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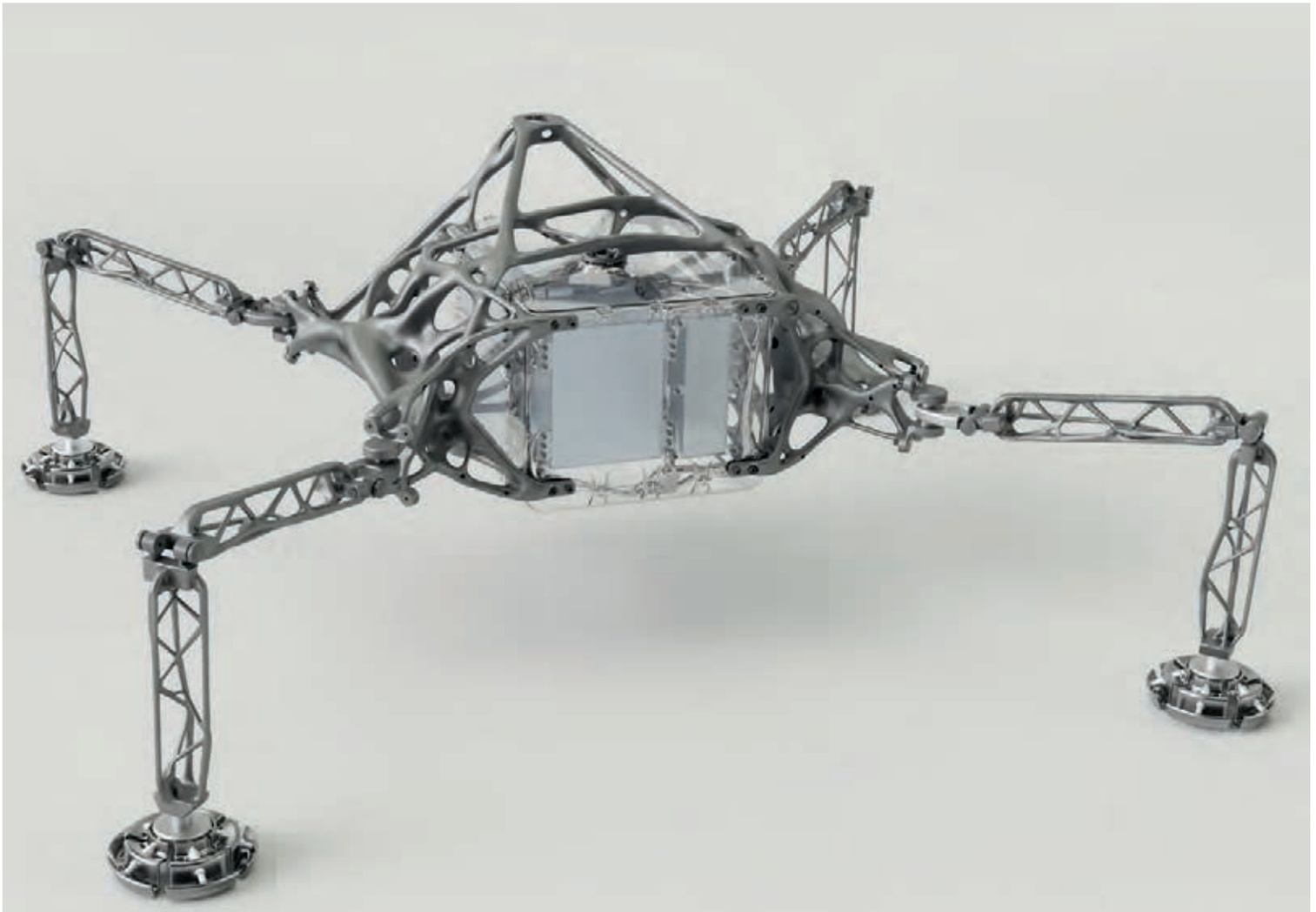

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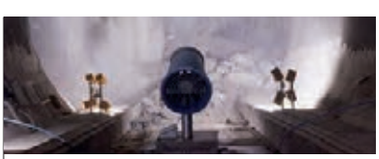

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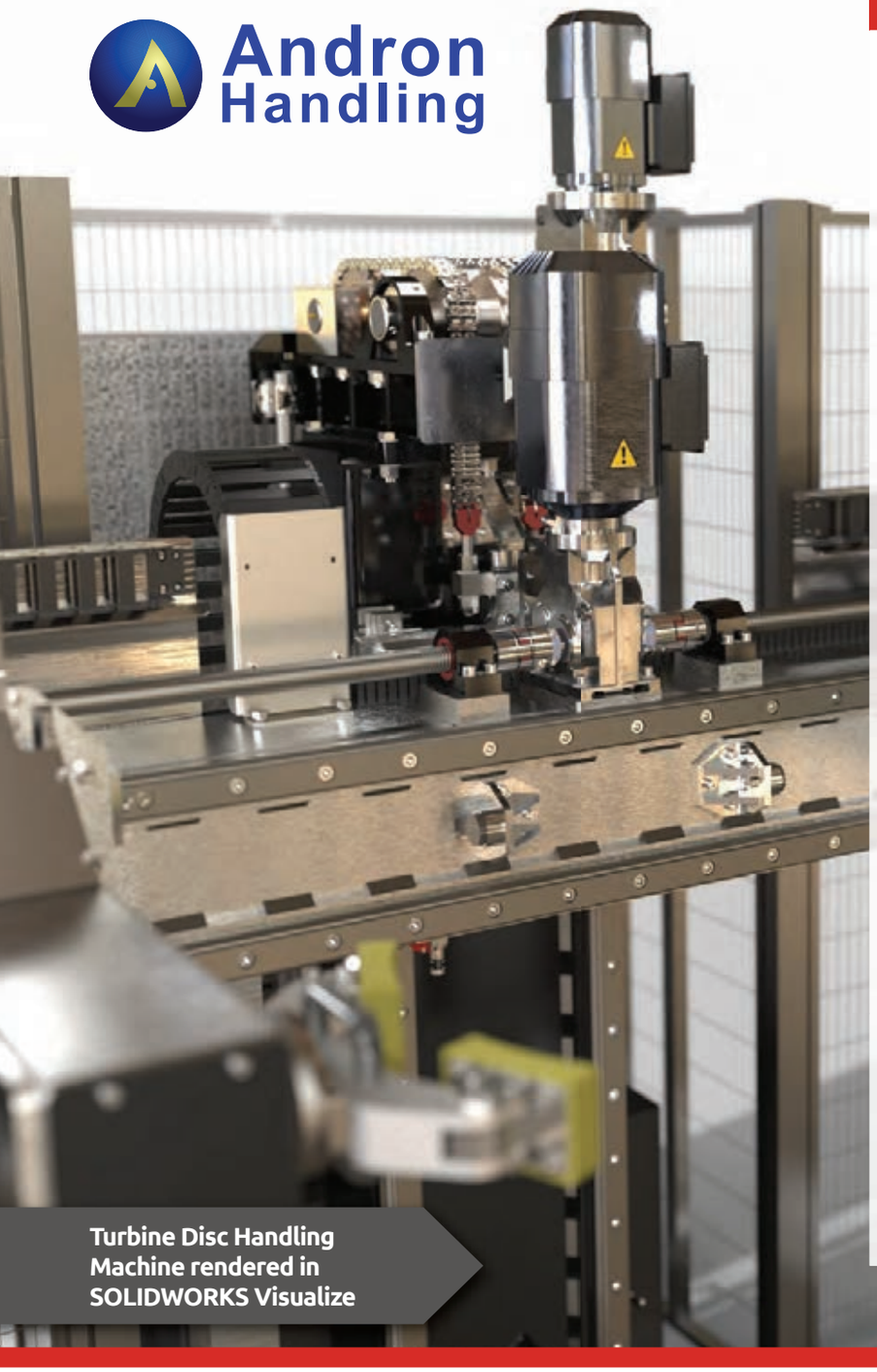

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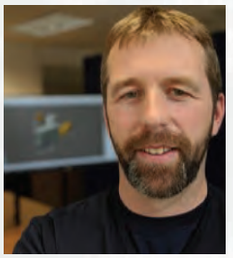

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Calls to action

I was going to dedicate this column to the ongoing Brexit debacle, and in particular the remarkable and unprecedented breakdown in the relationship between manufacturing and government. Never, in two decades of reporting on UK manufacturing and engineering, have I seen so many in the business community regard the government with such open exasperation and contempt. Here's hoping that by the time this issue lands, industry will have more, not less, cause to be optimistic about the political and economic backdrop against which it operates.

But for now, on to a more positive subject. Specifically, the launch of a competition which embodies a spirit of teamwork and collaboration that the UK's politicians can only dream about: *The Engineer*'s 2019 Collaborate to Innovate Awards (page 17).

Set up to uncover and celebrate the UK's most exciting and innovative engineering collaborations, Collaborate to Innovate has become a key fixture in the engineering awards calendar, and an inspiring reminder of one of UK engineering's great strengths: an open-minded, practical ability to cut across disciplines, embrace new ways of working and deliver solutions that make the word a better place. If you're involved in a project that you think might fit the bill, let our judges know all about it at http://awards.theengineer.co.uk.

> "Collaborate to Innovate is a key fixture in the awards calendar"

On a different note, there is still time to take part in our 2019 salary survey. Now in its fifth year, *The Engineer*'s salary survey has become a fascinating barometer of the changing attitudes of the UK's engineering community, which informs our year-wide coverage of the ever-emotive issue of engineering pay and helps us identify which sectors and regions are offering the most competitive salaries, as well as highlighting progress, or otherwise, in addressing industry's diversity gap. By taking part in the survey you can help inform this coverage as well as enter our £250 prize draw. Visit our website – www.theengineer.co.uk – for more details on how to take part.

And finally, a quick plug for *The Engineer*'s annual conference which runs from 4-6 June at the NEC, Birmingham. With presentations from some of the UK's top engineers on subjects ranging from electric aviation, supply chain reshoring, nuclear fusion and digital manufacturing, it promises to be a fantastic celebration of the best of UK engineering. Find out more about our amazing line-up of speakers on page 40.

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

ISSN 0013-7758. Printed by Precision Colour Printing, Haldane, Halesfield 1, Telford, TF7 4QQ. **Visit www.theengineer.co.uk for constantly updated news, products and jobs and to sign up for our FREE weekly email newsletter and tailored job alerts**

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CENTAUR MEDIA

AUTOMOTIVE

Motoring on with 5G tech to step up safety in cars

Partnership to investigate autonomous vehicle tech and aid safety

HELEN KNIGHT REPORTS

Vehicle technology is improving with 5G

Technologies to allow cars to more easily communicate with each other and the world around them will be developed as part of an alliance between AT&T and Vodafone Business.

The companies have announced they will work together to accelerate the development and use of Internet of things (IoT) connectivity within the automotive industry.

As part of the alliance, the companies are planning to work on projects to improve the safety, security and entertainment capabilities of cars.

In particular, the alliance will investigate 5G and autonomous vehicle technologies, as well as vehicle-to-vehicle and vehicle-to-infrastructure communications, and in-vehicle entertainment, according to Phil Skipper, head of business development, IoT, at Vodafone.

Unlike personal transportation today, where cars are typically owned and driven by a single person or household, the industry is moving towards shared ownership, with cars as a service, said Skipper.

That shift will see companies wanting to protect their assets with advanced telematics and asset tracking technologies, and to do that, they will need IoT connectivity.

"On the other hand, you will also need a way for customers to buy those services, and they're going to do that using their smartphones," Skipper said.

The companies are aiming to simplify the deployment of IoT technology, as well as developing new systems and making the network certification process easier.

Vodafone has been testing cellular-vehicle-to-everything (C-V2X) technology in Germany for the past two years.

The company has integrated the C-V2X technology with adaptive cruise control, a driver assistance system that warns the driver if something untoward happens on the road, and automatically speeds up or slows down in response.

The company has also opened a 5G lab and test track at Aldenhoven in Germany, where it works with car manufacturers and tier one suppliers to develop these new technologies using 5G.

"So for example, we have done tests using 5G to create a see-through van," said Skipper. "So if you're driving behind a van you can actually see from your car what is in front of the van," he said.

The company has also tested the use of a drone flying over a hidden dip in the road, to allow oncoming cars to see if there is anything on the other side of the dip, he said.

"We have also done tests for vehicle-to-vehicle communication, so if a vehicle that is further along the road than you starts to aquaplane, say, it can send you a message to warn you there is a problem with the road coming up," said Skipper.

What is more, Vodafone is also involved in a cross-industry research consortium in Germany, which is testing 5G technologies on the A9 motorway. The consortium is testing systems such as vehicle-to-vehicle and vehicle-to-infrastructure technologies, and heavy goods vehicle platooning.

"So 5G is going to be quite game-changing in the way that vehicles operate together," said Skipper.

When it comes to safety-critical services such as autonomous driving, Skipper believes some of the concerns about network coverage could be addressed by a staged approach, in which cars increase their functionality as they get closer to areas with a stronger signal.

"So if you're driving out in the countryside, you would be driving predominantly manually, and then if you move onto the A-roads you'll then start to take advantage of things like vehicle-to-infrastructure communication for traffic lights and motorway signage," he said. "Then when you get into the city, that's where you're likely to be driving fully autonomously." ■

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AEROSPACE

Space engine build takes off

Go-ahead for single-stage orbit STUART NATHAN REPORTS

Reaction Engines has been given the green light to start a testing programme for the core section of SABRE, its proposed single-stage-to-orbit spaceplane engine.

A three-year programme to design, build and demonstrate the core of an engine that could take a spaceplane from the ground into low-Earth orbit in a single stage looks set to pass a series of important milestones now that the European Space Agency (ESA) has approved a testing programme.

The UK Space Agency (UKSA) and ESA have been reviewing the preliminary design of the demonstrator core.

"The positive conclusion of our preliminary design review marks a major milestone in SABRE development," said Mark Ford, heading ESA's Propulsion Engineering section. "It confirms the test version of this revolutionary new class of engine is ready for implementation."

Reaction Engines is building a test facility for the core at Wescott Venture Park in Buckinghamshire.

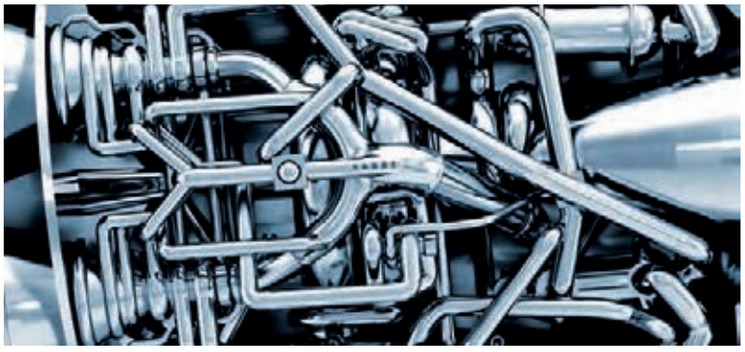
SABRE is a hydrogen-fuelled engine which, from launch to the top of the atmosphere, uses atmospheric oxygen in its combustion cycle, and once out of the atmosphere switches to an on-board liquid oxygen supply.

Its essential components include a pre-cooler that ensures the engine core runs with cold inputs and keeps the core components cool despite the heating effect of its high velocity; the engine core, containing heat exchangers plus combustion and turbomachinery modules; and the rocket nozzle.

ESA's involvement began in 2010 with an independent review of SABRE's viability, which opens the way to UK government investment via UKSA. ESA has invested €10m (£9m) in SABRE development via UKSA, along with £50m from UKSA, and continues to provide technical oversight for the project on behalf of UKSA.

The core demonstrator has been developed and built at a scale as representative of a SABRE flight engine, according to Reaction Engines, and testing is set to begin this year culminating in full system testing in 2020, by which point the entire cycle accelerating from a standing start to Mach 5 will have been demonstrated. In rocket mode, the engine is capable of propelling its vehicle at Mach 25.

"One of the great advantages of the SABRE propulsion concept is that it is totally modular from both design and operational perspectives" said Richard Varvill, CTO of Reaction Engines. "Therefore it is possible to subject each of the key components of the engine to rigorous ground testing, which fully mimics the operational conditions the engine will face up to Mach 5 flight at 25km altitude." ■



MEDICAL

Monitoring without pain

HELEN KNIGHT REPORTS

Wearable sensors – capable of monitoring patients remotely, recording information and communicating it back to healthcare professionals – are becoming increasingly important.

Now, researchers at the University of Exeter are developing sensors that can be integrated directly into textiles, to eliminate the discomfort of placing hardware directly in contact with human skin.

That is particularly important in the case of electrocardiography, which involves prolonged use of gel electrolytes to reduce the resistance between the skin and the electrode, and can cause allergies and skin irritation, according to Dr Ana Neves from Exeter's engineering department, who is leading the EPSRC-funded project.

The researchers will integrate graphene-based sensors into the textiles themselves. The graphene-coated textiles change in a predictable way when exposed to external stimuli, such as mechanical deformations or variations in temperature, allowing them to be used as sensors.

"Graphene also displays some antibacterial effects, which is an imported added functionality for healthcare applications," said Neves.

The sensors could be used to measure body temperature, cardiac activity and breathing rate. Body movement could also be used to power the wearable sensors.

Neves added: "Since human motion causes great deformations, the friction between layers of a fabric can be used to generate electricity, particularly in certain areas of the human body which bend and flex very often, like the elbow and knee."

The global number of remotely monitored patients is expected to reach 50.2 million by 2021. ■

Newsinbrief

Floating wind turbine test

The European Marine Energy Centre is to lead a €31m (£27m) project to test a full-scale floating wind turbine. The AFLOWT project (Accelerating market uptake of Floating Offshore Wind Technology) will see a floating wind turbine installed at the Atlantic Marine Energy Test Site, a facility in Ireland that is operated by the Sustainable Energy Authority of Ireland.

Green vehicle hub opens

Coventry University has joined forces with German engineering services giant FEV to open a new a £50m low carbon vehicle technology facility. The Centre for Advanced Low-Carbon Propulsion Systems has been set up to harness cutting-edge academic and commercial expertise to support the development of the next generation of electric, hybrid and combustion engines.

Neurotech to aid safety

McLaren is teaming up with tech startup MindMaze to use neurotechnology during the forthcoming Indianapolis 500 in an effort to improve driver safety. The MindDrive collaboration will see MindMaze's brain-sensing technology transmitting neural signatures from driver Fernando Alonso to a track-side medical team in real-time in the event of an incident.

Electronic skin creation

Underwater invertebrates have provided scientists with the inspiration to create an electronic skin that functions like jellyfish skin. The electronic skin is transparent, stretchable, touch-sensitive, self-healing in aquatic environments and could be used in everything from water-resistant touchscreens to aquatic soft robots, claim the team from the National University of Singapore. The skin is created by printing the novel material into electronic circuits.

