coup for PTC's UK operations, with EDF the UK's biggest supplier of electricity by volume. According to Boston-based PTC, ThingWorx will help EDF and its customers be leaner and greener through its extended suite of IoT applications. The software platform contains a broad set of features, including multiple connectivity options, application development tools, analytics, and AR.

"ThingWorx enables improved energy efficiency by providing operational intelligence to EDF Energy customers," said David Grammer, VP for UK and Nordics at PTC.

"Helping to reduce the carbon footprint is another excellent example of how the right IoT technology can positively impact businesses and the world." ■

Working on a CAD transformation

Immersive visualisation positions CAD products in contextual environments, alongside dependable data Supplier: Virtalis

Virtalis has enlisted Tech Soft 3D's HOOPS Exchange to transform CAD data into data sets for a myriad of applications in numerous sectors.

Visionary Render is Virtalis's platform for importing and visualising large datasets from a range of sources, while maintaining the geometry, naming hierarchies, metadata, and product and manufacturing information (PMI).

Accurately supporting the formats used in industries including aerospace, defence, construction, and geoscience is critical because companies need to visualise large amounts of data from diverse sources.

"When we import CAD data with HOOPS Exchange, we get the data that we expect," said Barry King, product owner at Virtalis. "Our customers expect to see reliable data when they're making important decisions based on visualisations and having reliable and dependable data is one of the most important things for them. What's great about HOOPS is that it supports almost all the formats, including VRML. Our customers have legacy data, and we rely on the fact that HOOPS Exchange supports those formats."

Virtalis goes beyond visualising CAD data from an external view by immersing users in the environment where the model may live.

"We're looking at products in the context of where they sit," said Gavin England, product marketing manager at Virtalis. "We could be looking at a product installed inside a factory, or a building structure coming from building information modelling (BIM) data. In addition to the core formats, being able to bring in data such as Revit is key as well."

The software allows products to be viewed within their natural environments

HOOPS Exchange provides access to data, including B-Rep geometry, metadata, PMI, model tree, views, persistent IDs, styles, construction geometry, and visualisation without depending on any CAD system.

"When we initially were getting to grips and integrating it, Tech Soft 3D was really responsive and collaborated with us to get the results that we needed," said King. "When we communicate an issue, we always get it fixed in the next release, and the releases come out steadily and reliably." ■

Northern lights

Northern Manufacturing & Electronics returns to EventCity, Manchester, from 2-3 October

The exhibition, which is the companion event to the Southern Manufacturing Show, presents a similarly inclusive approach, hosting a broad range of around 250 industrial products and service providers, ranging from component suppliers and subcontractors to advanced production systems.

This year's event will feature numerous well-known global brands, including CNC giant Haas Automation and XYZ Machine Tools, which will be showcasing its new robot-based automation cell Robo-Tend, designed to bring automation within the reach of traditional sub-contract engineering businesses.

Laser and additive manufacturing also figure prominently in the show's line-up of live demonstrations. China's Bodor Laser makes its Northern debut, showcasing its range of fibre and CO2 industrial laser equipment, including laser engraving cutting and marking machines. Closer to home, HPC Laser will show a sample of the 100 or so CE-Certified and HSE-inspected machines it holds in its Yorkshire warehouse. Laser Lines UK returns to Northern Manufacturing with its wide portfolio of over 20 plastic and metal 3D printers and rapid manufacturing solutions. Also exhibiting is 3D-printing specialist Tri-Tech 3D, which offers a complete package of services from initial specification and supply of hardware and software, to onsite 3D printer installation, staff training and full product support.

Additional leading suppliers include Dynamic Machine Tools and EDM specialists Makrep EDM Solutions. This year's show also features a n excellent free technical seminar programme.

Highlights of the speaker line-up include Dr Ben Hargreaves of NetComposites who will be giving an introduction to the world of composites and Janaina Gianfelice de Castro, from leading manufacturer SABIC, who will take an in-depth look at the firm's ULTEM resin portfolio and how advanced materials can be used to deliver thinner, lighter, more energy-efficient products. Elsewhere, award-winning author, creator of the Lean Iceberg Model and partner at SA Partners, Gary Griffiths, will share how 'excellent' organisations have delivered results for their business by embedding and sustaining lean and continuous Improvement.

Andy Brunskill, author of TPM: A Foundation of Operational Excellence will discuss an 11-step model that can be used to deploy an effective, systematic TPM programme. Popular presenter Tim Scurlock takes a detailed look at how Porsche improved performance by the use of lean techniques to reduced cost and lead times. Made Smarter and the Manufacturing Growth Fund will present an overview of how companies across the region have grown their businesses. Register online at www.industrynorth.co.uk ■

Additive showcase

TCT Show puts additive manufacturing centre stage

September sees the TCT Show opening its doors to almost 10,000 visitors from 80 different countries, for a three-day 3D-printing and additive manufacturing showcase at Birmingham's NEC.

As you'd expect, the event will celebrate the latest additive manufacturing technology solutions and innovations from nearly 300 worldwide exhibitors, including HP, Ultimaker, Trumpf, BOC, Formlabs, Siemens and Renishaw.

The organisers are confident that visitors will be inspired and gain insights from the event's conference and seminar programmes, which for this edition include TCT Summit, TCT Tech Stage, TCT Introducing Stage and TCT Insights Stage.

Debuting this year, TCT Summit is a user-led conference bringing together industry experts and will feature presentations on leading technology, innovation and market intelligence. The TCT Summit stage will also bring together leading authorities, engineers, designers and academics from aerospace, automotive, rail, healthcare and business sectors to share their insights.

