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FEBRUARY 2020

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SCAN ME

JON EXCELL

Wind in the sails of marine innovation

Driven by increasingly demanding emissions targets, the priorities of the automotive and aerospace sectors have been transformed in recent years.

From the bold electric roadmaps of the world's biggest car makers, to aviation's growing interest in hybrid electric propulsion systems, to say that these critical sectors are in the throes of a low carbon revolution is no overstatement.

There are numerous examples of this rich climate of innovation throughout this issue; from the truck industry's growing interest in hydrogen (News analysis, page 13) to the EV charging infrastructure advances discussed by the expert panel in our Q&A feature (page 36).

By contrast, the subject of this issue's cover feature, the commercial shipping sector, has proved somewhat more resistant to the changes sweeping other areas of transportation.

Perhaps secure in its unassailable position as the enabler of world trade, the sector - which is thought to be responsible for around 2.5 per cent of all global human-made greenhouse gas emissions - has tended to resist the winds of change sweeping other areas of transportation.

But a bold industry-wide strategy - set by the UN's International Maritime Organisation (IMO) back in 2018 - to eliminate GHG emissions as soon as possible this century has changed the dynamic in the sector.

Today, as we report, no stone is being left unturned in the sector's quest to reduce its environmental impact. And amongst the many technologies that look set to play a role are a new generation of systems that harness shipping's original energy source: the wind.

The technology behind these systems – a curious blend of Flettner rotors, aerospace industry inspired deck mounted wing structures, and even giant kites - is truly fascinating. And whilst it's early days, a growing number of ship operators and industry experts believe that this new generation of wind-assist technologies, coupled with existing powerplants - could play a key role in reducing the sector's emissions and boosting its fuel efficiency.

Who knows, perhaps these innovations might ultimately prove as disruptive as some of those pioneered by the subject of our latest Late Great Engineers article (page 42): possibly the most well-known late great engineer of them all, and one of the great innovators of transportation - Isambard Kingdom Brunel.

Jon Excell

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Industry's digital transformation; Huawei or not Huawei; and the challenges of net-zero

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SCAN ME

MISSION STATEMENT

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

5 THINGS WE'VE LEARNT THIS ISSUE

1. Commercial shipping accounts for 2.5 per cent of global greenhouse gas emissions
2. One kilogram of hydrogen has the same energy density as one gallon of diesel
3. Socket fit is one of the biggest challenges in prosthetics

4. More than fifty per cent of readers think HS2 should be axed
5. Brunel's role as the designer of the Clifton Suspension bridge is questionable

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NEWS

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All-electric Nikola lorry paves the way for fossil free freight

Battery-powered truck precedes fuel-cell lorry

JASON FORD REPORTS

Europe is set for the roll-out of zero-emission heavy-duty trucks with the introduction of the Nikola TRE, a battery-electric lorry that will act as a springboard for the launch of a fuel-cell freight vehicle.

Arizona-based Nikola will bring its advanced electric technology proprietary infotainment system to the TRE, which is based on IVECO's S-Way heavy-duty truck, which was launched in July 2019.

A maquette of the TRE was unveiled on December 3, 2019 at CNH Industrial in Turin, Italy. The unveiling followed the creation of joint venture between Nikola and CNH's IVECO commercial vehicles arm, and FPT Industrial, its powertrain division. Iveco has invested $250m into Nikola and the first battery-electric vehicles (BEVs) are expected to be delivered in 2021, followed by fuel-cell electric vehicles (FCEVs) in 2023.

Speaking in Turin, Trevor Milton, CEO, Nikola Motor Co. said, "What's really special about this truck is while a lot of other OEMs are building a lot of small battery electric trucks, or very limited range hydrogen trucks, we are actually doing it.

"This truck has around 750 kW/h of lithium battery in it, that will allow it to go over 300 miles on charge. It will also have between 60 and 80kgs of a hydrogen version that will allow it to surpass the battery range."

According to the partners, the BEV's modular lithium-ion battery system will have a total capacity of up to 720kWh, with the electric driveline delivering 480kW continuous power output with 1800Nm peak torque. The lorry will also have a maximum speed of 121kph (75mph), a 350kW charging capacity and an average recharge time of two hours.

They added that the nine-battery pack (800V each) BEV will be offered to customers who would 'pay by the mile' and will be able to tailor battery requirements to the job being undertaken by the vehicle, which is expected to have a range of 400km (in 4x2 tractor configuration) and will be available in 2-and 3-axle rigid versions.