OIL AND GAS

Drones to smell pipeline dangers

Mobile detection system could sniff out gas leaks from up to 100m away

HELEN KNIGHT REPORTS

Drones are to be put to work to sniff out gas leaks from transmission pipelines, thanks to a mobile detection system by ABB.

The system, which is capable of sniffing out even small leaks from a distance of up to 100m away, uses the company's industrial Internet of things (IoT) platform, ABB Ability, to allow it to upload signals to the cloud for immediate analysis anywhere in the world.

The system is based on technology originally developed to allow scientists to detect trace gases in the atmosphere.

To make the technology suitable for use in the oil and gas industry, the company reduced the size and weight of the system, allowing it to be flown by drone, said Doug Baer, global product line manager for laser analysers at ABB.

Drones could detect gas pipeline leaks

"In order to access and detect possible leaks in hard-to-reach areas like on bridges or underwater, you need to fly," said Baer.

Unlike conventional systems, which need to be close to a leak to detect it, the device can sniff even a few molecules of methane above the atmospheric baseline level of 1800 parts per billion, from great distances away, he said.

The self-contained box is equipped with a vacuum pump that pulls ambient air inside, and two mirrors.

A laser beam is shone through the measurement cell, where it bounces back and forth between the two mirrors before exiting the device and then being detected by a photodetector.

Consequently, although the measurement cell is only 10cm in diameter, the laser beam travels several kilometres, said Baer.

"That means you need far fewer molecules (of gas) in the pathway to detect a signal than you would if the pathway was only 10cm," Baer added.

The system is capable of measuring both methane and ethane, the two largest components in natural gas.

By using ABB Ability, signals detected by the system can be immediately uploaded to the cloud for storage and analysis by a remote operator using a secure connection, Baer said.

The system's software automatically processes the collected methane and ethane data, as well as GPS and wind information, to produce a report, which can be used to quickly identify areas in the pipeline that have leaks. ■

ROBOTICS

Mamut could be cream of the crop in capturing health and yield data

Cambridge Consultants has developed an autonomous four-wheeled robot called Mamut that captures data on individual crop health and overall yield.

The robot's sensor suite includes stereo cameras, LIDAR, an inertial measurement unit (IMU), a compass, wheel odometers and an onboard AI system that collates all of the input data. This combination of technologies allows Mamut to navigate autonomously and map unstructured environments (simultaneous localisation and mapping, or SLAM) without the need for GPS or the fixed radio infrastructure used by other agritech systems.

According to Cambridge Consultants, automating the capture of crop data from the field provides farmers with more reliable and actionable information, improving efficiency and increasing yields.

Data capture on a mass scale is largely undertaken by drones, but this can lack accuracy for many crops hidden beneath a canopy. Autonomously travelling through fields allows Mamut to inspect and analyse individual crops from close range. SLAM was developed in navigation trials through a maze and orchard. AW

AEROSPACE

UAVs to support military air operations

Boeing model will protect manned jets

JASON FORD REPORTS

Boeing and the Australian government are to develop an unmanned aircraft that will provide fighter-like performance in support of manned military aircraft.

Australia's Ministry of Defence will invest up to $40m (£22m) in developing the aircraft, which is set to take its first flight in 2020.

The prototype, dubbed Loyal Wingman – Advanced Development Program, will feed into the production of the Boeing Airpower Teaming System (Boeing ATS), a platform that represents the company's largest investment in a new unmanned aircraft programme outside the US. A model of the Boeing ATS was unveiled at the Australian International Airshow by Christopher Pyne, the Australian minister for defence.

"The Boeing ATS will provide a disruptive advantage for allied forces' manned/unmanned missions," said Kristin Robertson, vice president and general manager of Boeing Autonomous Systems. "Our newest addition to Boeing's portfolio will truly be a force multiplier as it protects and projects air power."

Measuring 11.7m in length and able to fly over 2,000 nautical miles, Boeing ATS' suite of sensors will enable it to support intelligence, surveillance and reconnaissance missions and electronic warfare.

Artificial intelligence will support independent flight, or support of manned aircraft, while maintaining safe distance between other aircraft.

Steven Ciobo, Australia's minister for defence industry, said Boeing will look to work with large, medium and small Australian firms and partner with research organisations. ■

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MATERIALS

Recycled metals to transform alloys

High-strength aluminium could assist with vehicle construction progress

HELEN KNIGHT REPORTS

High-strength aluminium alloys produced from completely recycled metals could be developed as a result of a UK-led research partnership.

Aluminium production consumes 3.5 per cent of the world's electricity supply, while producing one per cent of global carbon dioxide emissions.

However, the metal is theoretically infinitely recyclable, with its recycling consuming just five per cent of the energy needed to produce the metal in the first place. Over one billion tonnes of aluminium has been produced since 1908, of which over 75 per cent remains as accessible stock.

Now, in a bid to reach a full circle aluminium use and recycling system, researchers at the Brunel Centre for Advanced Solidification Technology (BCAST) at Brunel University, working with Netherlands-based aluminium products manufacturer Constellium, have established a strategic research partnership which will develop high performance aluminium alloys, and investigate their applications in lightweight vehicle construction, according to Prof Zhongyun Fan, project leader and director of BCAST.

High-strength aluminium alloys

Aluminium alloys have a range of benefits including low density, high strength, and high corrosion resistance. As a result, demand for aluminium products is increasing, particularly in the transport industry.

However, even with the reduced weight offered by aluminium car components, a vehicle must be run for 10,000 miles before it becomes effective in reducing carbon dioxide emissions, said Fan. That is because the process of mining and producing aluminium is extremely energy-intensive, he said.

"But if you use recycled aluminium, from day one you are reducing carbon dioxide emissions," he said.

The STEP (Strain Enhanced Precipitation) project will develop a new generation of alloys with ultra-high strength – approximately twice that of conventional aluminium alloys – as well as good ductility, high crashworthiness and high thermal conductivity.

The researchers will use a combination of production techniques, including deformation, and a reduction in the crystal size of the alloys developed, to increase the overall strength of the metal, said Fan. The researchers also plan to develop a novel melt conditioned direct chill (MC-DC) casting process, in which liquid metal is intensively sheared before solidification.

The MC-DC casting process produces aluminium feedstock with much higher quality.

"It has much finer crystals, resulting in higher strength and making it easier to process later on," said Fan. ■

AEROSPACE

Drones piloted to make quicker shore-to-ship payload deliveries

Engineers at Airbus have demonstrated the use of a drone to carry and deliver payloads from a port to vessels anchored out at sea.

The trial, a first in real port conditions, used the firm's Skyways parcel delivery drone to carry 1.5kg of 3D-printed components from Singapore's Marina South Pier to a vessel anchored 1.5km off the coast. The entire flight took 10 minutes.

During the ongoing trials, which are being carried with Wilhelmsen Ships Services, the drone will lift off from the pier with payloads of up to 4kg, and navigate autonomously along pre-determined 'aerial corridors' to vessels as far as 3km from the coast.

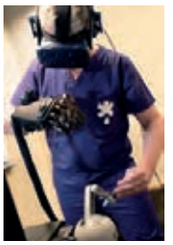
Airbus and Wilhelmsen signed an agreement in June 2018 to drive the development of an end-to-end unmanned aircraft system for safe shore-to-ship deliveries. It is thought that the use of unmanned aircraft systems in the maritime industry could speed up deliveries by up to six times, lowering delivery costs by up to 90 per cent. **JE**

MEDICAL

Surgical glove simulation

HaptX to have hand in assisting VR feedback

ANDREW WADE REPORTS



FundamentalVR is enhancing its VR surgery simulation platform with the addition of the HaptX Glove, giving surgeons haptic feedback directly to their hands.

Fundamental's Surgical Haptics Intelligence Engine mimics the feel of operating on human tissue.

The platform is hardware-agnostic and can be used with off-the-shelf haptic equipment.

Until now, this has consisted primarily of haptic pens and arms that simulate surgical tools. But with the integration of the HaptX Glove, users will now be able to engage directly with the VR simulation via their hands, guiding a tool held separately or manipulating the patient's body.

The HaptX glove is powered by microfluidic technology, with 130 actuators providing feedback to the user's skin. This force feedback exoskeleton can apply almost 2kg of force per finger.

Combined with motion capture technology that tracks the user's hand movements with sub-millimetre precision, the glove delivers its haptic experience in coordination with the virtual world.

FundamentalVR said the glove allows users to fully interact with the simulation, engaging the body, assisting the other hand, or even gripping a surgical tool of its own.

"When it comes to surgical training simulations, a sense of touch is a game changer, but has traditionally only been possible with immobile equipment costing hundreds of thousands of dollars," said FundamentalVR CEO, Richard Vincent.

"Our platform currently works with haptic arms, but is designed to evolve as hardware innovations allow new products such as HaptX Gloves to come to market." ■

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MARINE

No more fretting at sea thanks to mesh

Wireless nodes on board ships could help locate stranded crew members HELEN KNIGHT REPORTS

When a ship gets into trouble at sea, finding every crew member on board and getting them to safety in time can be an enormous challenge, and lives can be lost.

Now crew members could be immediately located during an emergency, thanks to a wireless mesh-based Internet-of-things (IoT) system, developed by Norwegian maritime technology company ScanReach.

The In:Mesh system is based on a series of individual wireless nodes, placed in each room on board the vessel, according to John Roger Nesje, CEO at ScanReach.

Conventional Wi-Fi networks, which operate on a frequency of 2.4GHz, do not work well in the largely steel environment on board ships. Wi-Fi access points also require cabling, which is difficult and expensive to retrofit onto existing vessels, and can be damaged, said Nesje.

"We realised quite early on that we couldn't rely on any system with cables, because during a fire the cables will burn, and during very many emergency situations power will be lost," he said. "So we needed something that could still operate during an emergency situation, which meant something that was locally powered by battery, and completely wireless."

Information flows through the wireless mesh in all directions, to and from each node, and up to a central computer, typically on the bridge, Nesje said.

Unlike Wi-Fi networks, the system operates at a sub-1GHz frequency, which can be transmitted much more effectively through steel. Each crew member can be fitted with wearable tags, called In:Range, which can be used to locate them in an emergency, said Nesje.

"If you are in an emergency situation on board a large vessel, and you are mustering people, to stop and search for one missing person in such a huge space could take hours," he said.

"With our system, the captain can easily see where this crew member is located, and send the rescue team directly to their location."

The wearable tag also has an alarm button that can be pressed in an emergency, he said.

What's more, it is also possible to add a wide range of sensors to the mesh network, allowing it to detect everything from dangerous gas leaks, to temperature, humidity, vibration, noise and light levels, using a system dubbed In:Sense. In this way the network can create a map of the entire vessel, turning it into a smart ship, said Nesje. ■

ScanReach has developed lifesaving tech for ships

ENERGY

Aspen leaves are the inspiration to blowing power into remote sensors

An energy harvesting device inspired by the trembling motion of aspen leaves could be used to power remote sensors or even as a back-up supply for Mars rovers, according to its creators at the University of Warwick.

The aspen leaf has a flat stem that facilitates a large amplitude quiver even at low wind speeds. The team mimicked the shape of the leaf using mathematical modelling, then tested its device in a wind tunnel. A cantilever beam acted like the flat stem, while a curved blade tip with a circular arc cross-section mimicked the leaf's body.

Orienting the blade perpendicular to the wind flow direction allowed the harvester to produce self-sustained oscillations at uncharacteristically low wind speeds, just like an aspen leaf.

The tests showed that the airflow becomes attached to the rear face of the blade when the blade's velocity becomes high enough, performing more akin to an aerofoil compared with other device shapes typically used for wind energy harvesting. **AW**

CONSTRUCTION

Welding done in seconds

New generator will deliver high power

STUART NATHAN REPORTS

Researchers at the Cockrell School of Engineering at the University of Texas in Austin claim a breakthrough that could reduce the welding time for infrastructure components to seconds.

The team is working on homopolar welding, which uses very high electrical currents to join metal. Its crucial equipment is the homopolar generator (HPG) which produces currents in the mega-amp scale.

The most useful characteristic of an HPG is its ability to store energy at low power for a long time in a rotating disc, then deliver very high power over a short time, which leaves it subject to the drawbacks associated with rotating electrical machinery.

In research sponsored by the US Department of Transport, the Austin team has used components such as ceramic rolling element bearings to replace more expensive hydrostatic bearings, commercial electric brush mechanisms to replace bespoke brushes, variable speed low-inertia induction motors to spin the generator rather than a high pressure hydraulic motor, special-purpose bus bars with cross sections designed to resist high forces, and completely eliminated high-pressure hydraulic auxiliary systems. The result, they claim, is a compact HPG some 60 per cent cheaper than previous versions, which is suited to on-site civil engineering applications.

The main task it is targeting is butt-splicing steel plates made by rolling mills to produce the longer plates needed for bridges.

Homopolar welding could also be used to weld together sections of train track. Outside transport, it could also be used to repair oil and gas pipelines. ■

TRANSPORT

Smart solutions to ease congestion

Strategies in place to boost sustainability in London using mobility tech

HELEN KNIGHT REPORTS

Smart mobility technologies designed to solve London's congestion problems will be developed in a new innovation hub created by Bosch.

The London Connectory, based in Shoreditch, aims to bring together start-ups, government and large organisations to develop automated, electric and connected transportation technologies.

Transport for London (TfL), the first partner to join the Connectory, will work with Bosch on an 18-month project to investigate how best to meet the Mayor of London's goal of ensuring 80 per cent of trips in the city are made on foot, by bicycle or using public transport by 2041, according to Olivia Walker, head of city development at Bosch UK.

"The guiding strategy for [the Connectory] is the Mayor's transport strategy, which outlines various measures that are needed if we want to achieve the sustainable future that London deserves, in terms of the quality of air, the ease of commuting and the general quality of life, and that is what led us to partner with TfL," said Walker.

The London facility is the fourth Connectory to be established, after Chicago, Guadalajara and at Bosch's headquarters in Stuttgart, but the first to specialise in mobility technologies.

The Connectory will attempt to use as much data as possible to understand the city's mobility challenges, according to Professor Nick Reed, head of mobility research and development at Bosch UK. This could include data from the city's infrastructure on congestion levels, safety and air quality, or data taken directly from vehicles, said Reed.

"One of the things we have to do as a team is to look at which datasets give us the clearest understanding of what challenges there are, and help us to understand what solutions we need to introduce to address them, whether it be improving the walking infrastructure, or introducing a driverless bus system, for example."

To this end, the Connectory will need to build relationships with those gathering these datasets, including universities and public and private organisations, he said.

"Our scope covers everything from walking and cycling, to car sharing, ride-hailing, and all the way up to automated vehicles," he said. "The important thing is to have the data so we understand what solutions are going to work in which locations." ■

Smart mobility plans are in place to ease London's congestion problems

MATERIALS

New £2.4m centre to carry out large-scale testing of tidal blades

The University of Edinburgh and Babcock International have revealed plans for a new £2.4m composites test facility, located at Babcock's Rosyth dockyard in Fife.

Known as Fastblade, it will be the first centre of its kind to carry out large-scale accelerated testing of tidal blades. According to Babcock, the facility will employ complex testing equipment that will simulate real-world forces, helping to speed up product development cycles. At the heart of this will be a hydraulic system that enables structures to be tested more efficiently than existing technologies. The system will also recover energy between load cycles, reducing the cost of testing.

Babcock said that advanced measurement systems will enable developers to understand damage accumulation and optimise blade structures using data-driven design.

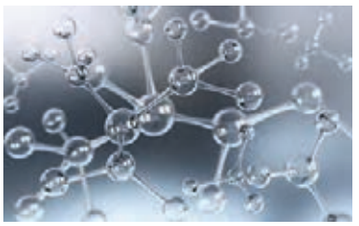
It added that work on Fastblade will start later this year, with the facility operational by spring 2020. **AW**

MATERIALS

Fibre force is unbreakable

Thread can stretch to seven times its length

STUART NATHAN REPORTS



Engineers at North Carolina State University have developed a fibre that combines the elasticity of rubber with the strength of a metal.

Capable of stretching up to seven times its length without breaking, the fibre can absorb a lot of energy as it deforms, becoming tougher than the materials in its composition.

Developed by a team led by Michael Dickey, Alcoa professor of chemical and biomolecular engineering, the fibre consists of a gallium metal core surrounded by a sheath of poly (styrene-ethylene butylene-styrene) (SEBS).

The team explained that the fibre mimics the behaviour of tough biological materials such as collagen or titin, the giant protein which acts as a molecular spring in muscle.

Under stress, gallium fractures, but the SEBS sheath absorbs the strain between the breaks in the metal and transfers the stress back to the metal core.

"Every time the metal core breaks it dissipates energy, allowing the fibre to continue to absorb energy as it elongates," said Dickey. "Instead of snapping in two when stretched, it can stretch up to seven times its original length before failure."

The new fibre is said to be 2.5 times tougher than titin and can hold more than 15,000 times its own weight for 100 times longer than a hollow SEBS fibre. It uses relatively simple and low-cost chemistry, in contrast to other attempts to create tough fibres by synthesising polymers which incorporate sacrificial bonds that release "hidden" lengths of material when the bond breaks, or have complicated structural architectures such as interpenetrating polymer networks. ■

Why the future belongs to the digital twin

Ben Salama, UKI Industry X.0 Lead, Accenture Managing Director & Yen-Sze Soon, UKI Industry X.0 Delivery Lead, Accenture Managing Director

As industrial companies move from designing and creating standalone products to developing increasingly connected smart services and experiences, they face a number of common challenges. They need to innovate at speed as well as coordinate ever-more complex ecosystems of partners, suppliers and customers. And they need to make maximum use of huge and growing volumes of data. In addition to customer information, as new smart products generate insight, businesses have a means to continuously optimise operations and customer experiences. Understanding every process around the lifecycle of every product and asset is essential. It's also a major challenge.

Part of the barrier comes from having the insight. A strong majority of professionals who need data for their roles – 70 per cent – say they don't have access to everything they need. This is before we even consider the challenges of analysing that data.

The second challenge is around applying that initial insight in a way that can lead to the most impactful outcomes. Digital twin is one of the technologies that can help businesses to apply this insight in new ways. Establishing virtual development and testing as well as remote control can support new data-driven business models and drive new value propositions.

What is a digital twin?

The concept of Digital Twin is not a new one. As the name suggests, a digital twin is a virtual replica of an actual process, service, or product. Using the digital twin concept, companies can 'virtualise' almost anything. There are practically no limits: from machines to factories and offshore oil rigs, from cars and their driving characteristics to entire cities—all these and more can be captured and recreated virtually. Engineers can then change functions, test new settings, and calculate complex simulations at a fraction of the costs and time required for traditional methods.

A digital twin is not a single concept, but a number of different virtual models that are progressively more sophisticated, data-rich and intelligent. The simplest is a static 3D image of an asset such as a factory or an offshore drilling rig. Next is a twin that also contains engineering data, making it possible to look at a specific component. For example a pump for which you can see the make, model, sub components and detailed engineering properties, such as the amount of pressure it's able to handle. The third level of sophistication comes with the integration of real-time operational data from sensors into the virtual model. This makes it possible to monitor conditions such as temperature and throughput.