TCT Tech Stage hosts CPD-certified sessions on topics surrounding powder metallurgy, metrology, and plastics manufacturing. Visitors are also invited to attend the #3DTalk panel session dedicated to software, hosted by Women in 3D Printing and Cyant, featuring female leaders in the 3D printing and additive manufacturing industry.

With the rapid growth of 3D technologies, it is becoming increasingly difficult to keep up with the recent innovations. TCT Introducing Stage will showcase inspiring talks, live debates, and interactive sessions on the latest additive manufacturing product developments and services across hardware, software, and ancillaries. The three-day programme is led by TCT Show's most prominent exhibitors, including Formlabs, Protolabs, EOS, Materialise, Fraunhofer IWU, and many more.

In a new innovation for 2019, the TCT Insights Stage will focus on the essential aspects required to understand the entire spectrum of the current and emerging additive manufacturing technologies. The programme includes a workshop on the fundamentals of additive manufacturing, delivered by Graham Tromans, which is ideal for attendees who are new to the 3D printing industry.

Day two will be notable for the TCT Awards, which are are set to showcase world-leading projects and recognise the most influential and impactful members of the additive manufacturing industry in the TCT Hall of Fame.

The TCT Show takes place on September 24 – 26. Register online: www.tctshow.com ■

OLED tech promises improved screens

Supplier: Nextgen Nano

Researchers from UK solar-cell company Nextgen Nano have discovered an OLED manufacturing method that demonstrates high luminosity at lower voltages.

Organic light-emitting diodes (OLED) underpin today's most cutting-edge display technology and can be found in high-end smartphones, as well as the latest televisions. The new research, published in Nature Communications, could lay the groundwork for efficient high-performance OLED devices and may change future approaches to organic semiconductor technology.

Nextgen Nano's New Fusion division team at North Carolina State University (NCSU) found that certain organic molecules were able to achieve electroluminescence at lower driving voltages than is typically required by current OLEDs. The molecules exhibited fluorescent properties at lower energy values, allowing them to illuminate at notably lower voltages than phosphorescent OLEDs and to produce a stable blue OLED with a higher operating power efficiency compared to existing blue phosphorescent OLEDs.

This means it will be possible for display applications in the future to provide superior levels of luminosity while using half the energy, which will also extend the operational life of the device. The study found that the tested blue OLED produced 1,000 candela per square metre at 3.4V, which was less than 50 per cent of the voltage required by other tested blue OLEDs.

"The current challenge in the OLED technology is blue," said Nextgen Neo CTO and NCSU engineering Prof Franky SO.

"Our finding shows that it is possible for make a fluorescent OLED with half of the voltage required for phosphorescent OLEDs." ■

Heads up for next-gen driver info

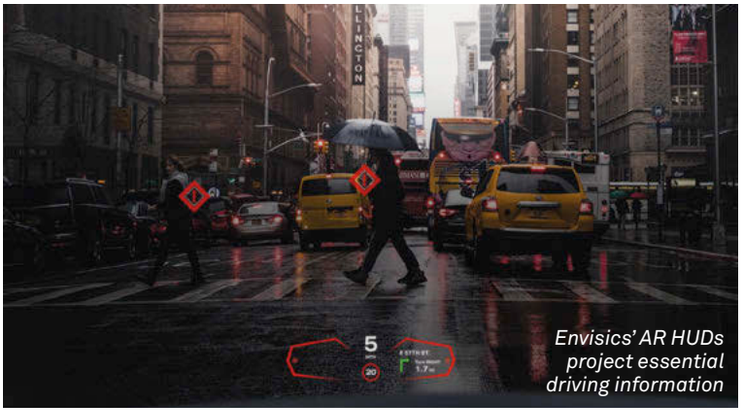
Supplier: Envisics

The automotive industry is in the middle of an innovation renaissance. Many organisations are focusing their research efforts on electric and autonomous vehicles. However, safety should remain a top priority with research into reducing the cognitive load of interpreting in-vehicle navigation instructions and increasing drivers' situational awareness.

Augmented reality (AR) head-up displays (HUDs) help address keeping drivers' attention on the road at all times. Traditional dashboards positioned below the windscreen force drivers to take their eyes off the road for information, which can be fatal considering at 30mph/50kph a car will travel 13.5m in one second.

Envisics' AR HUDs project essential driving information, a near image (at 2m) displaying speed and warning symbols and a far image (at greater than 10m) displaying intuitive navigation guidance and information about oncoming hazards, into drivers' field of vision, addressing the universal challenge of improving drivers' perception and awareness. Envisics' AR HUDs operate using holographic light manipulating technology with over two million light speed modulators, each 15 times smaller than the thickness of human hair to create multiple depth images and an annotated view of the environment. These modulators are controlled by an algorithm that calculates over 700 holograms per second.

The safety applications of AR HUDs will be a key feature in the next generation of vehicles, especially autonomous vehicles (AVs). The RAC Foundation conducted the first study into handovers from control in AVs, which reveals motorists often had poor control when asked to take on driving duties mid-journey, veering across lanes and picking up speed.



Envisics' AR HUDs project essential driving information

AR HUDs can be used to facilitate the transaction of responsibility from the vehicle to driver, alerting them to potential hazards in the process. Envisics is working with several manufacturers to introduce AR HUDs into their vehicles. ■

Electric and autonomous

Supplier: Nvidia

Autonomous vehicle developer AutoX and Swedish electric vehicle manufacturer NEVS are partnering to deploy Robotaxis in Europe by the end of 2020. To this end, the partnership aims to bring self-driving and electric vehicle technology to everyday urban transportation, which is expected to lead to cleaner and more efficient mobility.