IVECO added that the gross vehicle weight (GVW) will range between 18 to 26 tonnes for urban distribution and local authority missions.

Gerrit Marx, president of IVECO commercial and specialty vehicles said the move to a FCEV version of the TRE will help customers meet EU emissions targets, assist in the development of a more circular economy, and offer a 'conflict-free' method of developing a fuel source.

"Hydrogen truly is the fuel of the future. Both the drivetrains between the electric and the hydrogen trucks share the same platform," said Milton. "There is almost no difference. The battery allows us to refine that platform very well. It allows us to bring the fuel cell in right after that to make sure that that platform is ready for it."

Read more at www.theengineer.co.uk

Read more online

Jobs online

Southampton spin-out finds right fit for prosthetic devices

CES 2020 launch for 'right first time' software solution

JASON FORD REPORTS

Last month's consumer technology show CES 2020, saw the launch of software designed to give clinicians a tool to ensure the fit and comfort of prosthetic devices prior to manufacture.

Spearheading this 'right first-time approach is graduate entrepreneur Dr Joshua Steer, whose company, Radii Devices, was spun out from Southampton University in April 2019.

NHS England's Prosthetics Patient Survey Report 2018 found socket fit to be one of the most common complaints among prosthetic users. Furthermore, an average of nine fitting sessions are required to achieve a comfortable fit.

Dr Steer, a Royal Academy of Engineering Enterprise Hub fellow, told *The Engineer* via email that there are two packages of analysis which are used to provide information to clinicians who design the prosthetic limb.

The first package captures information from a laser scan of the limb to model how the limb changes over time, the socket design at each visit and the resultant comfort score.

"We can then aggregate and compare this data across the population to determine which sockets are suitable for particular individuals and provide this information back to the clinic," Steer said. "Our second package of real-time pressure prediction requires an MRI scan. This enables us to capture shape of the bones and soft tissues to generate the computational model required to predict the pressures at the interface between the limb and the socket."

Steer added that Radii Devices is using the same simulation technology that has been used successfully across engineering disciplines to streamline design processes and reduce the number of protypes which need to be manufactured and tested.

"Much as an engineer will use computational models in tandem with their expertise to arrive at the final design, our aim is to make this technology accessible and available to clinicians at the point of care," he said.

Radii Devices' solution is initially focussed on prosthetics for lower limb amputees, but Steer said the technology can be applied to any external medical device which applies pressure to the skin such ankle-foot orthoses, wheelchair seating, and footwear.

"Designing devices to fit the complex geometry of the human body is a real challenge, and we want our tools to be used to improve quality of fit across all these devices," he said.

INSECT GIVES INSIGHTS INTO BETTER SUCTION

STUART NATHAN REPORTS

Engineers are often seeking better methods to stick articles to surfaces and a discovery by zoologists at Cambridge University may have the potential to help solve these problems.

The researchers are studying the net-winged midge, an insect with aquatic larvae that attach to rocks in fast flowing streams. They do this using suction cups on their underside and the Cambridge team, as described in BMC Zoology, has imaged these suction cups to reveal how they work.

The cups can stand up to any force below 600 times the larvae bodyweight, said Victor Kang, a PhD student and first author of the paper. "The force of the river water where the larvae live is absolutely enormous, and they use their suction organs to attach themselves with incredible strength. If they let go they're instantly swept away," he said. "They aren't bothered at all by the extreme water speeds."

Using scanning electron microscopy, scanning confocal microscopy and x-ray computed micro-tomography, the team obtained images of the larvae suction cups and discovered that the cups have a central piston, which is controlled by specific muscles.

The cups also have a dense array of hairs on their inner surface, which come into contact with the surface of the rock on which they anchor. The piston then creates a tight seal and a strong vacuum to anchor the larva onto the surface. When it needs to move, more muscles control a tiny slit on the suction disc, which pulls it open allowing the larva to detach.

NEWS IN BRIEF

BETTER BLADES IN BRISTOL

Rolls-Royce has opened a £25m advanced manufacturing hub in Bristol that will develop fan blades and fan cases that will reduce weight in jet engines. According to Rolls-Royce, the fan blades and fan cases being made at the composite technology hub are a feature of the company's UltraFan engine demonstrator, a new engine designed to reduce fuel burn and CO2 by at least 25 per cent compared to the first Trent engine.