And finally, an intelligent digital twin enables simulation and prediction, which means companies can carry out advanced testing of scenarios to understand how an asset will perform in different conditions, predict the likely failure rates of specific components and understand the impact of modifications or increases in production. Not only is this beneficial for testing, but also for training and re-training. This is particularly valuable where deployment is in remote or hazardous environments, as well as where the production of physical test models can be lengthy and/or expensive.

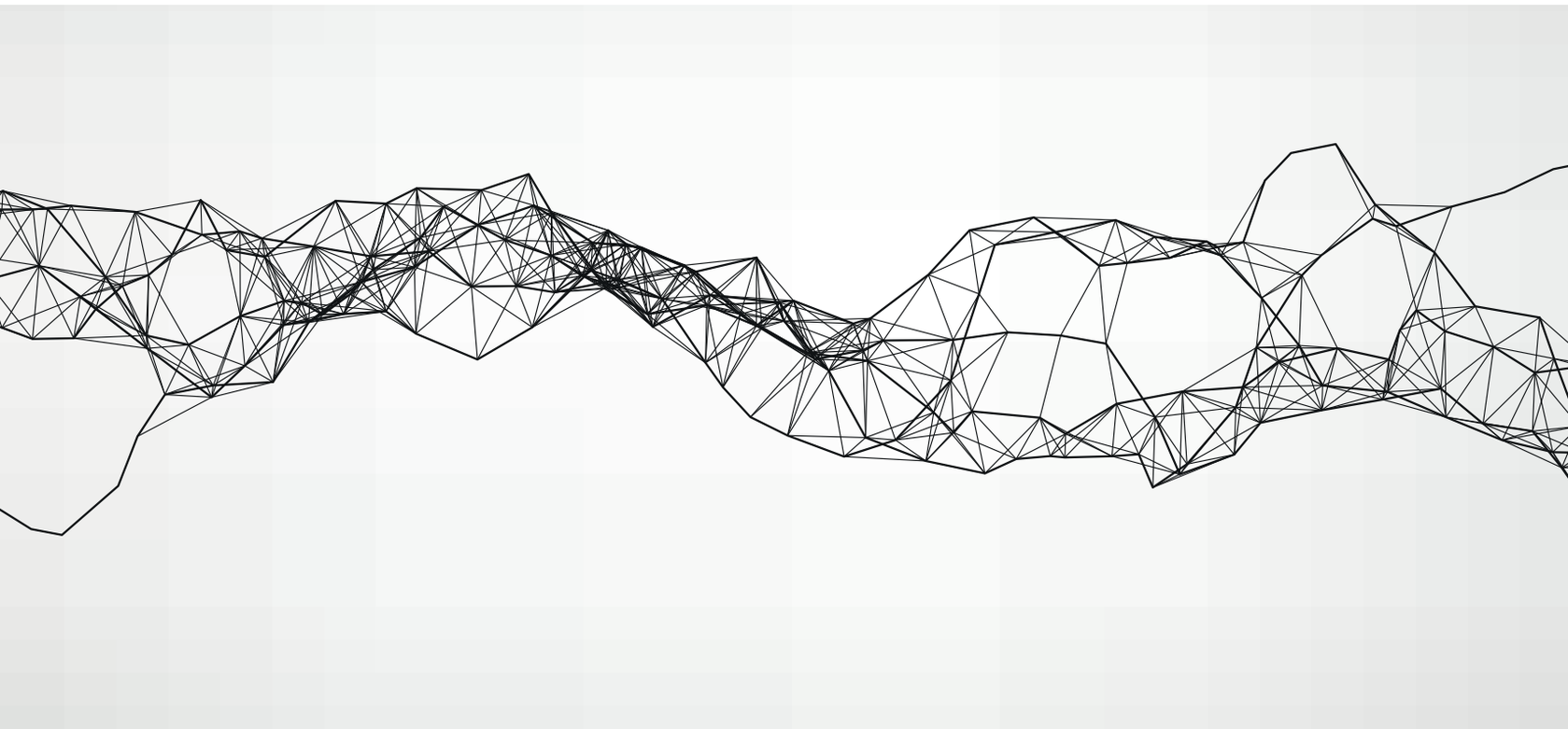
Simplified cooperation

Digital twins can simulate extremely complex systems in real time, breaking down the boundaries between departments and companies. As a result, they compile data from a wide range of areas on a single platform.

This means that a car manufacturer, for example, can keep a constant overview of a supplier's production data, a logistics partner's component inventory, and the effectiveness of its own engine plant.

As well as day-to-day functions, digital twins help innovation. Teams of developers, researchers, designers, and scientists can work on projects together, regardless of their location. They can collaborate on a virtual model of a product, shortening development cycles and often improving the end result because coordination is much smoother.

Improvements in safety are a further core benefit to digital twins. In an industrial workplace, safety hazards and potential for human harm are significantly higher



and more serious than in other industries. Digital twins can minimise the requirement for human interaction and physical monitoring within hazardous plants, where there can be a risk of explosion or exposure to chemicals. Via a digital twin these operations can be inspected remotely, assessing the live data being fed-back from the genuine model reflecting any potential faults or even have modification simulations run on them. All without the need for a human to directly interact with the hazardous location.

Twins and threads: driving the free flow of data

A digital twin 'accompanies' its real-life counterpart throughout its lifetime – providing a continuous cycle of day-to-day usage data and optimisation.

Feedback to the manufacturer also makes it easier to improve future products. This unimpeded flow of data between the 'real' machine and users' or manufacturers' IT systems is called the 'digital thread' which continuously runs alongside the physical product and creates a big value boost.

Mackevision, for example, used its CGI expertise to develop a digital twin of a Daimler motor block. This enables Daimler's developers to simulate the behaviour of motor components at various speeds. It also facilitates cooperation between engineers and designers across departments, while simultaneously streamlining numerous work processes.

Or take GE, which developed a digital twin for each wind turbine to improve wind farms' efficiency and power generation. Each turbine's operation is evaluated and compared with the output data from the other turbines in the wind farm. That enables operators to optimise performance across the entire array, making turbines up to 20 per cent more efficient.

An engineering company in oil and gas, recreated digital models of old assets such as an offshore platform. They then used CAD to design new add-ons to the asset and ensure full fit and compatibility without having to go on site saving time and minimising safety risk.

On a larger scale, Dassault Systèmes has created a virtual replica of the city state of Singapore, which serves first and foremost as a sand box for the city's planners. This digital twin allows city administrators to model a huge variety of scenarios with incredible accuracy, from the impact of construction work on traffic conditions to the noise pollution created by a new high-speed rail line.

So how can companies get started?

If companies are operating assets that were designed and built recently, they will likely have access to the digitised plans and drawings created with modern, sophisticated CAD tools. These make the development of an initial digital twin relatively straightforward. But many of today's industrial assets, for example drilling platforms or factory production lines, were designed and developed before that. But that shouldn't be a barrier either.

Today's technology makes it possible to create a 3D image of any asset. Once that 3D image is available, machine learning tools can extract relevant engineering data from existing documentation and integrate it into the 3D image. Then, it's possible to connect sensor data to provide live operational monitoring and – finally – algorithms can support advanced simulation and prediction capabilities.

Of course, that's a journey that needs to be approached systematically. The crucial first step? Engaging the wider business in the potential value a digital twin can deliver. That means starting small, with a working twin that operational and engineering teams can engage with and see the positive impact it will have on their role. With their buy-in secured, moving ahead to create increasingly sophisticated and intelligent digital twins will become a project that the entire business can get behind and drive forward.

Contact IX.0-Zone@accenture.com to get started on your digital twin journey.

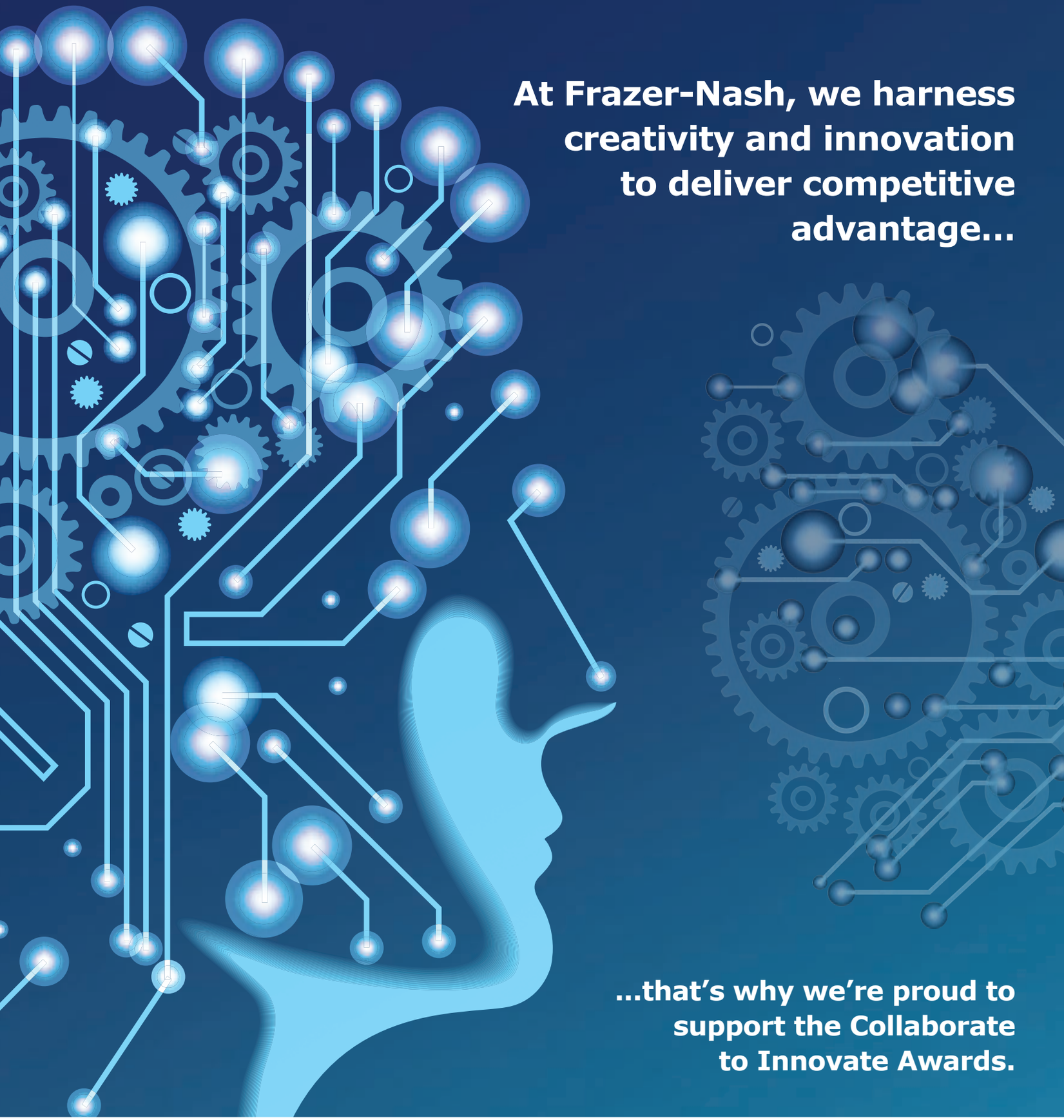
If you would like to learn more about how the latest technologies can help your industry thrive in the digital revolution, please read our report Combine and Conquer: Unlocking the Power of Digital – accenture.com/combine-conquer.

Creating twins – the technology foundation

Digital twins are much more than simple graphical mimics. First and foremost, they are 'data bundles', generated in real time and constantly updated to provide a stream of new insights. They support better decision-making, new value opportunities and transformational efficiencies.

Here's what industrial companies need before they can develop a digital twin:

1. Inventory information from the company's IT systems, such as design and master data relating to the object being digitised
2. IoT sensors on the machine, system, or product, that continually record operating data
3. A cloud in which all of this data comes together in a digital twin platform
4. Analytics algorithms that continually examine the platform data, 'understand' it, and make their findings available to other applications
5. Where possible and practical, 3D models and visualisations of a twin, so that it can be represented within virtual reality applications



At Frazer-Nash, we harness creativity and innovation to deliver competitive advantage...

...that's why we're proud to support the Collaborate to Innovate Awards.

Frazer-Nash is a leading systems and engineering technology company. We're renowned for our work in the aerospace, transport, nuclear, marine, defence, industrial, power and energy sectors. The breadth of expertise and the insight we apply deliver successful outcomes.

We have some of engineering's most talented people working for us. And they're doing what they love the most – solving our clients' toughest challenges and adding real value to their businesses.

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FRAZER-NASH CONSULTANCY

Collaborate to Innovate 2019 awards is open for entries

The annual search for the UK's most exciting and innovative engineering collaborations is under way

We are excited to announce the launch of the 2019 Collaborate to Innovate Awards, *The Engineer*'s annual search for the UK's most innovative, collaborative engineering projects.

Now in its fourth year, Collaborate to Innovate was launched to uncover and celebrate great examples of engineering collaboration – a dynamic considered critical to solving many of the challenges and problems faced by society.

The competition is open to any project that is truly innovative, represents a collaboration between two or more separate organisations and has had, or is likely to have, a demonstrable impact in its area of application.

For this year's awards, entries are invited from projects addressing fundamental engineering challenges across eight categories, including automotive; aerospace, defence and security; information, data and connectivity; healthcare and medical; energy and environment; and manufacturing technology. The awards also feature an 'academic innovator' category – for academic groups able to demonstrate sustained excellence in innovation and collaboration; and the coveted 'young innovator' award, which celebrates collaborations between businesses and school students.

As in previous years, entries will be judged by some of the leading figures from the UK engineering community, including Alan Newby, director of aerospace technology and future programmes at Rolls-Royce; Neil McDougall, managing director of Frazer-Nash Consultancy; Dr Kedar Pandya, associate director for business engagement and industrial strategy at EPSRC; Danielle George, professor of radio frequency engineering at the University of Manchester; John Halton, director for business and industry at EngineeringUK; Professor Andy Wright, director of strategic technology at BAE Systems; and Rosa Wilkinson, communications director at HVM Catapult.

This year's competition is supported by EPSRC and EngineeringUK, and sponsored by Frazer-Nash Consultancy, COMSOL, Mazak and HVM Catapult.

The closing date for entries is 3 May. Winners will be announced at a party in London on 6 November. For awards information, including the criteria for the categories and how to enter, visit **http://awards.theengineer.co.uk**

Neil McDougall, managing director – Frazer-Nash Consultancy

We cannot deliver innovation from inside a silo; we need to work together to change the world.

At Frazer-Nash, we believe that the future depends on innovation. That's why, in our third year, we continue to support the Collaborate to Innovate (C2I) Awards, and celebrate the achievements of all those who enter.

Since its inception in 2017, we've witnessed a wide range of exciting and compelling innovations – many will undoubtedly change our future and change lives. From nuclear energy teaching, research and innovation, and keyhole surgery for jet engines, to universal plasma filtration systems and the decarbonisation of heating through the innovative use of heat pumps, these innovations are making a difference, addressing and solving the problems and challenges that face us in today's world.

Like our own specialists, many of the organisations that enter the awards work to make a real difference. They're helping to keep people safe and well; supporting the generation and distribution of power to keep the lights on; enabling goods and people to move vast distances. They're embracing new digital technologies to make things work better… smarter… and they're trying to make the world a more sustainable place.

But they're not doing it alone. This is where the collaborative element of C2I is so important. Working in teams with others in partnership is vital to delivering innovative solutions, with complementary skills and experience brought by each team member. Importantly, these collaborations don't just involve the engineering sector. They cross every divide, connecting industries from manufacturing and insurance to healthcare, with academia and research organisations, and with sectors from government and defence to renewables.

At Frazer-Nash, collaboration is an approach that we embrace: we collaborate with academia; with other areas of industry; with suppliers, regulators and even competitors. Working across a diverse range of sectors, our opportunities for collaboration are correspondingly broad.

A key aspect of collaboration is that its benefits are experienced by all those involved. With universities, for example, while collaboration enables businesses to see the ideas that are being generated at a grass roots level in academia, conversely it allows academics to see the real-world problems that companies are trying to solve. Universities are keen to understand the issues being tackled by industry, so they can ensure that their courses are relevant and up to date.

A key element of C2I is the help and support it gives to the future of innovation, by recognising those initiatives that are developing young people's skills and creativity, inspiring them to become innovators and to solve the challenges of the 21st century and beyond.

For example, in 2018, the 'young innovator' category winners showed us all how innovation in education – through comedy, interactive workshops, performances, games and experiments – can be a catalyst to widen participation and build diversity in science, technology, engineering and maths

It is for these reasons that we were delighted to sponsor *The Engineer*'s Collaborate to Innovate Awards once again.

Automotive – sponsored by COMSOL

This year, COMSOL is delighted to sponsor *The Engineer*'s Collaborate to Innovate Awards. COMSOL brings innovation to everyone involved in the product development process through multiphysics simulation and applications.

Industry engineers and researchers are already accelerating product development by building numerical simulation applications in the COMSOL Multiphysics® software and distributing them throughout their organisations.

Now simulation is accessible in the field by deploying applications through COMSOL Server™ and COMSOL Compiler™ so engineers can run real-time analyses on-site. Widespread access to simulation applications and digital twins allows design engineering teams to tap into their greatest asset: each other.

Aerospace, defence and space – sponsored by HVM Catapult

The High Value Manufacturing Catapult, the go-to place for advanced manufacturing innovation support in the UK, is proud to sponsor *The Engineer*'s Collaborate to Innovate Awards. Innovation is at the heart of every successful organisation.

The wise recognise that in times of change and in the face of challenging conditions, they must act if they are to survive and grow. Those that do deserve our support and our celebration, as they are laying the foundations for long-term success.