The vehicles are based on AutoX's autonomous driving software and use NVIDIA's Drive AGX Pegasus platform, which incorporates an architecture built on two NVIDIA Xavier processors and two next-generation TensorCore GPUs. Combined, this AI computer runs deep neural networks simultaneously and can tackle highly automated and fully autonomous driving.

"The processing power and efficiency of the NVIDIA Drive platform is incredibly beneficial to this deployment," said Jianxiong Xiao, founder and CEO of AutoX. "It's an excellent way to achieve scale and reliability."

Robotaxis must blend with traffic to operate efficiently, which is where AutoX software comes in. Running on the automotive-grade Drive AGX Pegasus, the autonomous driving algorithms can learn and quickly adapt to local driving conditions. The AI supercomputer platform is based on the Xavier system-on-a-chip (SoC): the first production-level SoC dedicated to autonomous driving.

Drive AGX Pegasus also achieves 320 trillion computing operations per second without taking up more space than a laptop computer. Backed by this performance, the AutoX system can perceive busy urban environments in real time, allowing the vehicle to react safely at all times.

Rather than building vehicles dedicated to specific cities, the flexibility of the AutoX system and Drive AGX Pegasus makes it possible to deploy Robotaxis in diverse environments, such as narrow city streets, crowded tourist areas and residential blocks. The companies are set to start testing in Europe. ■

The Engineer drives: Hyundai Nexo – a glimpse into the hydrogen future?

There have been hydrogen cars before, but the Hyundai Nexo is perhaps the most convincing example to date. writes Chris Pickering

When asked to name the most technologically advanced car on sale, most people would probably hazard a guess at the current Mercedes S-Class (the latest in a long line of cars that has famously introduced such landmark innovations as ABS, active cruise control and crumple zones). But there's another contender for that title, which comes not from Stuttgart or Silicon Valley, but from South Korea: the Hyundai Nexo.

The most obvious feature that sets the Nexo apart is the fact it runs on hydrogen. Located in its nose, the fuel-cell stack silently strips electrons away from the most abundant molecule in the universe, creating a steady flow of electric current. This is used to charge a 1.56kWh lithium-ion battery, which provides power to a 120kW electric motor, also mounted under the bonnet. The only tailpipe emissions are purified air (passed through the fuel cell's sophisticated filtration system) and droplets of water vapour.

The Nexo is the second hydrogen car to come from Hyundai, following on from the ix35 Fuel Cell. At its heart is an all-new 95 kW fuel cell stack that's said to offer 50 per cent better power density at 3.1kW/litre, while the overall powertrain efficiency now climbs to 60.4 per cent. Internal differences include a new design for the bipolar plates that separate out the individual cells, providing a more effective dispersion of air and hydrogen. Careful attention has also been applied to the humidity of the cells to ensure that they can function over a broad temperature range. Hyundai claims this has given the Nexo a class-leading cold-start capability, with the fuel cell capable of reaching working temperature in less than 30 seconds following an overnight soak at -29°C.

> "The Nexo will park itself automatically at the touch of a button"

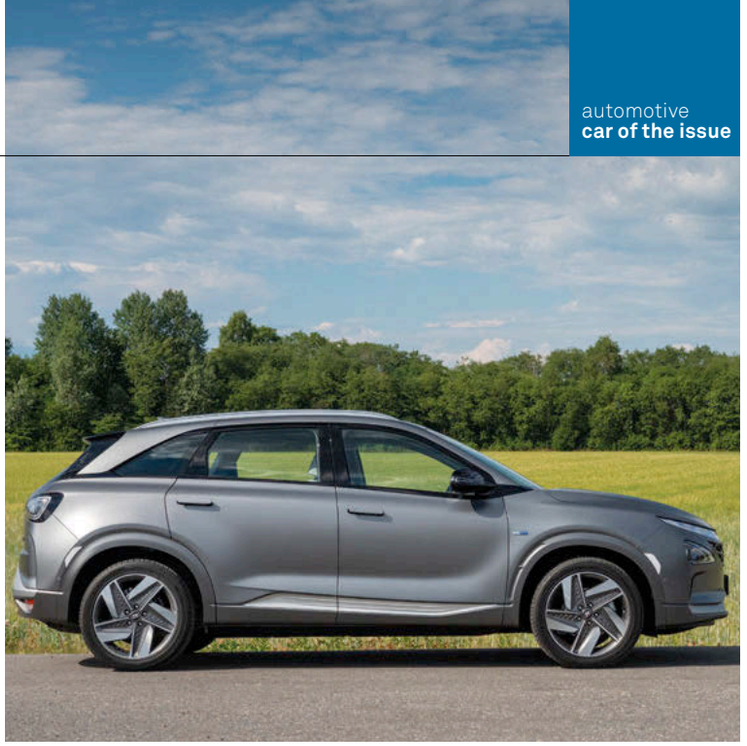
Notably, the Nexo has also been designed as a fuel-cell vehicle from the ground up, whereas ix35 was based on a combustion-engined platform. The new chassis uses a relatively conventional high-strength steel construction, but it has been carefully designed to suit the fuel-cell system's packaging needs. In place of two tanks that took up a significant portion of the boot space in the ix35 there are now three carbon-fibre tanks – two of which sit under the rear seats. Not that you would guess from sitting in it, because the Nexo offers bags of rear-seat room and a generous 461-litre boot.