FUTURE RAIL INVESTMENT

Funding worth £9.4m is being made available through the 2020 First of a Kind (FOAK) competition which aims to make Britain's railways greener, more economical, and accessible. "Having already supported trains that run on sunlight and hydrogen, drones to survey our tracks and technology to tackle leaves on the line, the UK is fast becoming once again a hub of global innovation in transport," said George Freeman, the UK's future of transport minister.

COASTAL DEFENCE UPGRADE

Work has started on a £40m project to upgrade Great Yarmouth's flood defences. The refurbishment works will extend the working life of the existing defences and is expected to provide protection to over 4,500 homes and businesses. According to Defra, the project will see 46 flood defence walls refurbished at locations across the town using a technique that will extend their lifespan by up to 30 years.

Read more at www.theengineer.co.uk

All-weather autonomy with radar-based perception system

Algorithm helps radar deliver driverless

JASON FORD REPORTS

Vehicles will be able to operate with Level 4 autonomy following the launch of a radar-based navigation and perception system that is not reliant on any external infrastructure.

Developed in a partnership between Oxbotica and Navtech, the so-called multi-module localisation system - consisting of radar, vision and laser - allows end users to deploy autonomy in on-road and off-road locations in weather conditions where standard GPS or lidar cannot function.

According to an Oxbotica spokesperson, the technology can be deployed on vehicles ranging from airport cargo pods, mining trucks, on-road cars, and delivery shuttles. In use, the radar has a range of approximately 300m.

Set for launch this year, the solution from Oxbotica and Navtech can operate independently or be fused with other location services driven by GPS, lidar or laser vision.

"The incorporation of radar into Oxbotica's localisation stack provides robustness to weather (e.g. snow and heavy rain), dust clouds, low/no light conditions, and regions with little or ambiguous geometry," said the Oxbotica spokesperson. "The primary challenge with implementing a multi-modal localisation system - vision, laser and radar - is intelligently deciding which mode to rely on to provide the best pose estimate at a given moment in time."

Oxbotica's autonomous driving software has been deployed in cities, mines, airports, quarries and ports as part of its Universal Autonomy commitment, which aims to give autonomy to any vehicle without the need for external infrastructure. Notably, the company was part of the DRIVEN consortium that demonstrated vehicle autonomy to the public in a week-long demonstration around a circuit in Stratford in east London. Autonomous vehicles were simultaneously demonstrated in a quarry and a forest, using Oxbotica's software.

Phil Avery, CEO of Navtech, said: "Despite the potential of radar very few companies have successfully developed the necessary algorithms to use it properly. Oxbotica are world leaders in this area and together with our high-performance radar sensors we believe the resulting system will deliver a step change in the performance available for all weather all environment localisation and perception."

LIFT-OFF FOR ELECTRIC TAXI

Hyundai is to develop an electric vertical take-off and landing air taxi as part of the Uber Elevate initiative, which is working towards a future aerial ride share network.

The full-scale concept for an Uber Air Taxi was unveiled at CES 2020, which took place in Las Vegas in January 2020.

"Hyundai is our first vehicle partner with experience of manufacturing passenger cars on a global scale," said Eric Allison, head of Uber Elevate. "We believe Hyundai has the potential to build Uber Air vehicles at rates unseen in the current aerospace industry, producing high quality, reliable aircraft at high volumes to drive down passenger costs per trip."

The S-A1 PAV (Personal Air Vehicle) will have a cruising speed up to 180mph (290km/hr), a cruising altitude of around 1,000-2,000 feet (300 - 600m) above ground, and to fly trips up to 60 mile (100km).

S-A1 will also utilise distributed electric propulsion, powering multiple rotors and propellers around the airframe for noise reduction and increased redundancy. ***JF***

Read more at www.theengineer.co.uk

DEPLETED URANIUM COULD BE CATALYST FOR REDUCING WASTE

ANDREW WADE REPORTS

Scientists have developed a catalyst based on depleted uranium that could help cut stockpiles of nuclear waste and reduce the burden of its storage.

Depleted uranium (DU) is one of the primary by-products of generating nuclear energy, and as one of the oldest nuclear powers, the UK has found itself with a significant nuclear waste problem. Finding non-military uses for depleted uranium has proved difficult, with costs rising for the resulting storage.