Manufacturing technology – sponsored by Mazak

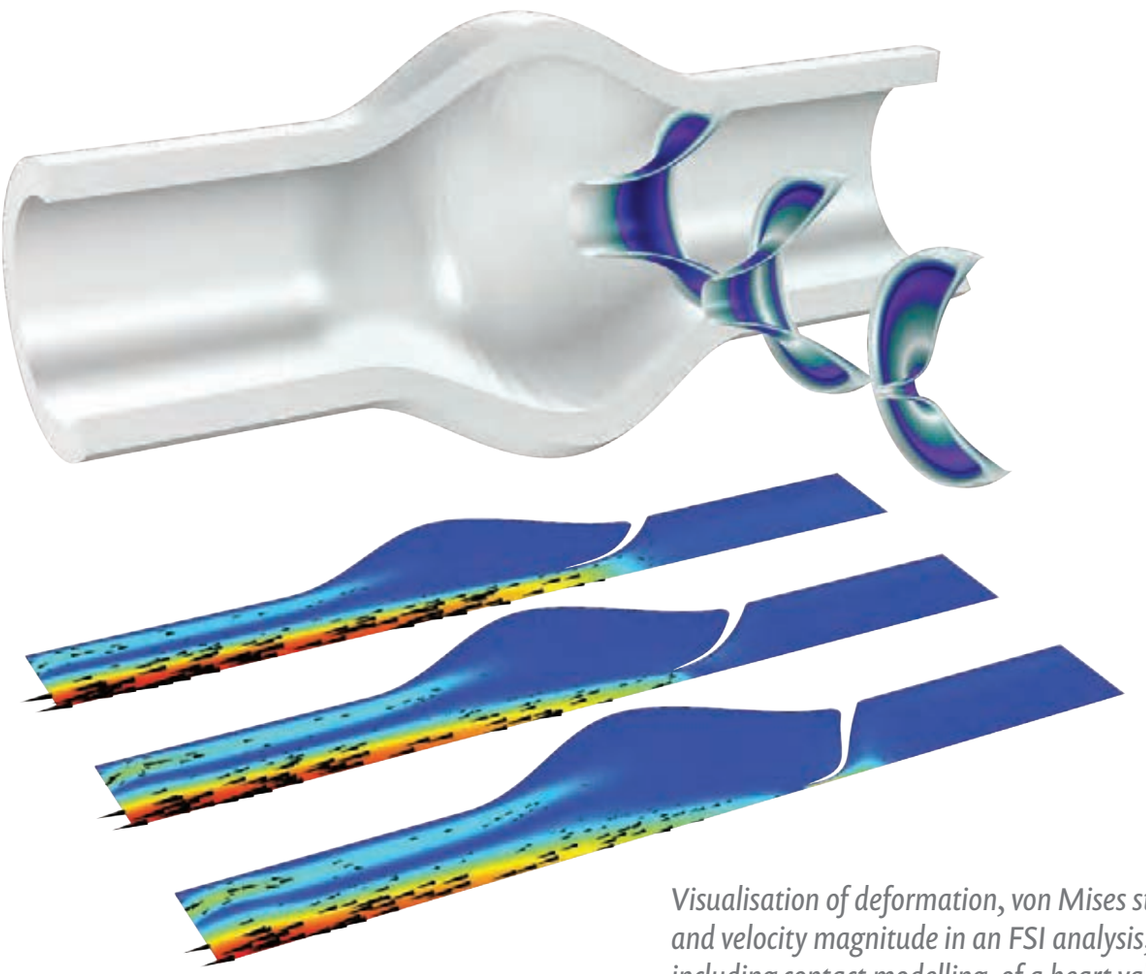
Collaboration and innovation are the keys to productivity, competitiveness and continued success for UK industry. Our own experience, working closely with customers and supply partners in the development of new machining and automation technologies, is proof that true innovation, which pushes the boundaries of what is possible, cannot be achieved in isolation – only with partnership and collaboration.

Mazak is proud to sponsor the Manufacturing Technology Award and its celebration of those companies who have placed technological innovation at the heart of both their own organisations and their customer and supply partner relationships – in the process creating a culture in which collaboration and innovation can truly prosper.

"Collaboration is an approach that we embrace: we collaborate with academia; with other areas of industry; with suppliers, regulators and even competitors. Working across a diverse range of sectors, our opportunities for collaboration are correspondingly broad"

Neil McDougall,
managing director,
Frazer-Nash Consultancy

Visualise and predict heart valve behaviour with multiphysics simulation.



Visualisation of deformation, von Mises stress and velocity magnitude in an FSI analysis, including contact modelling, of a heart valve.

Open fully, close tightly. The four valves in the human heart are expected to do this with each beat. When the valves do not function properly, cardiac health issues arise. In the quest for more effective treatments, medical researchers are studying heart valves to understand and predict their behaviour. To accurately visualise a heart valve, you need to account for many coupled effects. Multiphysics simulation is up for the task.

The COMSOL Multiphysics® software is used for simulating designs, devices, and processes in all fields of engineering, manufacturing, and scientific research. See how you can apply it to FSI analysis.

comsol.blog/heart-valve

COMSOL

The power of partnerships

Additive International's chair Professor Richard Hague explains the importance of continued collaboration to drive greater success in AM

The additive manufacturing (AM) industry has always been a fairly close-knit community. While there are rivalries among key players, when it comes to advancing the technology and what it can offer, there has always been healthy collaboration. Research institutions and industry experts are well aware of the limitations and opportunities of additive and regularly come together, working across universities, businesses and borders to improve and advance technology.

A good example of collaborative working can be found in the materials arena, where we are seeing a lot of organisations work together to research and develop new materials, and to enhance the performance of others.

As an exemplar, in a collaboration that spans multiple universities and industrial partners, Iain Todd at Sheffield University is currently leading a large EPSRC initiative (a Future Manufacturing Research Hub), focused on delivering on the "promise of advanced powder processing technologies through creation of new, connected, intelligent, cyber-physical manufacturing environments".

Together with UK and European business, industry and academic partners, he and his team are paving the way to reduce energy and waste in AM. Using particulate science, they are working to create powders that are active and designed, rather than passive elements in their processing.

This transformation will lead to greater surface control, resulting in particles designed for process efficiency, reliability and product performance. Their work will ultimately extend the palette of available materials for current and future manufacturing.

Collaborating for medical advancement

At my own institution of the University of Nottingham, Ricky Wildman is also leading groundbreaking work in materials. At last year's Additive International summit, he shared some of the advancements and discoveries he and his team of research partners from American and European institutions had made in another EPSRC project

"In these challenging times, technological advancement cannot happen in isolation"

that is looking to develop functional and bio-materials for AM. One area that they are working on is to improve and ultimately customise drug delivery for patients.

Collaboration is also fuelling commercial success in AM, as evidenced by Stryker Orthopaedics' joint licensing agreement with Chris Sutcliffe, who has had an auspicious career at both Liverpool University and Renishaw. The agreement applies to his work in developing 3D-printed metal implants that mimic spongy bone tissue and enable rapid integration between the implant and the bone in both humans and animals.

As a result of their successful partnership, Stryker has launched five families of implants and its Joint Replacement and Spine franchises continue to help relieve pain and injury for thousands – as well as thrive commercially.

Additionally, Sutcliffe has extended the work by founding a spin-out – Fusion Implants – that uses the bone-integrating technology to treat animals.

So collaboration and sharing of ideas are key, and the Additive International summit champions the coming together of people and the sharing of ideas for the betterment of the crucial area of AM.

Over the past 14 years, our delegates and speakers have always included our European and international colleagues; in these changing and challenging times, technological advancement cannot happen in isolation and we remain committed to facilitating the collaboration that drives success and look forward to welcoming all to the conference. ■

If you would like to hear more from – and network with - AM leaders, visionaries and innovators, head to Nottingham for this year's Additive International summit on 10-11 July. Visit https://www.additiveinternational.com for more details.

Mailbox

Thehottopic

Turning the tide

Warnings from the Environment Agency that the UK could face water shortages within 25 years prompted a discussion on the role engineers could play

Surely reducing water leakage across the network has to be the greatest priority. From memory, only one in four litres actually gets to our taps.
Alasdair Green

A national distribution system was mooted in the 1970s but scrapped due to cost. How short-sighted; oil, gas and petrol are pipeline-shipped over long distances, so why not water from the 'wet' areas of the country to the 'dry'?

London and the South East will always be short of water due to geography and climate so bring it in from areas that have excess, like the Lake District and Scotland.
MJ

A water 'national grid' is not the answer. Regional water distribution is done for sound geographical reasons, exploiting our natural waterways, and uses gravity as far as possible.

The last thing we need is a massive new demand for electricity to pump water hundreds of miles to supply the South East, just at the same time we've decided to electrify transport and domestic heating. In effect, these pump stations would be 'negative' hydro-electric schemes.
Trevor

Declaring an interest (as an ex-employee of a water company subsidiary), I would encourage anyone with an open mind to look at the role of the regulator Ofwat and how the asset management period system – now in its sixth five-year programme – has worked in practice, to deliver the slow, steady investment over decades which has improved water quality to the point they can now reintroduce oyster beds into the Humber. Privatisation plus a regulator with a big stick is working, in my view.
Trevor

We don't need a trillion-pound national grid for water; just a small pragmatic point-to-point system where the need is greatest.

Pontcysyllte aqueduct (the tallest aqueduct in the world) in North Wales bridged a missing link in the canal network at the time. It was funded by supplying water from the River Dee to Bristol. I hear there is plenty of water in Lancashire. There are canals to the south; why not use them? Water isn't like electricity where the supply has to meet the demand instantaneously. There are reservoirs.

If Cornwall is short of water in summer, it only needs a small tube from Axbridge to Cornwall, to gradually migrate water from Lancashire over 12 months, to satisfy the peak demand for two months in summer.
Ian Downie

If it is true that two of the major issues facing the planet are rising sea levels and water shortages, then more efficient desalination should go some way to addressing both.
David Harrison

The water companies immediately think of supply-sided solutions as it is in their interests to sell more water. But often the demand side approach is the most economic, socially and environmentally appropriate solution. This tends to be the least-cost option, much lower than building new reservoirs, piping water from one region to another, building new treatment plants or building desalination plants.
John Daglish

My workshop has an old Victorian underground beehive cistern, which is fed from half the roof gutters. The water is used to flush two toilets, wash hands and feed a steam cleaner.

Being commercial premises, I also have a water meter and it saves a fortune. I never run out of water. This could easily be built into new properties, maybe even a communal one on estates. We do not have a water shortage; we simply do not save enough water, allowing it to pour into rivers and disappear into the sea.

Our local canal had all its locks restored years ago, with dire warnings global warming would mean there was not enough water to use them. It is in a constant state of overflow, with all the lock bypass channels running!
Phil Whitle

Thesecretengineer

Engineers, with their clear and objective mindset, have a role to play in helping take some of the anger and name-calling out of the public debate, writes our anonymous blogger

The Brexit debate has led to unprecedented levels of social media rage. I think the time has come to talk about Brexit but, not wishing to prod the proverbial stick into the equally proverbial hornets' nest, it is at least an aspect that I hope the vast majority of us can agree on.

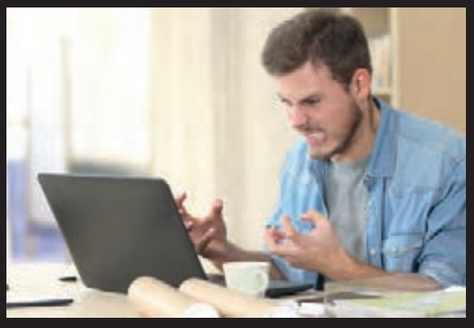
Most of us in Britain made one of three decisions a few years ago – stay, leave, don't vote – and I think it's fair to say that what has happened since is best described as tortuous.

It was a highly emotive subject even before the vote but the protracted farce played out subsequently has only ramped up the tension.

A problem I am seeing on a certain social media website is an increase in the vitriol and outright hatred being openly expressed for opposing views – invariably supported by shared and clearly ludicrous 'proof'.

I'm sure there have always been those with an in-built rage just waiting to be triggered but I honestly find some of what I see shocking, not only in the intensity of the self-feeding hatred but the willingness to completely accept obvious rubbish as validation for it. I don't know what the answer to this is, other than ridicule and trying to put together coherent arguments by return.

It's not only that I'm seeing a greater frequency of this sort of stuff, but also an increase in others seeing it as a green light to wade in with other inflammatory remarks that don't actually address the issue. So what has all this got to do with us as engineers?



For a long time now, the idea of 'the engineer in society' has been seen as an important one. As professionals, we see ourselves as having a duty to use our specific skill sets for the benefit of mankind as a whole. We are unusual in that those skill sets encompass not only the analytical but the creative. We must work within the confines of the physical world to produce novel solutions; consequently, we must deal with both the factual and the speculative.

Brexit – whatever it may mean – has key factual criteria but is mostly based on speculation, the uncertainty surrounding that speculation only serving to increase the emotion.

We, however, no matter which path we chose and why, should be well equipped to sort fact from opinion on both sides and give weight to them accordingly. So although we perhaps think of the engineer in society in terms of joining voluntary administrative bodies or encouraging and guiding those within the educational system, I would argue that it goes beyond that.

Especially in the less compartmentalised society that we now live in. We no longer socialise only with those who share our class, locality or general views. We come into personal contact with far more of the world, the people within it, and their own in-built biases. This will inevitably lead to differences that can polarise and be corrosive around subjects like Brexit.

As engineers, we have the mindset to be clear and objective, to lead by example – to be professionals in our dealings online.

This is one example that may be seen as a tad incongruous but it is specifically where my considerations for this piece started.

If we now look further outwards, where are the opportunities for us to influence the society we now find ourselves in? Rather than going into the local school, is there a chance to hook up with an educational establishment and field questions about our profession from a global audience online and in real time?

As there are already various YouTube-based lessons regarding engineering and related matters, could members of our institutes submit vlogs for peer review and release under their institutes' banner; giving a verified and quality-assured output that can be used by anyone?

The world has changed an awful lot in the past 20 years or so and I'm not sure that our view of where we fit into it has evolved to keep up. ■

Inyouropinion

Bloodhound returns

We owe Ian Warhurst a huge debt of gratitude. There are many ways to create engineers, scientists and technical people for the future, and Bloodhound and its engagement with the public stands out as a very good one indeed.

Richard Jenvey

Great news! The adventure continues!

Brian

Well done, *Engineer*. The best and most comprehensive article I have read about the renewal of the project. Great to hear that Ian Warhurst is keen to support the education programme, and presumably those ambassadors who have been so supportive of the car-build, public events and the education programme itself.

Peter McCree

Reaction Engines' SABRE to start testing

This is truly an elegant design and I am completely fascinated by the air pre-cooler. The helium turbine is somewhat a surprise to me, albeit this has to be the source of the cold for the pre-cooler, where heat is being picked up from outside, with fuel burn making up the remainder.

Why not go with super-critical carbon dioxide in this step? Would this not reduce compressor load on total power output, so even more reaction air could be provided?

James A Stewart

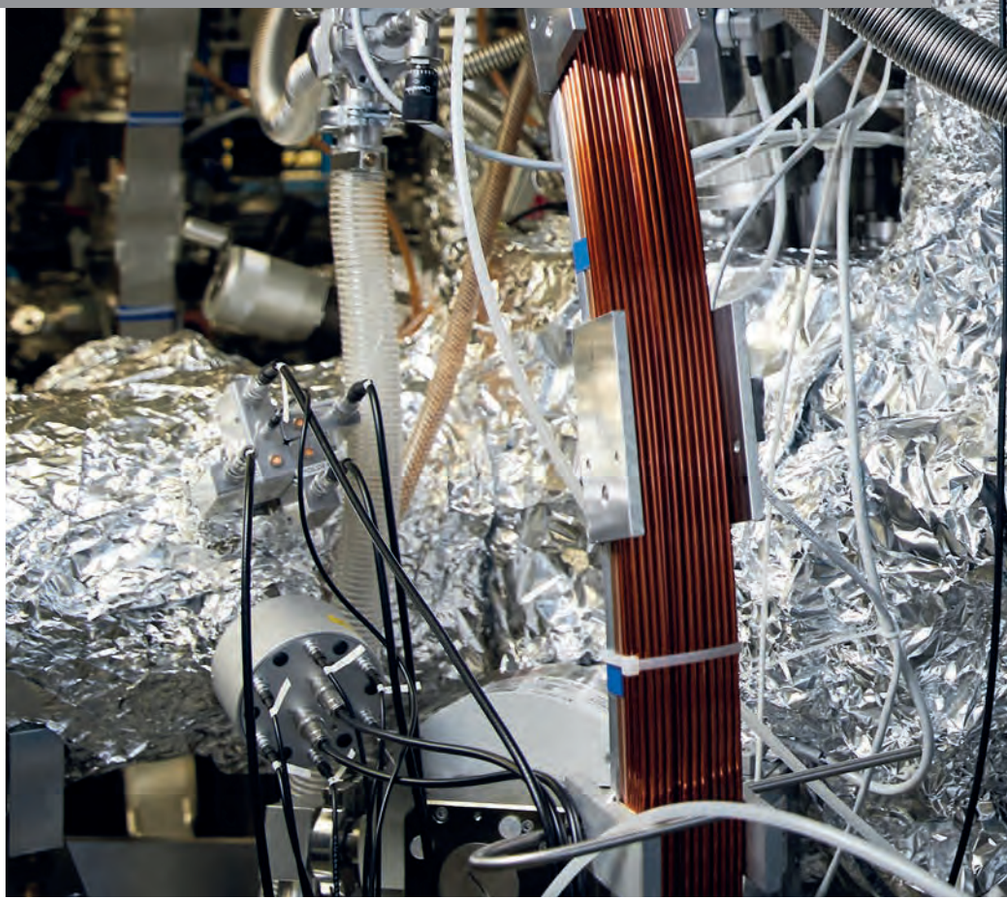
My reading of the use of a (closed) cycle helium loop is that it can warm up the liquid hydrogen (without blockages occurring) and then the chilled helium can cool the (hot) incoming air and be recycled (and, of course, drive the compression of the air). The use of helium as a heat transport fluid (between hydrogen and hot air) is that it reduces issues of hydrogen embrittlement of the pre-cooler; quite neat. I would worry that carbon dioxide might be frozen in a heat exchanger with liquid hydrogen as the coolant.

Julian Spence

Join the debate theengineer.co.uk

A ray of light in academia

Stuart Nathan **talks to Ursula Keller, who overcame significant challenges to rise to the top of her profession in physics, specialising in ultrafast pulsed laser technology and helping to improve the vision of millions**



Millions of people owe the acuity of their eyesight to Ursula Keller. The semiconductor saturable absorber mirror (SESAM) she invented while working at AT&T Bell laboratories in New Jersey in the 1990s is the crucial component for converting continuous laser light into pulses lasting from picoseconds to femtoseconds. It turns lasers into a surgical tool that can make millions of tiny incisions per second, a property which is used to create diffraction grids on the surface of the cornea in femtosecond Lasik surgery – the most common surgical treatment to correct defects in vision.

In addition, such lasers have become crucial to manufacturing many electronic components and are also finding uses in extremely accurate clocks.

But none of this came easy to Keller. Growing up in a working-class background in socially conservative rural Switzerland during the 1960s and 70s, she had to face the all-too-common prejudice against women studying and entering careers in science. Moreover, she is severely dyslexic. At the time, diagnosis of dyslexia was far less prevalent than it is today with the condition barely recognised.

Determination

Despite this, her determination and aptitude for mathematics and physics led her to university, where she studied physics engineering at the Swiss Federal Institute of technology (ETH) in Zürich. After graduating, she secured a scholarship at Stanford University in California, where she switched to pure physics and gained a masters then a doctorate in applied physics.