Things feel a little more radical from the front seats. The dashboard has been cleared entirely of buttons, which instead sit on a giant floating centre

01 The cabin has a sci-fi appearance that's more space station than SUV

02 The 95kW fuel cell stack is claimed to reaching working temperarture in less than 30sec.

From the outside, a convetional vehicle, but the Nexo might be the most advanced car on sale



console. Meanwhile, the infotainment functions are handled by a vast touchscreen display, while another large screen behind the steering wheel provides a virtual instrument cluster. Combined, these features give the cabin a distinctly sci-fi appearance that's more space station than SUV. It feels entirely in keeping with the Nexo's cutting-edge character and its £65,995 price tag.

The materials are clever too. True, there's the odd flimsy bit of plastic, but generally the quality is very good. All the major cabin surfaces, including the bamboo-based headliner, plastics, trim, soft skin and floor mats all come from UL-certified bio-materials. Hyundai says this represents the most extensive use of such materials on any vehicle to date.

Perhaps not surprisingly, the driving experience is much like a fully electric SUV. The Nexo feels quicker than its 9.5-second 0-to-60mph time would imply, with a steady stream of smooth, silent torque fed through a single-speed transmission. Unlike other fuel-cell cars we've driven you never hear the compressor at work either. Wind and road noise often become more noticeable in electric vehicles, but both are well suppressed here – aided in part by the Nexo's impressively low drag co-efficient of 0.329 (down from 0.35 on the ix35).

The feeling of serenity that comes from the Nexo's powertrain refinement is bolstered by its soft, pillowy ride. There is a degree of body roll, but the handling feels reasonably precise, aided by the Nexo's comparatively trim 1,825kg kerb weight (battery electric SUVs, in contrast, are often over two tonnes). This also helps to maximise the range, with 6.3kg of hydrogen (stored at 700 bar) good for a theoretical distance of 414 miles. That's enough to take you from London to Leeds and back again.

Refuelling the Nexo only takes around five minutes and the process is barely more complicated than filling up a conventional car. Admittedly, the choice of filling stations is curently limited, with only around 20 in the UK (mostly around London and the Midlands) but that number looks set to grow.

So, it's a thumbs up for the fuel cell, but that's only half the story. The Nexo also has one of the most comprehensive suites of driving-assistance functions on the market. In addition to the usual autonomous emergency braking and lane keep assist there's now a system that Hyundai dubs Blindspot View Monitoring (BVM). This uses a pair of wide-angle cameras mounted under the wing mirrors to capture a live video feed of the Nexo's blindspots. As soon as you indicate left or right, the blindspot view from that side is automatically displayed in the instrument cluster. It sounds like something of a gimmick, but it works brilliantly, expanding your field of view while driving.

The Nexo also has a remote smart-parking function. This allows you to select a parking space then step out of the car, whereupon the Nexo will park itself automatically at the touch of a button. The practical application of this is that it allows you to guide the car into and out of very tight spaces, but it's also a step towards fully autonomous parking. With Hyundai talking about offering SAE Level 4 autonomy in smart cities by 2021, it's possible that future models may be able to drop you off in the city centre and find their own way to a car park.

The great thing about the Nexo, however, is that it still works here and now. It offers similar performance to its combustion-engined counterparts, with refinement levels that even a lot of electric vehicles would struggle to match. Crucially, it feels like a finished product, with enough practicality to use every day and sufficient quality to justify its aspirational price tag. The scarcity of hydrogen filling stations remains a challenge, but in some respects that's a chicken-and-egg situation because there are so few fuel-cell vehicles currently on our roads. The Nexo, however, demonstrates that there is clear potential to tip that balance. ■

Nikola Tesla: current thinking

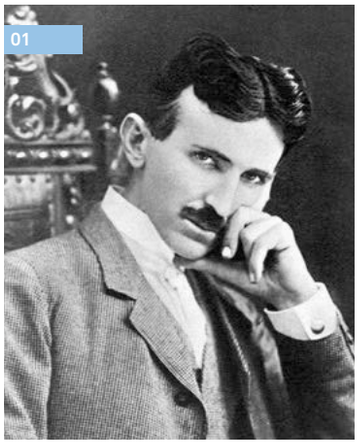
In the first of a new series of articles Nick Smith **surveys one of the founding fathers of modern electrical power, Nikola Tesla, whose career was a roller-coaster of breathtaking successes and monumental failures**

At around midnight on 9-10 July 1856, while thunder and lightning raged, one of the greatest electrical engineers of the early 20th century, Nikola Tesla, was born. The midwife said he'd be a 'child of the storm', while his mother thought he'd be a 'child of light'. Looking back at Tesla's career as an engineer, inventor and futurist – one defined by controversy and innovation – it's tempting to think that both women present at his birth had a point. This is because Tesla, while playing a robust scientific role in bringing electrical power to the modern world, also dabbled in death rays and interplanetary communication. Both eccentric recluse and shameless self-publicist, he was a godsend for journalists looking for sensational copy. But he was also a headache for more responsible newspaper editors who were never quite sure how seriously to take the archetypal mad professor's claims.

Tesla was born at a time when the world as we know it today was being invented. Rapid industrialisation was spreading across Europe and the US. The second Industrial Revolution of rail and telegraph networks, mass production and machines, was ushering in the early dawn of globalisation. And somewhere on the outskirts of the Austrian Empire, in the tiny village of Smiljan (in what's now Croatia), the son of an Eastern Orthodox priest was embarking on a journey that would bring electricity to a world lit by gas and powered by steam. Despite his fascination with his physics teacher's demonstrations of electricity, and his ability to juggle differential calculus in his head, the young Tesla was initally destined for a career in the church. But, seeing his son dying of cholera at the age of seven, his father promised that if the young Nikola could only recover, he'd be released from his obligation to the clergy and sent to engineering school. Duly recovered, Tesla was to excel at the Austrian Polytechnic, before becoming chief electrician at the Budapest Telephone Exchange.

In 1882 Tesla moved to Paris, where he joined the Continental Edison Company, eventually getting himself noticed for his work on designing and building dynamos and motors. By June 1884, he'd emigrated to the US – legend has it, with just four cents in his pocket and the calculations for a flying machine – to join the Edison Machine Works in New York, where he ended up trouble-shooting the company's efforts to create an urban power utility. While the young engineer only met the great Thomas Edison in person a few times, he made a big impression, with the American saying: "This is a damned good man."

Tesla's stay at the Edison Machine Works was not a happy one. He competed for, and won, a $50,000 bonus, only to discover it had been a practical joke and to be told that he didn't understand American humour. Understandably, Tesla felt no regret at leaving the cash-strapped organisation at the end of 1884, scribbling in his diary: "Good by to the Edison Machine Works." He then independently established the short-lived Tesla Electric Light & Manufacturing company, during which time he filed patents for new types of alternating current (AC) motors and power transmission equipment. In 1886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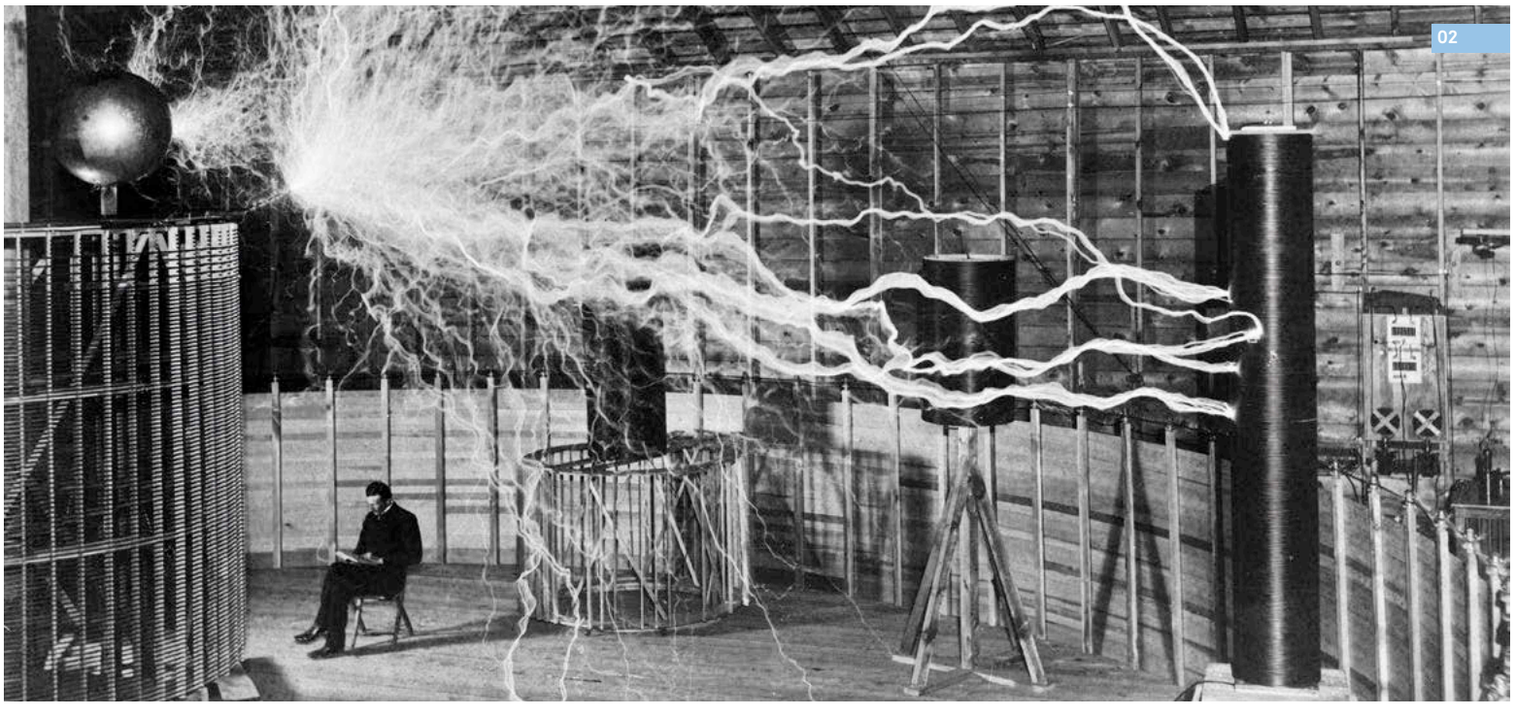
his investors pulled the plug, leaving Tesla flat-broke and reduced to digging ditches for a living at $2 a day.