She went on to work at Bell Labs in New Jersey before returning to ETH as the school's first female full professor of physics, becoming director of the Swiss National Research Centre for Ultrafast Molecular Sciences and Technologies. She founded the ETH Women Professors' Forum as a support network to help female researchers advance their careers, both in terms of their position in the university and in their research, and was last year honoured with a lifetime achievement award from the European Patent Office.

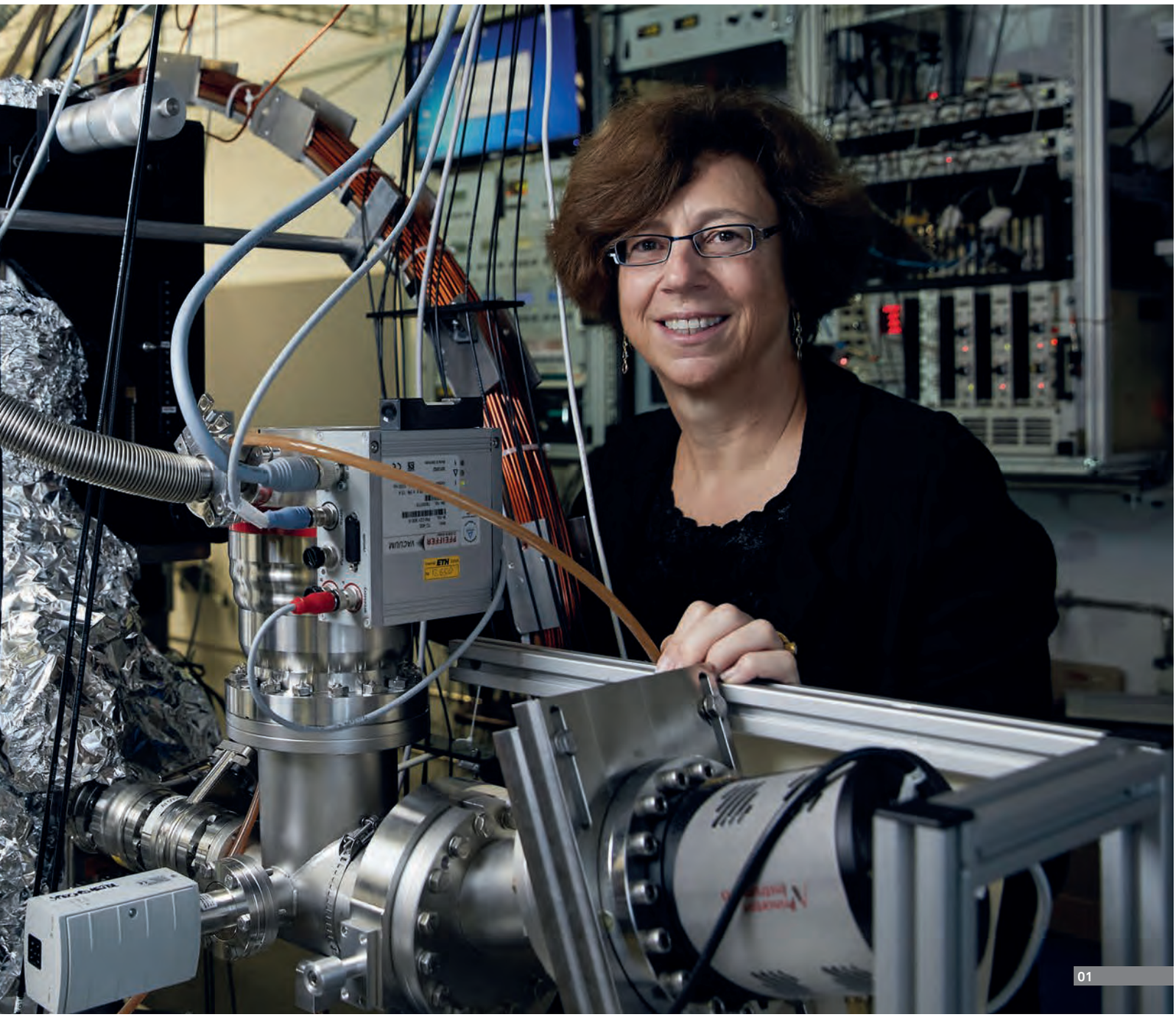
Keller explains: "In Switzerland there was a test you took at the end of primary education to decide what sort of secondary school you went to. The top level only took the highest 20 per cent and I didn't get into that, so I was supposed to go the next level down where you were trained mainly to go into vocational jobs. So I went to the government advisory service for aptitude tests to see what kind of career I would be best suited to.

> "When I started I could barely read and the teachers said 'you don't belong here' but my grades were good in maths"

"They also did some general tests, including maths, and those came out really well because they had graphical sections on geometry and I was really good at those.

"The adviser said I should stay in school. As I got older, my grades were not so bad any more and I got a bit better at languages, although when I started I could barely read and the teachers said 'you don't belong here' but my grades were so good in maths they couldn't understand it and the other students would say 'Oh Ursi, you explain this to us' when the teacher couldn't teach the problems."

Keller believes the effects of her dyslexia reduced as she got older. "I was still never able to learn anything by heart and I still have trouble with that, but I learned over



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01 Millions of people who have had laser eye surgery owe their improved sight to the genius of Ursula Keller

the years to organise things in my head so I could remember them better. In a way I think that is what makes me a very efficient data scientist. I can take basic maths and apply it so I can see things very clearly and that's because, early on, it was the only way I could memorise things.

"This allowed me to transfer to the top school, the 'Gymnasium'. Things were better there because I could specialise. For example, I never had to do Latin and my languages were good enough to not hold me back – although my final results were top grades in all the sciences and just good enough in the languages."

Physics was Keller's primary choice of science. "I was pretty strong in all of them but I felt to progress in biology and chemistry you still had to do a lot of learning by heart and, although I'd found ways of organising information, the way they were taught – at least at the time – didn't suit me. I can see now ways of learning chemistry but at the time I'd look at a chemical reaction and see all the possible ways it could go and the teacher couldn't explain to me the way it would actually happen. I'd just have to remember it. Maybe if they'd explained something more about energy levels and quantum mechanics I would have understood it better."

After finishing secondary school, many of Keller's friends took a gap year and went travelling. Although she wanted to do likewise she couldn't afford it so she applied directly to university.

"I was attracted to physics theory but I was always told it was difficult to get a job if you specialise in theory. I made the decision at the last minute to go towards experimental physics, basically because I needed to get a job. I still wanted to travel after university and I needed to fund that. While I was at ETH, I found out you could apply

for a fellowship which would allow you to travel and be funded. I applied for the Fulbright fellowship, graduated top of my class and won a full five-year fellowship. I was accepted at every US university I applied to but decided to go to California."

A professor at ETH offered to help her because he had been impressed with her grades. He suggested she spend some time in the UK to learn English. She says: "I really like the outdoors and skiing so I decided to ask Heriot-Watt in Edinburgh and I was accepted there. I took some English classes, so I learned with a slight accent, and had a great time.

"It was the early days of optical computing, around 1984, and in 1979 I had seen a demonstration of lasers back in Switzerland and become intrigued by that. At the time, optical computing was desperately oversold because they had only one or two types of logic gate but the potential was obviously there for physics theory to have a major impact on engineering."

At Stanford, Keller began to study laser physics more intensively and went on to make experimental laser physics the subject of her PhD.

"That stood me in good stead when I went to Bell Labs; because I was an experimental physicist they counted me as an engineer and I had a higher starting salary. At Stanford, there had been no looking down on engineering, everybody was always looking at applications, which was a difference from Switzerland and Germany where physicists tend to be perceived as having a higher status than engineers. At Bell Labs, there was a culture that when you wrote up your paper from your research it would be suggested that you take out a patent. There was a lively start-up culture around both Stanford and Bell Labs and the importance of intellectual property was well understood by everybody."

It was at Bell Labs where Keller first developed and patented what became the SESAM technology.

"It was called something much more complicated then," she recalls. "I learned a bit later on that when you make an invention it's very important to think up a good acronym for it."

Chain reaction

SESAM is an adaptation of an essential part of lasers. Laser technology depends on a crystal which has the correct optical properties to amplify light as it propagates through the transparent medium; in simple terms, electrons are boosted to high energy levels and, as they fall back to lower energy states, they trigger a chain reaction where they cause electrons in neighbouring atoms to also drop through energy levels.

Mirrors at either end of the crystal bounce a light pulse backwards and forwards, promoting electrons through energy levels and causing more cascades as the energy builds up with each pass. A mirror at one end is only partially silvered, allowing some of the light to escape in a beam.

Keller's innovation was to replace this partially silvered mirror with a semiconductor film that acted as a mirror but only up to a point. Once this point, known as saturation, is reached the semiconductor becomes completely transparent for a very brief period, allowing a short pulse of 5 per cent of the energy contained within the crystal to escape. This destroys the saturation and the film becomes reflective again; then the cycle repeats. This produces the characteristic short pulses, with the precise composition of the semiconductor determining the saturation level and hence the length of the pulse.

"Bell Labs made a lot of money from the patent in licensing it out to major industry and whatever they paid me as a salary they made back many times over, which I think is good, in fact," she says.

One major advantage of laser pulses produced using SESAM is they do not heat the material that they strike, but effectively 'push' material from the surface into a plasma in a process called 'cold ablation'. This makes a picosecond laser very effective for cancer surgery, for example – because they do not damage surrounding tissues by heating them – and also for machining very small features in solid materials.

As there is no change in temperature, there is no change in composition or crystal structure surrounding the machined feature, which is very useful for semiconductors where both composition and crystal structure is vital to electronic properties.

> "Women know this group exists so they can see it's not necessary to be intimidated by the establishment"

The perfect CV

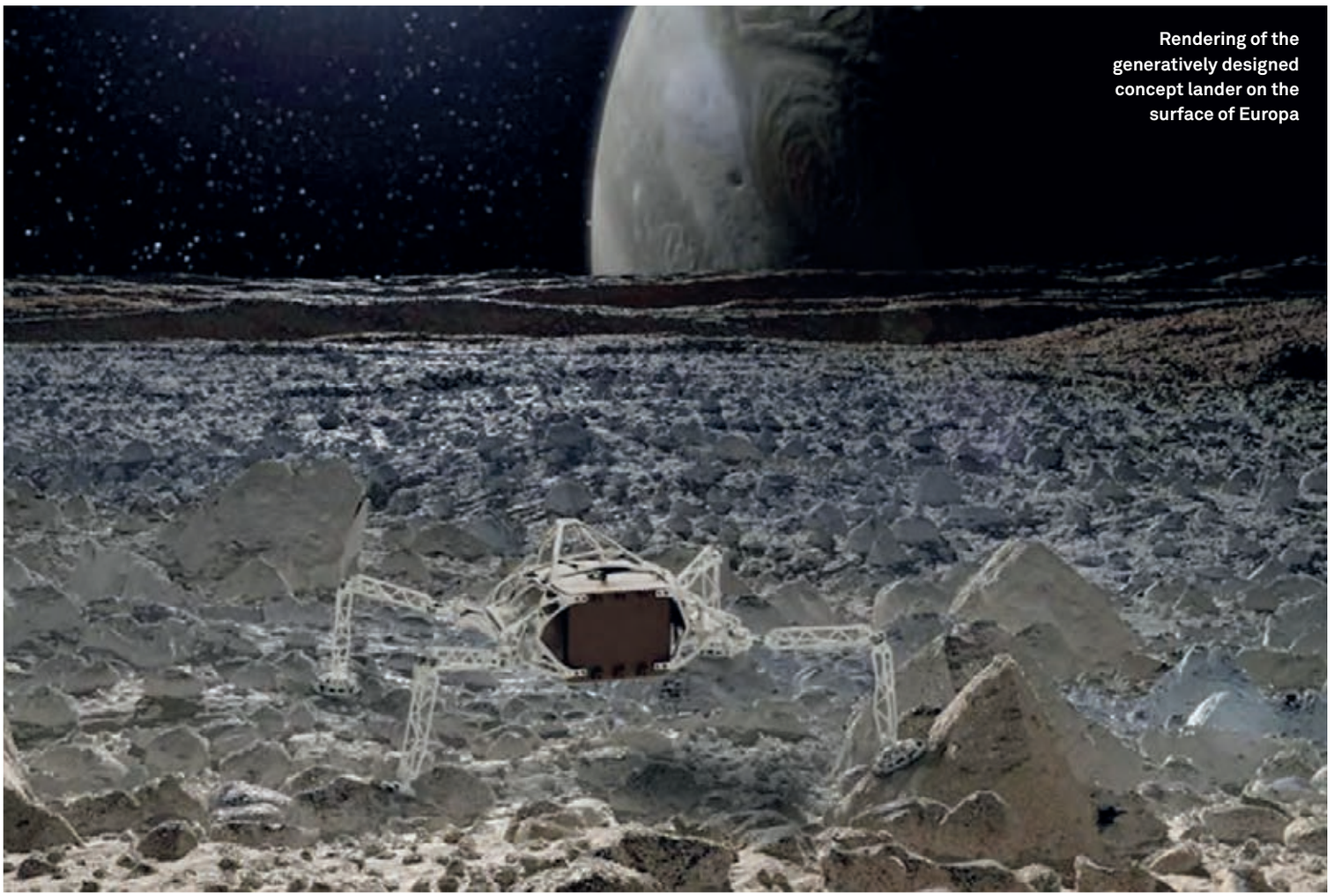
After four years at Bell Labs, Keller decided to return to academia and ETH. There was a drive to recruit more women in senior positions from the president of the university, and Keller was invited back to take up a professorship in physics to carry out research into new areas. "They remembered I had been top of my year and, by that time, I had the perfect CV."

Once back in Zürich, Keller was surprised to find there was no patent office. "The policy was, you need an industrial partner and will only take out a patent if industrial partner pays for it. There was no culture of starting spin out companies." Keller was instrumental in changing the situation and ETH set up a scheme where researchers who want to set up a company can use the university's facilities for two years.

Another innovation of Keller's at ETH was the establishment of the Women Professors' Forum. "We were fewer than 10 per cent women at the university and most of us didn't know each other. Very often there will be only one woman in a department and comparatively few female students, too. Often we would find the power structure in the departments, when it came to funding and appointments, was concentrated in established circles which is difficult to break into if you don't have allies. We had no clue what we could actually ask for."

The forum allows women at the university to build up networks and also creates a group of role models for female students. "It can be hard even to ask for advice but we now have this network where we meet three times a semester to talk about our work and we have people at different levels so someone can say 'can I see your grant proposal that was successful so I know what to put in mine?'. We can advise on how committee structures at the university work and women know this group exists so they can see it's not necessary to be intimidated by the establishment. There are several of us who have succeeded with each other's help." ■

The iteration



Rendering of the generatively designed concept lander on the surface of Europa

Bringing some of the key advantages of additive manufacturing to conventional manufacturing, generative design has the promise of optimised properties and striking shapes, writes Stuart Nathan

Las Vegas is a fitting place to present visions of the future. The whole city has an air of the unlikely, spotted as it is with oases of luxury and randomness plonked in the middle of the arid Nevada desert. When you have seen a rollercoaster teetering precariously on the edge of a skyscraper roof, or a facsimile of St Mark's Square in Venice that appears so close to the original until you look closer and realise that the Basilica is missing, the Doge's Palace is the wrong shape and the clouds in the sky never move, you may be more likely to believe anything you see on the exhibition floor.

It is therefore a favourite location for technology exhibitions and conferences and in November last year it hosted the annual Autodesk University event, showcasing the latest innovations from the manufacturing technology and software company.

In such an environment, the natural response to what appears to be a giant silver spider squatting on an exhibition stand is not "I must be seeing things" but "I wonder how that interesting thing got there".

Most engineers are now familiar with the characteristic look of objects produced using additive manufacturing (AM) or 3D printing. They tend to look organic and skeletal, with the rectilinear shafts and angles of conventional machined items replaced by sweeping curves, tapering columns and wasp-waisted members, thanks to geometry optimisation design programmes that analyse the patterns of mechanical stress through a component and ensure that material is built up only where it needs to withstand the forces that will be placed on them.

Although the cost of AM is falling fast it is still beyond the reach of many, if not most, companies in the manufacturing sector. Others are unwilling to completely redesign their processes to accommodate

generation

the new technology while, for some – notably aerospace – the certification of material properties remains an issue.

However, as manufacturing technology and software specialist Autodesk revealed in Las Vegas, conventional manufacturing and machining can still deliver some of the advantages associated with the newer technique.

The key to this, the company presented, is a process it calls generative design. It is powered by a basic – almost fundamental – property of computerised design: the ability to iterate, taking a design which is approximately close to what might be needed to fulfil a function and repeating the calculations that produced it over and over again to refine that design, bringing it closer to an "ideal" form with each iteration.

In this way, explained chief executive Andrew Anagnost, it is analogous to the process of evolution as explained by the theory of natural selection, where each subsequent generation makes species more advantageously adapted to their environmental niches.

"We believe that generative design will become an increasingly important part of engineers' toolbox," Anagnost told journalists.

"It fits in ideally with the digital workflow, from design through to manufacture, that we are seeing take hold across automotive, aerospace, construction and many of the other industries in which we are involved."

The basic algorithms driving this kind of design are the same as those used in geometry optimisation for AM, placing material at the points in a structure where they need to withstand the greatest forces. However, generative design works by regarding this as merely a constraint on the form of the final component.

The capabilities of the machine that is to make an item are regarded as additional constraints. The design system takes into account where tools such as grinding heads will not reach. The software then iterates through its constraints, both those of stress distribution and of machining capability, refining the design with each set of calculations and eventually arriving at an optimised shape.

Although this form may be made by five-axis machining, casting, CNC bending or whichever forming and shaping method the manufacturer chooses, the items tend to resemble the bird-bone-like forms of AM components.

Which brings us back to that silver spider. Its four legs are composed of curvaceous ladder-like sections, hinged at the 'knee' and 'ankle' and terminating in organic-looking pads. Where the thorax of the spider should be, a boxy construction with walls resembling sections of skull sits suspended.

This is a conceptual lander for missions to explore the rocky and icy moons of the solar system's gas giant planets, manufactured by NASA's Jet Propulsion Laboratory (JPL) in Pasadena in partnership with Autodesk using generative design principles as part of a digital workflow to power conventional metal shaping equipment. JPL's first foray into generative design, the lander was a third lighter than conventionally-formed landers without sacrificing any performance in mechanical terms and would not require any compromise in the functionality of its payload.

01 The concept lander on display at the 2018 Autodesk University event in Las Vegas

02 JPL engineer goes to work on the lander body structure

03 The bodywork was produced through casting, while CNC cutting was used for the leg assemblies

Payload mass is always a vital consideration in space exploration missions; every extra gram makes it more difficult to launch a payload out of Earth's gravity and to catapult it beyond the inner planets of the solar system. Every gram saved on lander structural elements can be used for sensors and other scientific instruments.