He was to have better fortune with the similarly named Tesla Electric Company, established with entrepreneurs Alfred S Brown and Charles F Peck. In a deal where each owned a third interest, Tesla was also provided with a Manhattan laboratory in which he developed his polyphase induction motor. The technology patented, a press release was circulated and, at the arrangement of the editor of Electrical World, Tesla demonstrated it before the American Institute of Electrical Engineers. Word reached George Westinghouse (of the Westinghouse Electric & Manufacturing Company), who had been looking for such an invention to integrate into his AC power system. Westinghouse licensed Tesla's motor for $60,000 in cash, plus stock and royalties, as well as hiring him on a colossal monthly stipend of $2,000 (about £50,000 in today's money) during a time when the so-called 'War of the Currents' was flaring up between proponents of AC and direct current (DC), with Edison Electric making claims for the superior safety of its DC system over Westinghouse's AC technology.

Two years later, during an economic panic created by the near collapse of Barings Bank, investors in Westinghouse started to call in their loans, causing the company to reduce its commitment to research and development. Tesla was forced out of

> "I do not think there is any thrill that can go through the human heart like that felt by the inventor as he sees some creation of the brain unfolding to success" Nikola Tesla."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01 Nikola Tesla (Wellcome Images)

02 The famous Century Magazine image of Tesla (Wellcome Images)

03 A leading EV company now bears Tesla's name

his royalty arrangement, but six years later managed to sell his AC patents to Westinghouse for $216,000, leaving him enormously wealthy and, perhaps more importantly, free to follow his own interests, that included the invention of an electrical resonant transformer circuit (the eponymous 'Tesla coil') that would revolutionise wireless telegraphy. Its first public demonstration was in 1891, the year he both patented the technology and became an American citizen.

During the last decade of the 19th century, Tesla would become essentially a freelance inventor, working initially on wireless lighting systems and the development of a steam-powered reciprocating electricity generator (known as 'Tesla's oscillator') that was intended to simplify the steam engine. But in 1893 there was to be a cardinal event in the history of electricity supply, when Westinghouse Electric won the contract to illuminate the World's Columbian Exposition using electric light generated by a fully integrated AC system, with Tesla in attendance, hired by Westinghouse to assist with demonstrating the technology.

Later that year Tesla acted as a consultant to the Niagara Falls Cataract Construction Company advising on how to transmit power generated by its new hydroelectric plant. The year 1895 saw the establishment of the Nikola Tesla Company that, while attracting few investors, was to handle Tesla's patents (of which there were some 300) for decades to come. Patents were a subject on which Tesla appeared to have a resigned sense of humour. On being informed that his rival inventor Guglielmo Marconi was transmitting wireless messages across the Atlantic, he said: "Marconi is a good fellow. Let him continue. He is using 17 of my patents."

The next big challenge for Tesla was wireless power and communications transfer. Neither had been done over any distance with any success, and by the mid-1890s he was working on experiments in his East Houston Street laboratory to conduct electricity either through the earth or the atmosphere using a large resonance transformer magnifying transmitter. This was followed by a laboratory at Colorado Springs, in which he conducted larger-scale experiments than he could not safely perform in New York.

It was at this time that Tesla observed rogue signals that he took to be communications from another planet and wrote an article to that effect in one of the popular magazines of the day (he'd probably intercepted one of Marconi's test transmissions.) But, at the time, the press was running riot with space


03

stories (HG Wells's The War of the Worlds had been published in 1898), and in June 1900 Century Magazine published a clever multiple exposure photograph of Tesla in his lab, dwarfed by lightning discharges. Over the next few years Tesla attempted to raise the stakes by building an even bigger transmitter at his Wardenclyffe Tower facility 100 miles outside New York with backing from the US banker JP Morgan. But with Wall Street now heavily backing Marconi, and the once pro-Tesla media dismissing Wardenclyffe as a hoax, the by now debt-burdened Tesla was forced to call it a day.

Tesla's career declined into self-parody, with the fallen engineer reduced to hosting bizarre annual press conferences, claiming in 1932 to have invented a motor that could run on cosmic rays. In 1933 he announced his discovery of a new form of energy altogether. In 1934, a death-ray superweapon, and in 1935 a mechanical oscillator that would earn him $100m in two years. On 7 January 1943 the increasingly eccentric engineer died alone in his room at the New Yorker Hotel, aged 86. Two thousand attended his funeral at New York's Cathedral of Saint John the Divine. The FBI ordered the confiscation of his papers and his ashes are now kept in a golden orb at the Nikola Tesla Museum in Serbia's capital Belgrade, where there is an airport named after him.

If the last decades of Tesla's career are overshadowed by pathos, his rehabilitation has been spectacular. Today, the SI-derived unit of magnetic flux density is the tesla. On the silver screen he was played by David Bowie in the movie The Prestige, while his name is now a globally recognised consumer brand in the form of the world's best-selling plug-in passenger car, produced by the US company known by one word: Tesla. ■

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For whom the bell tolls

September
1939

A Moscow bell that captured the attention of Napoleon

The ill-fated Great Bell of Moscow (or Tsar Bell) is now a tourist attraction in The Kremlin, but for 103 years it sat gathering dust in a 33ft-deep pit into which it was cast in 1733 by order of the Empress Anna Ivanovna.ar.

Ivanovna envisioned the Great Bell of Moscow as the successor to Tsar Alexis Mikhailovich's 100-ton bell, which was destroyed by fire at the Kremlin in 1701.

The new bell was to be taller at 20ft 7in, have a larger diameter (22ft 8in) and weigh in at 200 tons. By 1737 it was being decorated with reliefs and had been hoisted above the casting pit to cool down when another fire broke out in the Kremlin, causing blazing rafters to fall on the bell. In their haste to rescue it, onlookers poured water onto the inferno, which caused the bell to crack and dislodge a piece that weighed 11 tons. The bell fell to the bottom of the pit and, in September 1939, The Engineer's JR Nichols took a fresh look at the story.