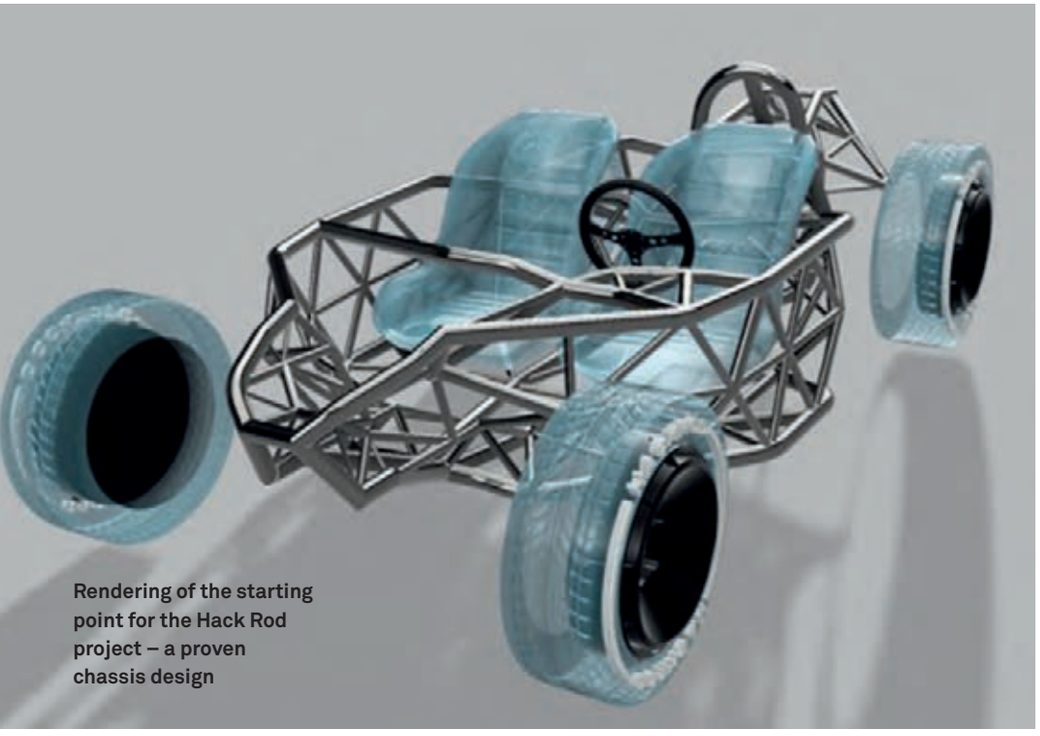
With their complex atmospheres rich in organic chemicals, and surfaces covered with water oceans, the moons of the solar system's gas giants Jupiter and Saturn are fascinating environments believed to be similar to those of early Earth. Planetary scientists are very keen to explore them for signs of the precursors of life. But getting there will require significant advances in design of landers, so JPL teamed up with Autodesk to investigate whether its technology could be of help.

Unfortunately, since the beginning of the joint project, budgetary constraints and changing priorities have led to the shelving of the missions to land on these moons but it remains a future goal for NASA. The demands of such a mission are extreme: Jupiter is 385 million miles away from Earth and Saturn 381 million miles beyond that. The temperature on the surface of their moons is typically hundreds of degrees below zero and radiation levels are thousands of times greater than those on Earth

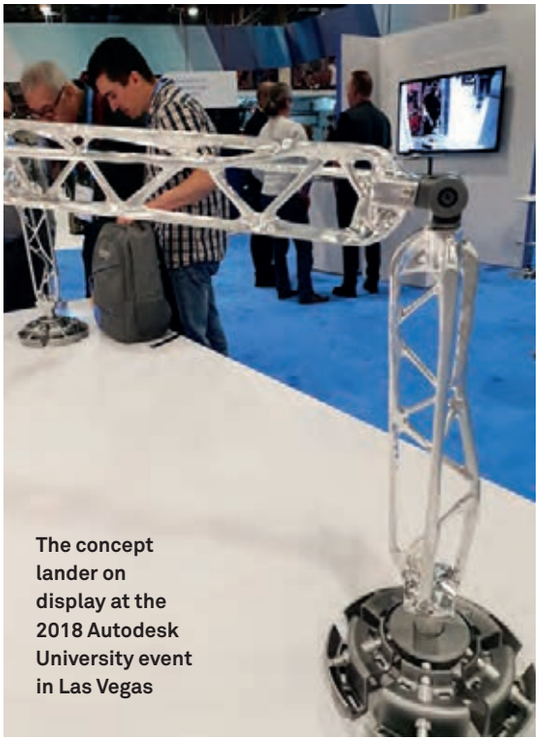
Made using a combination of CNC machining, AM and casting (used for the central body section, the only sign of which is its matt-finished surface compared with the highly-polished machined leg elements), the concept lander is believed to be the most complex item ever made using generative design. At 2.5 metres across and a metre tall, it's certainly one of the biggest. Autodesk approached JPL to pitch the project, and found it to be a demanding potential partner.

"They were clear that they weren't interested in incremental gains: if they were only able to improve performance by 10 per cent, they basically weren't interested," said Mark Davies, senior director of industry research and one of the team which first approached JPL.

"If we could deliver software tools to help them achieve a performance improvement of 30 per cent or more, then we had their attention. This project demonstrates that Autodesk technologies may deliver mass savings at this level."



Rendering of the starting point for the Hack Rod project – a proven chassis design



The concept lander on display at the 2018 Autodesk University event in Las Vegas

Exploring new technologies is second nature for JPL. "What they do is carefully infuse new technology into their processes," said Karl Willis, Autodesk's technology lead on the project. "They know they have to explore new ways to do things while keeping risk at a minimum."

In the Lander project, JPL took advantage of previous Autodesk's experience with other sectors that demand high performance. "We had developed a custom version of our software for high performance motorsports that enabled us to help our customers solve for multiple constraints at once. We then applied it to the problems JPL needed to consider," Davis said. "We took a system developed to help our customer solve system level suspension problems on a Formula 1 race car and applied new requirements for structural constraints critical to space exploration. This gave us a chance to push the capabilities of the software even further and help our customers solve larger and more sophisticated problems."

Closer to earth, generative design has also been used in the automotive sector, allied to some of the techniques which come under the Internet of things (IoT)/ industry 4.0 banner. Custom car builder Hack Rod – founded by Felix Holst, former creative vice president for a toy manufacturer, and Mike "Mouse" McCoy, a film director and former motorbike racer, is no stranger to using advanced technologies and new ideas in projects. Holst and McCoy decided to work with Autodesk to see whether its design techniques could be used to create visually striking new cars with high-performance properties.

The first stage was to optimise one of its existing designs. The Hack Rod team, working with Autodesk research fellow Mickey McManus, made a 3D scan of an existing chassis with a proven design and uploaded it to the cloud. They then wired the chassis with dozens of wireless sensors and gave it to a stunt driver to take it on a joyride around the Mojave Desert, observed by a drone which captured a 3D model of the driving landscape. This resulted in an enormous dataset on the car's structure and all the forces acting upon it.

> "The power of generative design running with cloud processing outstrips anything a team of human minds can come up with"
>
> Felix Holst, Hack Rod

This information was then sent to Autodesk's cloud-based CAD system. Known as Project Dreamcatcher, the system incorporates the user's design objectives, the project's material types and available manufacturing methods, and the required performance criteria and cost restrictions. Dreamcatcher is a generative design system that iterates around the defined constraints and presents the user with a series of design alternatives.

"The power of generative design running together with cloud processing outstrips anything a team of human minds can come up with," said Holst. As with many generative design projects, the resulting structure looks skeletal; but not like any skeleton evolved on Earth.

The team put together the chassis from chromium-molybdenum steel using conventional welding techniques and the resulting structure measures 3.6m x 2.1m x 1.2m and weighs 136kg. The skin that surrounds the chassis was also designed digitally. The full results from the project, however, are not yet available. McManus, McCoy and Holst continue to refine their design through additional runs in the Mojave, generating more data for Dreamcatcher to refine the car.

Despite the ever-evolving nature of this project, the team believe it could form the basis of a new philosophy for vehicle manufacturing, using the IoT capabilities of networked sensors with cloud-based solutions to refine designs and eventually drive manufacturing. ■

04 The chassis clothed in its digitally designed bodywork

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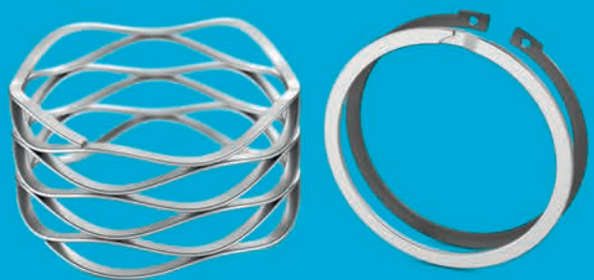

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Surveying from space

Satellite radar can now monitor how tunnelling is impacting buildings above. Andrew Wade reports

The subterranean world beneath London is some of the most heavily tunnelled of any major city. From Bazalgette's sewer system to the ever-evolving Tube network, the UK's capital has for centuries plumbed its depths to provide all manner of utilities for the populace. With recent projects such as Crossrail and the Thames Tideway Tunnel adding yet more complexity underground, the need to assess the impact of tunnelling on surface structures has never been greater.

At the University of Bath, Dr Giorgia Giardina has been employing a new technique that uses satellite imagery to monitor surface building deformation, verifying the method by way of the Crossrail tunnels.

Combined with traditional monitoring techniques, it's a breakthrough that could provide engineers with a more accurate and comprehensive tool for assessing the impact of subterranean construction. The technology – known as InSAR (Interferometric synthetic aperture radar) – has evolved over the past decade with the launch of X-band satellite constellations such as the Italian Space Agency's COSMO-SkyMed.

"Civilian X-band satellites are characterised by improved spatial resolution together with a reduced revisit time, varying from a couple of weeks down to a few days," said Dr Giardina, lead researcher on the project and lecturer at Bath's department of architecture and civil engineering.

"The high-resolution of the COSMO-SkyMed X-band SAR data results in an improvement of 320 per cent and 550 per cent with respect to (the longer-serving) RADARSAT-1 and ENVISAT data C-band satellites. The X-band wavelength also enables unprecedented accuracy of the order of millimetres in the InSAR monitoring of ground and structural deformations in urban areas.

"Second-generation satellites were expected to provide more accurate data and a short-term monitoring of natural and man-induced hazards, like earthquakes, landslides and glacier movements. What was not clear until the actual processing of ground deformation data in urban areas was the full extent of the X-band satellite potential for structural engineering applications and in particular in integration with damage assessment tools. We are filling the gaps between two branches of electrical and structural engineering previously unexplored."

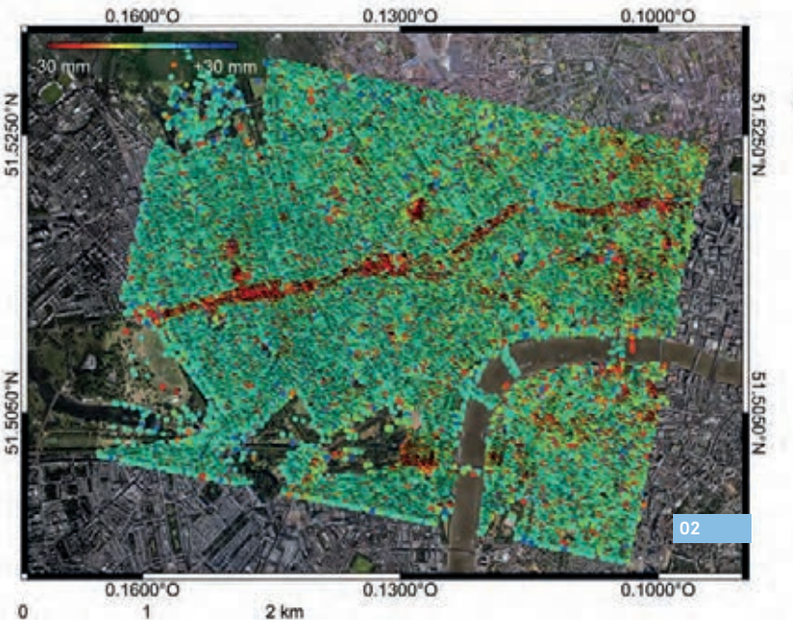
Anyone working in central London during the Crossrail tunnelling will likely have seen teams of engineers using geodetic prisms and manual levelling points to monitor building displacement. In Soho and other areas particularly vulnerable to damage, total stations were deployed that can monitor up to 100 levelling prisms on surrounding buildings, providing constant observation while the tunnel boring machines carved their way under the city.

However, for the majority of buildings above large-scale tunnelling projects, only a few points can be monitored constantly. Integrating InSAR with ground-based levelling allows virtually every point on every building to be observed, providing much more insight than just using traditional techniques on their own.

"During the Crossrail project, several commercial companies provided satellite-based monitoring, comparing them to ground-based data to prove the high quality of satellite measurements," Dr Giardina told *The Engineer*. "In our study, an initial comparison with ground-based data was only used as a validation of the InSAR measurements.

"InSAR data was then integrated to structural assessment procedures to prove the higher spatial resolution of satellite measurements with respect to the ground-based measurements, which were typically available for the buildings located along the Crossrail route, and also the additional insight – enabled by the use of InSAR data – on soil structure interaction mechanisms.

TBM Victoria breaks through into Liverpool Street station



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01 Dr Giorgia Giardina

02 An InSAR map shows deformation caused by Crossrail tunnelling

In both, ground-based measurements would not have been sufficient to obtain the same results."

To assess the expected impact of ground movements on existing structures, an estimate of the shape and magnitude of these movements must first be made. This requires information on the source of ground movement, such as whether it was caused by underground construction or a landslide. The features of the source must also be considered. With tunnelling, for example, one needs to know whether cut-and-cover or bored tunnels were used. Lastly, the soil type plays a key role, as anyone who has dug through London's mix of clay, chalk and alluvium can attest.

The shape and magnitude of the deformations affecting a building are also influenced by the characteristics of the building itself, including its dimensions, weight and stiffness. This soil-structure effect is typically not accounted for in damage prediction, potentially leading to an inaccurate damage assessment. Using InSAR, Dr Giardina and her team were able to accurately determine how buildings and soil were interacting with each other.

In terms of out and out precision, the sub-millimetre accuracy of InSAR compares quite favourably to 3D prism technology, though is not quite in the same league as precise levelling techniques that can measure changes of fractions of millimetres. Current satellite revisit times mean that InSAR cannot provide real-time monitoring, though future constellation expansions could go some way to addressing that.

Nonetheless, the radar technique can provide high resolution imagery day and night, independent of weather conditions. Another advantage is the fact that it is not susceptible to some of the more bizarre – though not necessarily infrequent – earth-based interference, such as vandalism and fouling from pigeons. Interestingly, the InSAR technique can also be retrospectively applied using older satellite data, allowing structural engineers to evaluate the response of buildings which were not part of an original monitoring plan.

"The high spatial resolution and accuracy of InSAR monitoring makes it already comparable to ground-based techniques, with the advantage of reduced costs, large area mapping and retrospective application," Dr Giardina explained.

"The current satellite revisit time of a few days only allows near real-time monitoring, while ground-based techniques can provide real-time measurements. Future satellite constellations are expected to fill this gap between InSAR and ground-based monitoring by shortening the revisit time even further, potentially offering a substitute for ground-based techniques."

Although the use of satellites for structural monitoring is in its early days, the Bath team is hopeful that its research and the success of the Crossrail project could help give the technology wider recognition across the industry.

Longer term, Dr Giardina hopes to develop a type of early warning system that could be deployed over large urban areas, where huge amounts of InSAR data could alert engineers to problems much more rapidly. This would require some level of automation whereby relevant measurements were filtered from the millions of data points collected.

"Thanks to their higher resolution and reduced revisit time, second-generation satellites, like the X-band satellites used in this study, can provide millions of monitoring points for a single city," said Dr Giardina.

"This huge amount of data is a limiting factor to its effective use. An automatic tool able to detect the most significant measurements would reduce the number of points to be analysed from millions to thousands, allowing data analysts to focus only on the most relevant areas." ■

Decarbonising heat becomes a hot topic

District networks that use locally available waste heat could be key to delivering on the UK's low-carbon energy commitments

Will Stirling reports

Engineers in the energy distribution and heating industry are working on a daunting but exciting challenge that recently received a government boost.

About half of all energy consumed is used to generate heat and hot water and, to achieve government carbon targets to comply with the UK's Paris Agreement obligations, the carbon intensity of this energy needs to be reduced by 90 per cent by 2050. As a vast amount of waste heat produced by sources like processing plants, data centres and even sewage is going up the chimney, literally, it is little surprise that the UK's energy and heat policy is now focused on capturing this heat to distribute it to consumers, cutting CO_2 emissions and lowering the amount of energy required to heat water.

> "We are wasting heat that is going up the chimney"
>
> Eoghan Maguire, Vattenfall

Engineers and heat experts are looking to Europe to adopt a system that redesigns heating and energy into a smart, decarbonised, integrated system – heat networks.

Traditional heating systems like gas boilers tend to be binary – either fully on or off, requiring high energy inputs to raise the temperature of water from the ambient temperature to be useful for heating buildings, say to 40°C. A heat network, drawing heat from waste sources, is designed to supply water at a higher temperature than the environmental temperature (that might be 10°C or lower), thereby lowering the energy needed to heat it up.

Other appealing features of a heat network are that a well-designed system can be used for both heating and cooling. It also sources what is locally available, minimising the expensive transportation of heat, as well as using untapped sources such as a processing plant, data centre or ground source.

"Britain has been very good at decarbonising electricity but decarbonising heat on a mass scale has been left in the too-difficult-to-handle box," said Dr Eoghan Maguire, head of business development at Vattenfall Heat UK. "But it is now addressing heating and is starting to address transport and connecting the system better through sector coupling."

Vattenfall Heat has 2.2 million customers in Europe. It is helping to transform Amsterdam's heat and energy demand into a smart grid involving recharging points for electric vehicles. It is now bringing its heat network expertise to Britain, establishing Vattenfall Heat UK in March.

Now the government has come on board. In October 2018, the Department for Business, Energy and Industrial Strategy (BEIS) launched the latest stage of a £320m programme to encourage the mass rollout of heat networks. Heat network developers are being offered grants of £5m and loans of up to £10m as part of the Heat Networks Investment Project, or HNIP. The government is hoping to unlock around £1bn of investment using the seed funding.

When HNIP was first launched in October 2016, the government stated that the full programme would aim to draw in £2bn of public and private sector investment. A BEIS spokesperson said it will assess first-round applications in spring 2019. The first funding awards are anticipated in the early 2019/20 financial year.

Overseas inspiration

For engineers, the scale of the task of meeting carbon reduction targets by 2050 appears more achievable when the potential for district heat networks in Britain is taken into consideration. The example of some European countries, especially Germany and the Nordics, is notable. In Berlin for example, 30 per cent of the city's demand for hot water and heating is met by the district heat network that is owned and operated by Vattenfall, with suppliers including E.ON providing even more of the city's heat network. That proportion is constantly growing in line with the network's expansion, currently running at the equivalent of 22,500 households per annum for Vattenfall alone.

"We believe heat networks have a huge part to play in contributing to carbon reduction both in the UK and globally – currently supplying around two per cent of UK heating demand but with the potential to supply up to 18 per

01 Vattenfall's district heating facility in Uppsala, Sweden

02 E.ON operates more than 60 district heat networks in the UK

cent by 2050," said John Armstrong, head of operations, UK district heating at E.ON, which also has a big footprint in Europe and operates more than 60 district heat networks in the UK.

That includes the Cranbrook district heat network in Devon, which is geographically its largest and is expected to lower CO_2 emissions by 13,000 tonnes per year once all of its properties are finished and occupied.

Cities hold the key

While Cranbrook is a town using a 'community energy centre' as the heat source, big cities are at the heart of the heat network proposition. As populations in big urban environments expand, this puts pressure on heating infrastructure and carbon emissions. "In particular, heat networks are essential to providing energy in cities, which consume two thirds of the world's energy and contribute 70 per cent of the world's CO_2 emissions," said Armstrong.

"By 2050, 66 per cent of the world's population are expected to live in cities – an additional 2.5 billion urban residents – so we see heat networks as a major part of the solution."

Vattenfall's Maguire said studies show overall demand for heat in London is 66 TWh (terawatt hours) per year. "A recent study done for the Greater London Authority shows the total heat delivered from secondary sources in London was 71 TWh," he said, showing that super-efficient heat capture could theoretically make heating London virtually fossil fuel resource neutral. "We are currently wasting heat that is going up the chimney and is literally producing global warming. This cannot continue."

An important feature of a heat network is it uses its environment in the best way to capture and distribute heat. Heat networks are designed in two principal ways.

One is a centralised system with a large single source of heat coupled to a heat pump – more of a giant heat exchanger – that adjusts the temperature of the original heat to a useful level, and the decentralised system that uses multiple, smaller boilers in buildings – an integrated network of mini units.

"Where we see there is a large, readily available waste heat source, it is viable to adjust the temperature and transport this heat in pipes but you don't want to transport it too far away to remain an efficient system," said Sandra Slihte, lead engineer at Vattenfall Heat UK. "Where there is no readily available waste heat source, the conduit is copper wire [rather than pipes] in a network of local heat pumps in buildings to create a system. There will be a combination of both these systems in the UK on a case-by-base basis."

One feature of heat networks being pursued by the utilities in the UK is a low-temperature network. Such networks allow you to use lower-grade heat – for example, the heat rejected from refrigeration or air conditioning.

E.ON has experience operating heat networks in both Europe and the UK and is looking to develop technology through next-generation low-temperature networks such as E.ON's Ectogrid, which delivers higher efficiency through decentralising energy generation, enabling buildings to both push and pull energy into and out of the network.

"If you use a lower-temperature network you can then use that heat again so you can almost recycle the heating and reuse it several times as it passes through the urban environment," said Armstrong.

The rise of heat networks should be good news for manufacturers. Today, much of the physical infrastructure for energy centres and connecting plants to the network are imported from big district heat network markets like Germany. More district heat networks in Britain will create a bigger market for pipes, valves, pumps, heat exchange kit and control systems.

Applications for the main £320m HNIP programme opened on 4 February. A BEIS spokesperson said: "The Heat Networks Investment Project has created a route to market for innovative energy projects across the country and demonstrates a key objective of the Clean Growth Strategy: to deliver technologies that lower bills, cut carbon and improve the quality of life for communities across the country." ■

Honda CR-V: Is this the hybrid game-changer?

Hybrid cars have always held great promise but they've often been a niche choice. The new Honda CR-V may be the model that brings this technology to the mainstream, writes Chris Pickering

The Honda CR-V responds crisply to driver's inputs

It's been said that 2019 will go down as the year of the hybrid. While the concept of hybridisation has been around for more than two decades, it's only relatively recently that this technology has truly begun to make an impact on the mainstream car market. And you won't find a much more mainstream model than the Honda CR-V. Underneath the skin of this new Hybrid version, however, there's an innovative drivetrain that's packed with interesting technology.

Conceptually, you could almost say that the CR-V Hybrid's powertrain is closer to that of a diesel electric locomotive than that found in a traditional passenger car. For much of the time it runs as a series hybrid, with the 2-litre Atkinson cycle petrol driving a generator, which in turn supplies power to a propulsion motor connected to the front wheels. Any excess power is used to top up a compact lithium ion battery pack located underneath the boot. At high loads, an automatic clutch kicks in to connect the engine to the front wheels via a single-speed transmission. The rest of the time, however, there is no physical connection between the engine and the wheels.

When there's sufficient charge, the combustion engine can shut down altogether, allowing the CR-V Hybrid to waft along on electricity alone. The battery's modest capacity is enough to give the Honda an electric-only range of around 1.2 miles, which might not sound like much but is bang on the money for a conventional 'full hybrid' (as opposed to a car with a plug-in option).

Compact and refined

The functionality offered by Honda's clever transmission design is not dissimilar to the eCVT setup found on cars like the Toyota Prius – it still basically provides a three-way connection between the engine, the generator and the wheels. However, because it uses a fixed-ratio transmission in place of the usual planetary gear setup, Honda claims its solution is both more compact and more refined. It seems likely the mechanical losses could be lower too, although that's purely supposition on our part.

Both two-wheel and four-wheel drive variants are offered but the battery and motor set-up is identical between the two. Instead, the four-wheel drive system features a 'hang-on' unit, which uses a multi-plate clutch operated by an electric motor and a hydraulic pump to connect the propshaft to the transmission at the front.

When the four-wheel drive capability is not required – such as during high-speed cruising – the propshaft is decoupled to reduce losses. The weight difference between the two variants is a modest 58kg, with the lightest two-wheel drive version tipping the scales at 1,614kg. That's only around 100kg more than the equivalent petrol-only model.

Even by electric vehicle standards the initial pullaway is impressively smooth, allowing you to glide away with the sort of finesse that only the very

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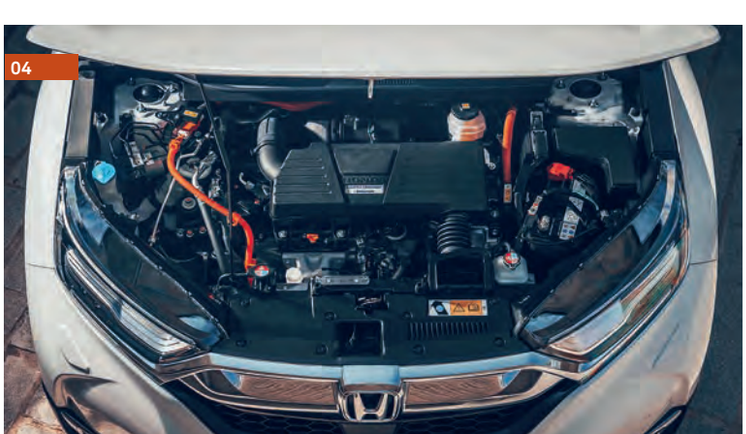

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01 The CR-V pullaway is impressively smooth

02 The drivetrain is quiet, with just a slight whine

03 The stereo enhances engine noise frequencies

04 The set-up under the CR-V's bonnet

best conventional cars can match. It's quiet too, with just the faintest whine from the 135kW electric motor. Progress is fairly sedate if you stick to electric power alone but the CR-V has never really been about performance.

That said, the Hybrid is actually the quickest model in the current CR-V range and, with the petrol engine on song, the two-wheel drive version will dispatch the 0-62 mph sprint in a pretty respectable 8.8 seconds. It handles neatly too, although you can sense the extra mass compared to the standard model.

What strikes you first of all is just how often the CR-V Hybrid seems to get by without calling upon its combustion engine. Despite the absence of a plug-in option it genuinely does feel more like an electric drivetrain assisted by a combustion engine rather than the other way around. And when the 2-litre inline four does wake up it's a relatively seamless transition.

Honda has worked hard to make the CR-V Hybrid feel linear and responsive. There's none of the 'rubber band' sensation that you can sometimes get with CVT-type transmissions. Instead, the hybrid drivetrain responds crisply to your inputs. It also sounds refreshingly conventional, thanks in part to Honda's Active Sound Control (ASC) system, which uses the stereo to boost certain frequencies in the engine noise. The idea is to create a more natural, proportional link between the engine speed and the rate of acceleration.

On a similar note, all CR-V models now come with Honda's Active Noise Cancellation (ANC) system. This uses a pair of microphones placed in the cabin to pick up low-frequency engine noise, which it then cancels out with signals played in antiphase on the stereo. As with the Active Sound Control system, this works whenever the car is running, regardless of whether the audio system is on or off. What's more, there are no tell-tale signs to betray the presence of either system – you don't get the slight hiss that's sometimes detectable with noise cancellation systems, nor the rather synthetic sound that sometimes comes with stereo enhancement.

The rest of the package is equally refined too, aided by a stiffer body shell than the old CR-V, which improves its NVH characteristics. In total, torsional rigidity is up by 25 per cent, thanks to increased use of high-strength steel, the introduction of a new hot-stamp ultra-high strength steel material in other areas and improved joining techniques. Unlike the old car, here the inner frame is assembled first, followed by the outer frame and finally the joints. A short-pitch welding places spot welds 20mm apart in critical areas of the monocoque (compared to traditional spacing of up to 45mm).

Of course, the big question with any hybrid is whether or not the efficiency benefits are worth the additional outlay. Our four-wheel drive test car recorded 49mpg in real world use, impressively close to its official combined figure of 51.4mpg (with 53.3mpg claimed for the two-wheel drive version). That's not a transformative difference compared to the regular petrol version at 39.8mpg but it does represent a worthwhile improvement.

At £29,105 the entry-level Hybrid is a little over £3,100 more than the equivalent petrol-only model. You'd have to cover a lot of miles to recoup that in fuel savings alone but throw in higher residual values and preferential first-year road tax rates and it's certainly possible that you could break even.

Factor in the Hybrid's far superior refinement, its increased performance and the fact that you effectively get an automatic gearbox as standard (which adds upwards of £1,500 to the price of the standard car) and suddenly it starts to make a lot of sense.

In fact, as far as the CR-V is concerned, it looks like we have genuinely reached the point where the hybrid is now the better all-round proposition. ■

SICK technology improves automated guided vehicle navigation

SICK's NAV-LOC localisation sets AGVs free from reflectors Supplier: SICK

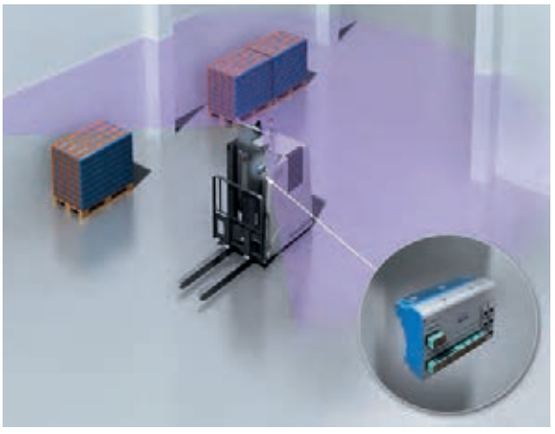
LiDAR-based scanning technology developed by SICK can improve the performance of automated guided vehicles (AGVs), the company claims.

The firm's NAV-LOC localisation solution dispenses with the need for reflectors or other physical markers and is said to enable AGVs to find their way around shop-floor and warehouse environments more reliably and efficiently.

The technology is based on a SICK NAV 360o LiDAR scanner that can be integrated into new or existing AGVs.

By recognising the pre-mapped contours of a factory or warehouse interior, the system eliminates the need for time-consuming and costly installation of reflectors, special paints, tracks, magnetic strips or coloured tapes.

The system uses precise 2D data from the SICK NAV310 LiDAR scanner to match its position to a reference map stored on a SICK SIM2000 Sensor Integration Machine, which is also mounted on the AGV. As the data is processed, a SICK algorithm continually compares the distances retrieved from the scan data with the reference map to provide position and orientation information to the AGV controller.



SICK's scanning technology for AGVs

Setting up the NAV-LOC system begins by simply 'teaching' the on-board SICK LiDAR scanner prominent contour features, such as walls, large static machinery and racking or bays, as the AGV is driven manually around its working environment. This data is used by SICK Service to create a precise reference map on behalf of the customer or machine builder, before being uploaded on the SIM2000, and easily commissioned on-site using SICK's SOPAS engineering tool. Unlike conventional systems, the SICK NAV-LOC does not require numerous reflectors to be positioned in groups of threes along a route to enable a laser scanner to triangulate its position. Tracks or magnetic strips installed in the floor or adhered to fittings, or special coloured or reflective lines, are also redundant.

There is no risk of reflectors or paint being dirtied or obscured and there is no routine maintenance or route inspection needed to minimise possible AGV disruption.

"The introduction of the SICK NAV-LOC is an important step forward in the availability of contour-based localisation systems that promise more flexibility, lower cost of installation and maintenance for automated transport, stacking and loading processes using AGVs," said Neil Sandhu, SICK's UK product manager for imaging, measurement and ranging. ■

World's smallest draw-wire sensor is the most robust yet

MT19 is designed for applications requiring high dynamics, such as crash-test dummies Supplier: Micro-Epsilon

Precision sensor manufacturer Micro-Epsilon has launched the wireSENSOR MT series of miniature draw-wire sensors (cable transducers) for displacement, movement and position measurements. The sensors stand out due to their ultra-compact design relative to their measuring ranges (from 40mm up to 130mm).

Three miniature MT versions are available, which can be integrated into extremely tight spaces. The sensors are protected by a robust aluminium housing, enabling their use in a wide range of industrial applications. Two through-holes in the housing, as well as an integrated ring eyelet at the end of the cable, allow fast, easy mounting of the sensor.

Micro-Epsilon's miniature sensor

Weighing just 8g and with dimensions of 19 x 19mm, the wireSENSOR MT19 is the most compact version and is currently the smallest draw-wire sensor in the world. With a measuring range of 40mm and a possible cable acceleration of up to 60g, the MT19 is particularly suitable for applications that require high dynamics, such as crash-test dummies, simulators and other impact test rigs.

Two further versions are available in the MT series: the wireSENSOR MT33 with a measuring range of 80mm and the wireSENSOR MT56 with a measuring range of 130mm.

MT sensors are equipped with a potentiometer and a stainless steel measuring wire. Linearity is +/- 0.4 per cent FSO. The sensors offer a typical service life of one million cycles. Depending on the industry and application, draw-wire position sensors are commonly referred to as cable transducers, cable extension transducers, string potentiometers, yo yo pots, linear position string pots and string encoders. Using a draw-wire sensor, a linear movement is transformed into a rotary movement. The free end of the wire is fixed to the moving object.

An encoder or potentiometer translates the rotary movement created by the extension of the wire into an electronic signal. The sensor works like a tape measure, except with a draw-wire sensor the user does not have to read off the measurement of the extended tape. The rotation of the drum on which the steel wire is wound is measured automatically and the measurement signal output is in analogue or digital format. ■

Five great reasons to attend The Engineer's 2019 conference

Join us in June to tap into the latest trends and technologies

The speaker programme for *The Engineer*'s annual conference – which runs from 4-6 June at the NEC, Birmingham – is now almost complete and, as in previous years, the event looks set to provide delegates with an unrivalled opportunity to tap into industry-leading insights on the trends, technologies and opportunities that will impact UK engineering and manufacturing in the months and years ahead.

The full programme will be published shortly but, to give you a taster, here are five key reasons for joining us in Birmingham this June.

The conference is an opportunity to network and share ideas

1 Hear about the technologies that are reshaping manufacturing

When it comes to manufacturing technology, we are experiencing a period of profound change and the conference's ***advanced manufacturing*** stream will examine the implications, challenges, benefits and practicalities of Industry 4.0 technologies.

This year's content is particularly focused on what this change means for the smaller firms at the heart of the UK's manufacturing economy. Key presentations include insights from MTC chief technologist Dr Lina Huertas on the current state of digitalisation in the UK and – courtesy of her MTC colleague Hannah Edmonds – an in-depth look at the Factory in a Box, a fascinating, newly launched initiative aimed at bringing Industry 4.0 technologies to the masses.

Delegates will also hear in detail about many of Industry 4.0's component technologies: from collaborative robots (Steve Banton, ABB) to augmented reality and additive manufacturing. We are delighted to be welcoming two of the UK's bona-fide AM pioneers this year: Jeremy Pullin (head of AM and design to manufacture at Sartorius Stedim) and Professor Neil Hopkinson, the inventor of high-speed sintering.

2 Supply chain opportunities

From the growing and evolving demands of emerging sectors to an increasing desire across industry to shore up domestic supply chains, there is no shortage of opportunities for ambitious suppliers and sub-contractors. And this year's stream of ***supply chain*** focused content will help delegates learn more about where these opportunities are and how to access them. Of particular note are presentations from WMG's Simon Garwood, who will be talking about electric vehicle supply chain opportunities, and Martin Little, from BCRRE Rail Alliance, who will highlight opportunities in the UK's growing but often overlooked rail sector. We are also delighted to welcome Julia Moore, CEO of GTMA, who will be giving some high-level insight on efforts to grow and develop UK supply chains.

Discussion topics include cutting-edge technology

3 Stay informed on Brexit/economy

At the time of writing (26 March), Brexit had reached peak confusion and hopefully by June, there will be greater clarity on the economic conditions that UK businesses will operate in.

Nevertheless, whatever the result of the current parliamentary discussions, it seems inevitable that Brexit will continue to exert a huge influence over the manufacturing landscape for some considerable time.

One of this year's keynote speakers, Make UK CEO Stephen Phipson, will offer delegates some valuable insights on how Brexit (whatever form it eventually takes) will affect their businesses and the measures they can take to ensure they can remain competitive and productive.

4 Be inspired

Since its launch, *The Engineer* conference has made a point of celebrating some of the UK's most inspiring innovations and disruptive technologies. This year's event is no exception.

Key presenters here include Riona Armesmith, who is heading up Rolls-Royce's hybrid electric aircraft project; Mike Lawton, the CEO of one of the UK's most exciting space technology companies, Oxford Space Systems; and Nick Hawker, CEO of First Light Fusion, an exciting UK firm with genuine ambitions to make commercial-scale nuclear fusion a reality sooner rather than later.

5 Hear from the leaders

As always, the conference also provides a fantastic opportunity to hear from some of UK industry's biggest names about the trends that are driving change in their businesses and the wider engineering community, and how this will affect everyone in industry in the months and years ahead.