"Some time ago – 27 August 1937 – in a reference to the Great Bell of Moscow in the correspondence columns of The Engineer, the present author mentioned that the raising of so great a weight over a century ago no doubt presented some problems," he said. "As a result of this remark, an interesting translation of an account of this feat has been received...The author of this account is Monsieur Auguste de Montferrand, who was responsible for raising the bell from the pit in which it had been cast... and placing it on the pedestal on which it still stands."

Work began on excavations when Montferrand reached Moscow on 25 March 1836, followed by a "strong coffer of carpentry" built around the giant bell and a further six weeks erecting scaffolding and other preparations. Once everything was ready, a date of 1 May was set for the first attempt to raise the bell.


THE ENGINEER

Sept. 1, 1939

The Raising of the Great Bell of Moscow

By J. B. NICHOLS

At 10am, the Te Deum having been sung, and in the presence of an immense crowd, the signal was given for soldiers to operate the 12 capstans that had been arranged around the bell.

"I shrunk at first when I considered that any mishap would bring many harms and much revilements from the inhabitants of the city... For blames and praises, honours and dishonours commonly accompany great works, and especially such as be public," Montferrand recorded. "I would add that, ordinarily, people are more prompt to speak ill when things go evil, than to speak well and esteem the labour should it be in all perfection."

"The bell began to rise slowly, but not without the breaking of two cables and a sheave of one of the pulleys," wrote Nichols. "This caused the bell to assume an oblique position, and two further cables broke. The signal was given to stop, and operations were temporarily suspended. The cables, which had been in store some six months, were found to be defective, and new cables were ordered; the capstans were also increased to 20."

A second attempt was made at 5am on 23 July and by 6.05am the bell, "covered with its ancient dust" was seen to rise slowly from the pit. In under 45 minutes the bell was above ground and the pit was immediately covered with strong rafters and flooring, which received the carriage on to which the bell was lowered, and from where it was hauled up an inclined plane to its pedestal on 26 July.

Nichols noted that the bell was then surmounted by a ball and Greek cross and was stood on an octagonal granite pedestal bearing a marble slab inscribed with a dedication composed by Monsieur Montferrand.

Unable to take the bell as a trophy, Napoleon ordered it to be blown up during the retreat from Moscow in 1812, but only managed to inflict damage on surrounding buildings.

A more benign action was enacted upon the bell in 2016 when a team from UC Berkeley, Stanford University, and the University of Michigan made the Tsar Bell ring for the very first time. To do so, they calculated the thickness, shape, movement and materials used to make the bell and created a computational model that simulated the real thing.

Word of the issue

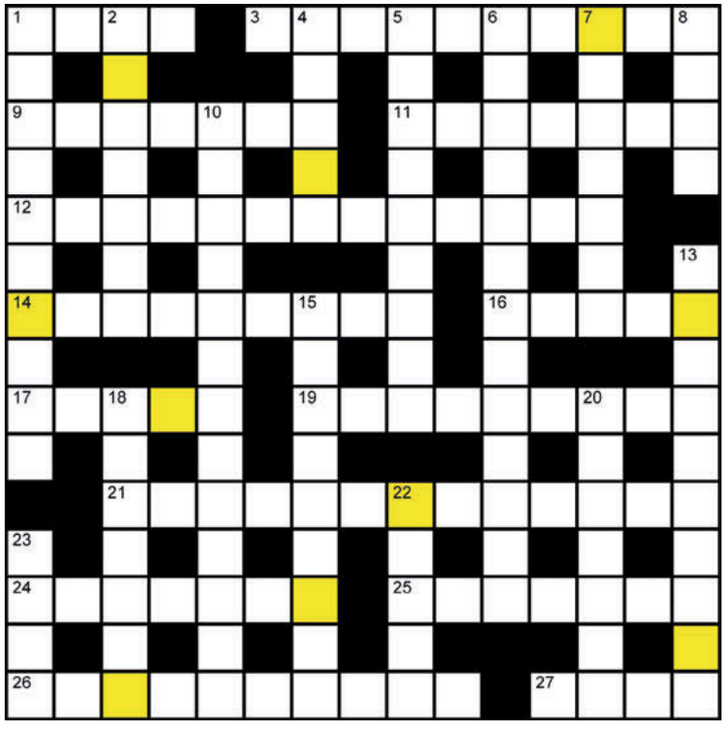
Anothony Poulton-Smith explores the origins of the word ‘drill’

Undoubtedly one of the earliest engineering processes developed by mankind. That the word is used in other senses – a small furrow in agriculture, a stout twilled cloth, a species of baboon, and in the military sense – is indicative of its simplicity and of its antiquity. In English, the word appears as a verb and as a noun, the verb not seen before the early 17th century while the noun is traceable to Proto-Indo-European of at least 8,000 years ago.

That Proto-Indo-European root was tere, used to mean ‘to rub, turn’ and has untold numbers of derivatives with meanings referring to twisting, boring, piercing, rubbing, (as well as seemingly unrelated and diverse words such as ‘trout’, ‘attorney’, ‘detour’, and ‘tribulation’). This root has also produced other terms in many other languages, including Dutch, Greek, Latin, Sanskrit, Lithuanian, Old Irish, Old Welsh, Slavonic, Proto-German, High German, French, and more – and all with the same sense of rubbing, wearing, and erosion.

Bigpicture

Aston Martin is introducing a service that will let owners create a bespoke garage for their car. Dubbed ‘Q by Aston Martin’, the service will see customers work with the Aston Martin design team and architects to fulfil a particular design brief.
Photo: ©Aston Martin



Prizecrossword

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Email your answer to **jon.excell@markallengroup.com**

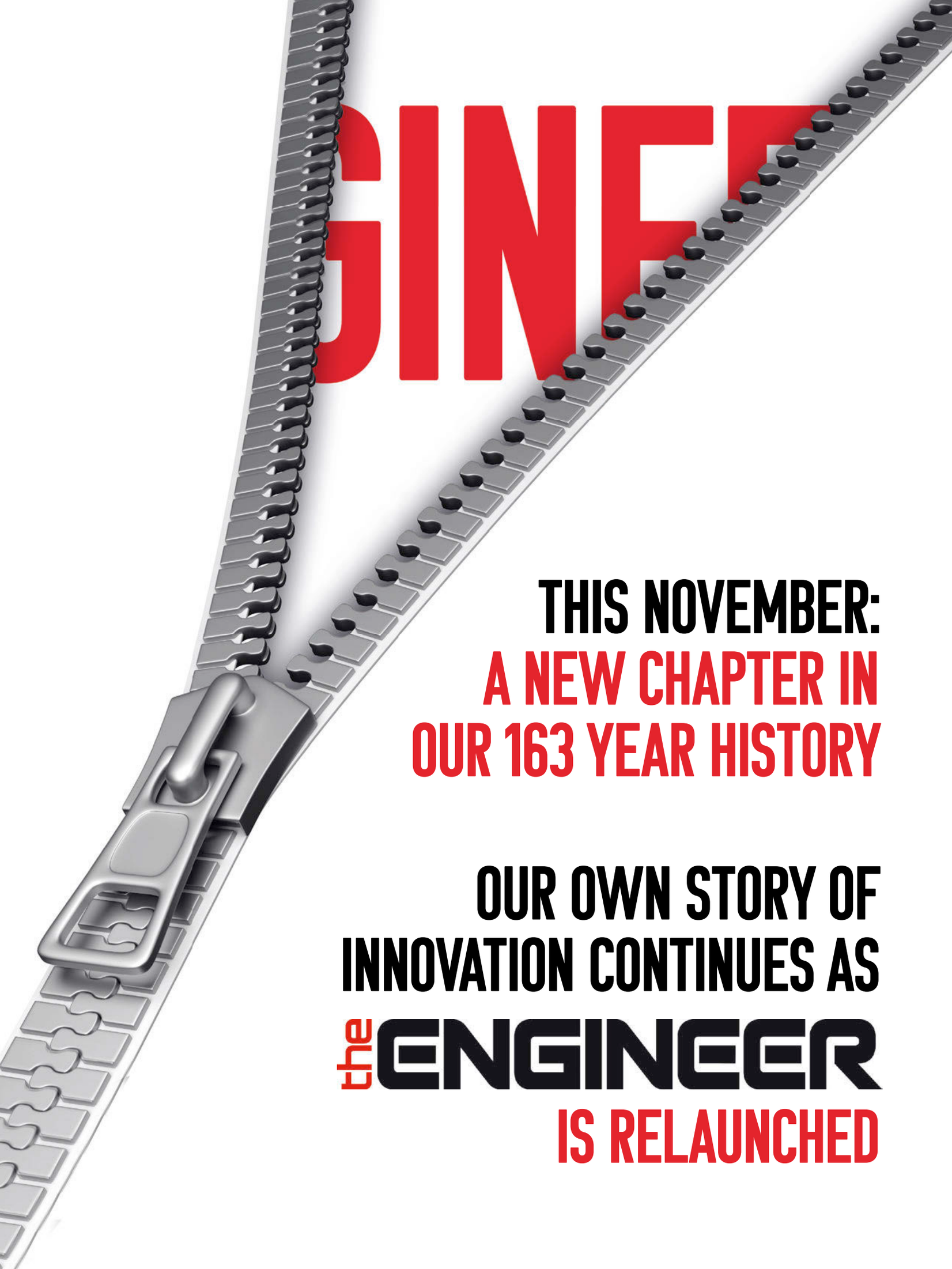
Across

1 Companies that provide a connection to the Internet (4)
3 Cover tightly in plastic (10)
9 Rich, frothy creams (7)
11 Thin metallic sheet (7)
12 Spool now taken over by DVD (13)
14 Areas of a concert hall where the audience sits (9)
16 Not burdensome or demanding (5)
17 Gain knowledge or skills (5)
19 Ring of rural land surrounding a town (9)
21 Drape used in a bathroom (6,7)
24 Discusses or mentions (5,2)
25 Act so as to delay an event (3,4)
26 All over (10)
27 Lower in quantity (4)

Down

1 Extremely stable (10)
2 Hit hard with a heavy instrument (7)
4 Robust east Asian clump-forming plant (5)
5 Having made no legally valid will (9)
6 Force exerted by a moving body (7,6)
7 Craftsmen working on top of a buidling (7)
8 Collection of objects laid on top of each other (4)
10 Without advance preparation (13)
13 Nonparticipant spectators (10)
15 Feeling sorrow for an action (9)
18 Let off the hook (7)
20 Consider in detail (7)
22 Having three dimensions (5)
23 Infection of the eyelid (4)

June’s highlighted solution was: **BUTTERFLY**. The winner was: **Chris Smith.**



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