At this year's conference, we are particularly delighted to be hearing from BAE Systems technology director Dave Short and Brian Holliday, managing director for Siemens Digital Factory. ■

The Engineer conference is free to attend and runs from 4-6 June at the NEC Birmingham alongside Subcon, The Engineer Expo and the Advanced Manufacturing Show (AMS).
For more information visit: www.theengineer-expo.co.uk

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Cleaning up and mixing it with 24-hour innovation

Stuart Nathan **speaks to manufacturer SharkNinja about its approach to engineering**

The market for domestic appliances is crowded with many manufacturers ranging from (literally) household names like Hoover and Kenwood, to companies that operate in a number of markets, such as Bosch. While these are not often thought of as innovative engineering companies in the same way that automotive and aerospace manufacturers are, the amount of innovation that it takes to launch new products, often in a variety of sectors such as floor care (vacuum cleaners) and food preparation, is considerable, and SharkNinja, a relative newcomer to the sector, represents an interesting study in how such companies operate.

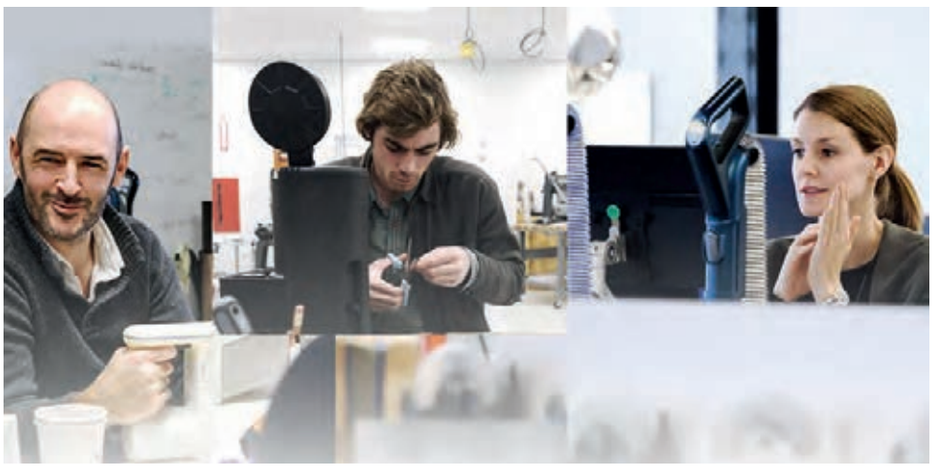
SharkNinja produces bagless vacuum cleaners, under Shark branding, and food preparation products, notably multifunction blenders and food processors, under Ninja branding. Originating in the US, the company operates technical centres in three locations: Boston, in Massachusetts, London and Shanghai, with manufacturing centred in East Asia.

Paul Bagwell, a design engineer who leads the UK operation, explained that the three locations help the company to operate a 24-hour development cycle. "Each office has an overlap with the others in terms of working time; Boston's working day overlaps London's by couple of hours, and London is closing up as Shanghai gets going. We can pass projects from team to team in the respective offices, and that works well for us; we don't need to open an office in an intermediate-time zone between London and Shanghai."

Choosing London as its European base was a matter of culture, languages and markets. "The business and technology culture in Boston is quite similar to that in the UK, possibly because it's quite common for people from the Boston universities to also study in Britain," Bagwell explained. "Also, especially in terms of food preparation, kitchen culture in Britain is more similar to that in America than the cultures in much of mainland Europe.

"Shanghai is a good base for us because it is such a big city for technology, it's close to our manufacturing bases, and we have important markets in Australia."

If SharkNinja is an unfamiliar name, it's because its marketing strategy is somewhat different from its competitors. Eschewing large and splashy advertising campaigns, it prefers to leverage and prioritise user experience. "We have a policy of targeting every product having four or five-star reviews on Amazon," Bagwell said. "We found the people are much more likely to buy on word-of-mouth recommendation than on the basis of advertising. Along with this, we utilise user panels when we test our new products, and will always take note of any negative remarks in reviews or in testing sessions."



SharkNinja team members get to work with their product innovation cycle

The policy is to launch an entirely new product, rather than a refinement to an existing line, every year, and Bagwell notes that the 24-hour innovation cycle allows the company to take a product from initial concept, through prototyping to full commercial launch in approximately six to nine months.

SharkNinja tends to outsource and specify many of its components. In contrast to Dyson, which invested heavily in developing its own 'digital motor' for its vacuums, the company believes that the component market can adequately supply its needs and its investment is better targeted at optimising the user experience. "Our motors may come from somebody else, and the blades for our blenders, but they are all made to our specifications," Bagwell said. "Everything that you see or touch is our own design, and that's our differentiation in the market."

Similarly, the plastic housings for the products are made by moulding subcontractors, but here the company's innovation approach is visible in London, with a workshop on the premises which combines old-school tabletop tinkering with the most up-to-date prototyping equipment: a variety of 3D printers are humming away during my visit. "We do go back to basics a lot; we will mock up housings in cardboard and use 3D printers to make solid models from our design software that we can then send through to our moulding subcontractors," Bagwell said. "We will also prototype components like gearboxes to test out how we might achieve different speeds and modes in our food-processing devices."

A test-kitchen with Ninja equipment allows staff to experiment with recipes: a couple of engineers were blending exotic smoothies during my visit. The workshop is a popular place for the London engineering team, Bagwell noted. "We all love using our hands and brains together, it's an integral part of being an engineer." ■

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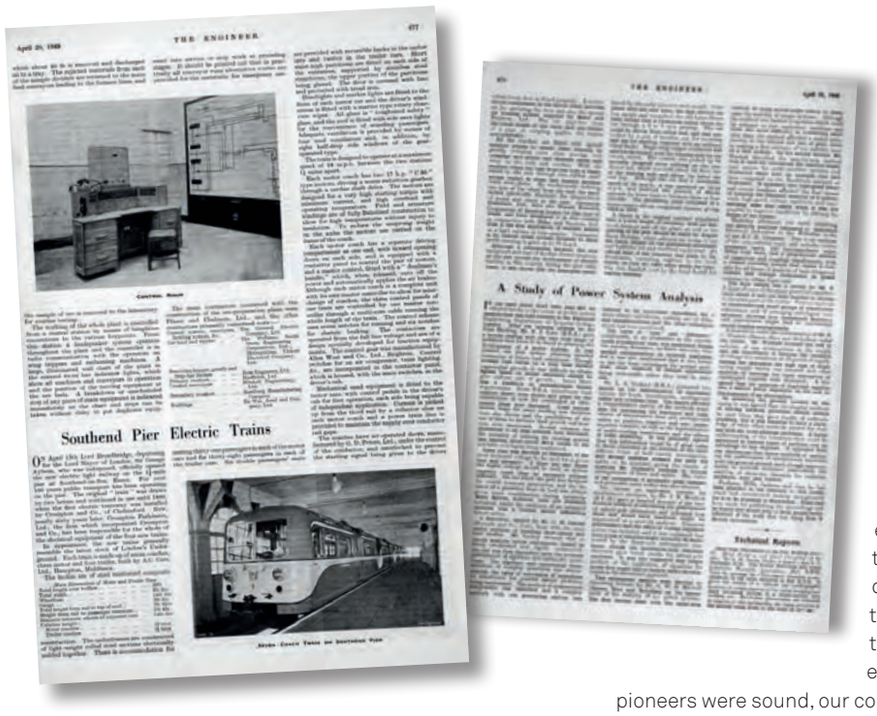
A peerless landmark

The Engineer takes you on an outing to the seaside

If a town can be defined by a single landmark then the jewel in Southend's crown must surely be its record-breaking pier.

While not the oldest – that honour goes to Ryde Pier, which was built in 1813 – it is the world's longest. The pleasure pier at Southend extends 1.34 miles into the Thames Estuary and looks likely to receive £18m in local authority funding for improvement work.

Included is £3.25m for new trains, which takes us back to April 1949 and the introduction of electric trains on to a pier which had provided public transport for its patrons for more than 100 years. This was not lost on our correspondent, who breezed through a description of the new vehicles before providing a potted history – and ringing endorsement – of their electric predecessors. As noted, the pier's original "train" was drawn by two horses and continued in use until 1890, when the first electric tramway was installed by Crompton and Co. of Chelmsford. The company was subsequently incorporated into Crompton Parkinson Ltd, which provided the electrical equipment for four new trains introduced in 1949.


Southend Pier Electric Trains

A Study of Power System Analysis

It is 1949 and Southend Pier is getting new electric trains

Resembling London Underground trains of the era, the new trains were made up of seven coaches – three motor (accommodating 31 passengers each) and four trailer (38 passengers each) – built by AC Cars Ltd.

"The train is designed to operate at a maximum speed of 18mph between the two stations 1.25 miles apart," noted *The Engineer*. "Each motor coach has two 17hp C 90-type motors, driving a worm reduction gearbox through a cardan shaft drive. The motors are designed for a very high starting torque with minimum current, and high overload and operating temperature.

"Field and armature windings are of fully bakelised construction to allow for high temperatures without injury to insulation. To reduce the unsprung weight on the axles the motors are carried on the frame of the coach."

Each motor coach, with a separate driving compartment at one end, was equipped with a contactor panel to control the pair of motors, and a master control, fitted with a "dead man's handle", which, when released, cut off the power and automatically applied the air brakes.

The light railway was the first in the country to incorporate a new type of wheel to ensure silent running "by greatly reducing noise when passing over crossings and points and decreasing stress and wear on the rails and coaches".

Our correspondent observed that, with the so-called 'resilient wheel', the load from the tyre was transferred to the axle through two rubber sandwiches loaded in shear and bonded between outer steel plates. By mechanically isolating the tyre of the wheel from the hub, the sandwiches "practically eliminate the transmission of sound and shock to the axle".

And while the pier's owners couldn't guarantee good weather, they did make sure patrons could be conveyed from one end of the pier to the other on windy days, thanks to the train's conical spiral spring suspension "designed to allow stable running in gales up to 70mph".

Although a comparison between the new equipment and that of the first electric tramway on the pier revealed the development of electric traction, it also showed that the principles established by the early pioneers were sound, our correspondent noted.

"Compared with the new train, the first electric car was simple and resembled the old horse-drawn tram except that a Crompton motor drove the car through a 3-to-1 spur gearing. The car could be driven from either end and was controlled by a pair of handles, one for reversing and one for starting, together with an ordinary wheel brake," *The Engineer* said. "Single-strip copper conductor was used for the supply, with the running rails for the return circuit.

"The current was picked up by specially designed shoes rubbing on the conductor rail, held about 1ft from one of the running rails and an inch below the rail top. Although the car had a maximum speed of 20mph it was operated at 12/14mph and reduced the journey of 15 minutes by horse tram to three or four minutes. The generating plant consisted of a steam engine-driven compound dynamo giving 150A at 200V."

The four trains carried passengers for 29 years before being retired in 1978 due to wear and tear of the track and the high cost of repairs. **JF**

Word of the issue

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

To be clear we're not talking about the amphibian, even if it's taken from the name of the amphibian and is related at some point in ancient times.

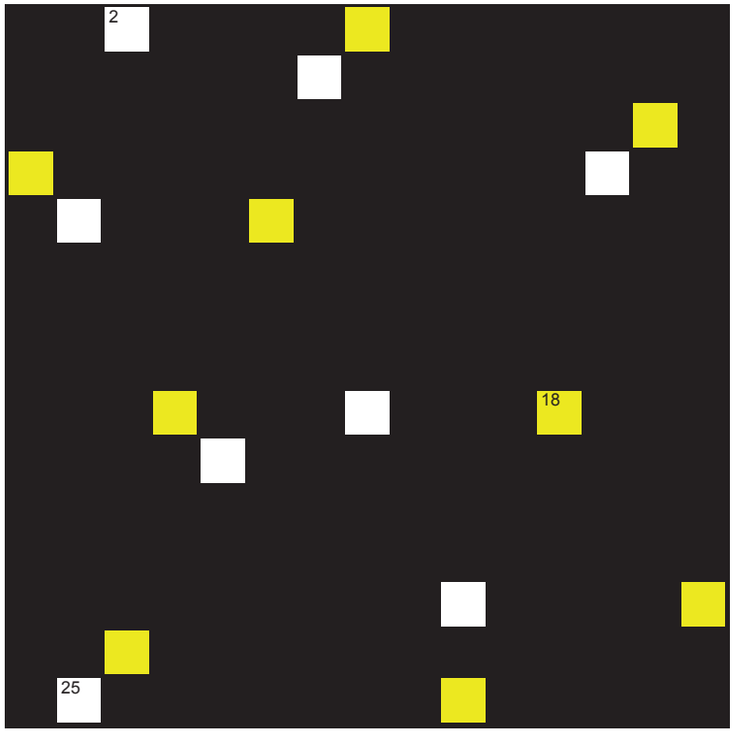
Frog is a Germanic word found with a variety of differences in that group of languages. When an etymology exhibits such traits it shows antiquity. Normally this would be reflected in the other major European language family, Latin. The Latin word is rana, imitative of the sound frogs produce. This is also why we speak of having 'a frog in the throat'.

In engineering, and particularly electrical, frog refers to a bridge or crossing point. A similar shape is seen in clothing fasteners where a peg is pushed through a loop.

The derogatory name Frog given to the French is not from their diet. Originally it wasn't even frogs. British soldiers picked up the term in the First World War from Belgians and Dutch who, in turn, had learned it from the French who used it when referring to richer inhabitants of Paris – a city with an emblem of two toads.

Bigpicture

Relocated and repainted, and with a fresh source of funding, the UK attempt to take the land speed record past 1,000mph is back in business. The car is now red and white, which is expected soon to be joined by sponsors' logos, and the core of the previous team has transferred over to the new organisation, which has been dubbed Bloodhound LSR (land speed record)



Prizecrossword

When completed rearrange the highlighted squares to spell out a term for taking a liquid above its boiling point without converting it into vapour. The first correct answer received will win a £20 Amazon voucher. Email your answer to **jon.excell@centaur.co.uk**

Across

1 Make into steps as for cultivation (8)
6 Roads that are not leveled or drained (4)
8 Japanese shrub with dense flowers (7)
9 Inner or enclosed surfaces (7)
11 Continuous movement that it usually prevented by friction (9,6)
12 List of people performing certain duties (4)
13 Variable factor in electromagnetic radiation (10)
17 Instrument for determining specific gravity (10)
18 Toroidal shape (4)
20 Workplace where music is produced (9,6)
23 Raise from a lower to a higher position (7)
24 Straits connecting two bodies of water (7)
25 Small unused part of something (4)
26 Posts used by traditional English dancers (8)

Down

2 Left one's country of residence for a new one (9)
3 Measuring device (6)
4 Transformed from a liquid into a soft semisolid or solid mass (9)
5 Tool for making holes in hard materials (5)
6 Make a new finding (8)
7 Line segments between the centre and circumference of a circle (5)
8 Increase pressure on a gas or liquid (11)
10 Existing at the same time (11)
14 Sudden unforeseen crisis (9)
15 Impressive because of unnecessary largeness (9)
16 Upright frame around an opening (8)
19 Sound transmission through two channels (6)
21 Fastener around which a rope can be secured (5)
22 Girder having a particular cross-section (1-4)

March's highlighted solution: **Laminate.** Winner: **Andy Knott**

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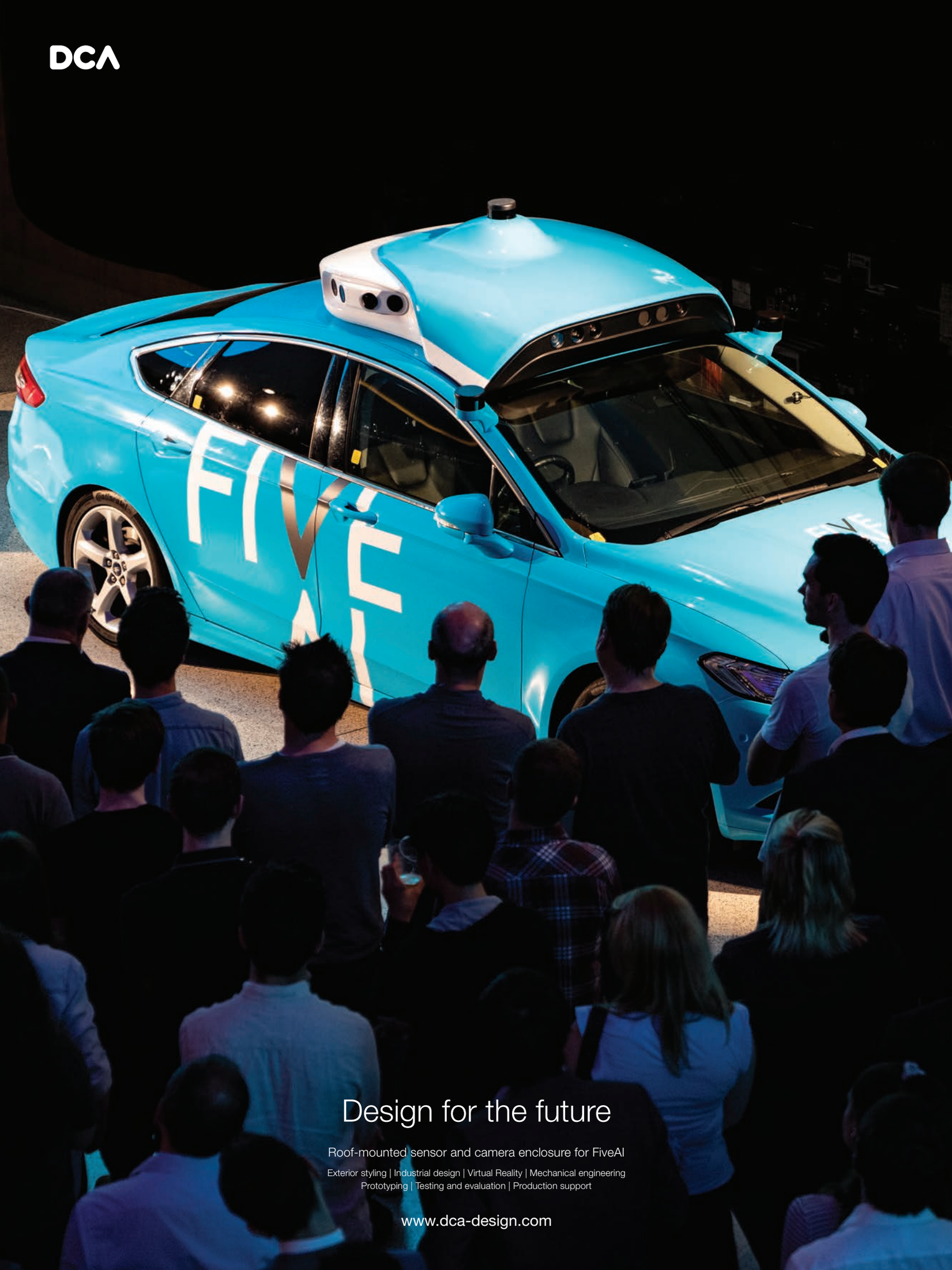

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