Sussex University researchers, alongside colleagues from Université de Toulouse and Humboldt-Universität zu Berlin, have found that an organometallic molecule based on DU could catalyse the addition of a molecule of hydrogen to the carbon-carbon double bond in ethylene (an alkene) to create ethane (an alkane), which can be used to create useful compounds including ethanol. The work is published in the *Journal of the American Chemical Society*.

"The ability to convert alkenes into alkanes is an important chemical reaction that means we may be able to take simple molecules and upgrade them into valuable commodity chemicals, like hydrogenated oils and petrochemicals which can be used as an energy source," said Professor Richard Layfield from Sussex University. "The fact that we can use depleted uranium to do this provides proof that we don't need to be afraid of it as it might actually be very useful for us."

Assystem takes next step in fusion power project

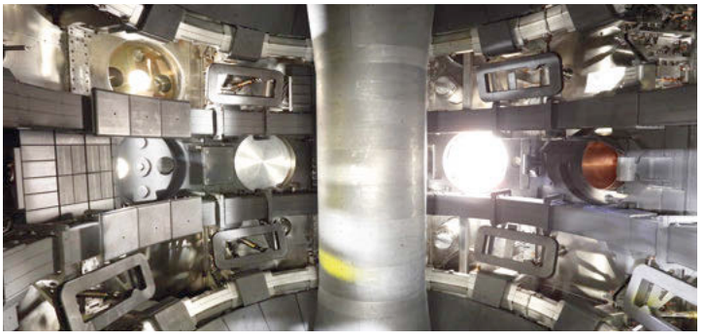
Team will develop designs for UK-led fusion reactor's breeder blanket

STUART NATHAN REPORTS

The Spherical Tokomak for Energy Production (STEP) project, which aims to design a power station fired by nuclear fusion, has announced Assystem as a new collaborator.

The France-based company will provide designs for a key component of the fusion system and provide services that will help other collaborators deliver the project.

STEP is a UK government-proposed project to take a lead in the development of fusion. In October 2019, the government announced a £200m investment to develop the concept behind STEP, which is to use a spherical Tokomak to perform and manage nuclear fusion and harness the heat produced to generate electricity.



The project's ambition is to have a power station – which would be the first fusion unit – sending electricity to the grid by 2040.

Spherical Tokomaks are being designed to generate nuclear fusion by heating and compressing plasma using electromagnetic technologies. They are, to date, the most successful kind of fusion reactor, with the Joint European Torus (JET) located at Culham in Oxfordshire, the current record-holder for fusion energy production.

Assystem's UK operations will develop designs for a breeder blanket for the STEP reactor. This component lines the reactor interior and performs two functions: it extracts the heat from the reactor so that it can be used to raise steam to run turbines, and it captures the fast neutrons generated by the fusion reaction and multiplies them so that they can generate tritium through a further reaction with lithium nuclei.

While the reactor itself is being developed by UKAEA (UK Atomic Energy Authority) at Culham, Assystem's contribution will be delivered from its locations in the North and Midlands. Assystems' Sunderland site is already involved in fusion development, as it is leading the design of a robotic device to handle components of ITER while the reactor is in operation.

"With global dialogue on reducing carbon emissions becoming an urgent priority, we commend the nation's commitment to investing in the development of fusion energy and are proud to be associated with STEP," said Kevin Wilkinson, business unit director at Assystem.

INDIAN TEST BED FOR BATTERY RESEARCH

Project will combat heat degredation

STUART NATHAN REPORTS

Loughborough University is among institutions hoping to find batteries that can cope with South Asian heat to improve air quality in congested cities.

As part of a project with Tamil Nadu, India-based Vellore Institute of Technology (VIT) and PSG College of Technology, Prof Rui Chen, Prof Jin Xuan and Dr Ashley Fly of Loughborough's School of aeronautical, automotive, chemical and materials engineering will work on the design and development of a four-wheeled electric vehicle for research, teaching and outreach in India.

Electric vehicles have difficulty operating in South Asia because lithium-ion batteries perform best at 25°C ambient temperature and degrade very rapidly when it is hotter. In India, where temperatures can often exceed 45°C, they tend to last as little as two to three years.

The Loughborough researchers will provide expertise in the operation and management of lithium-ion batteries, environmental test facilities for battery modules and advanced battery analysis techniques.

Fly said: "When our smartphones get too hot from being left in the sun, they notify us to move them into the shade. This is often not an option with a whole vehicle, so instead, we need to engineer intelligent solutions to manage the temperature."

Among the approaches the team intends to test are the use of phase change materials which absorb heat as they melt or vaporise, cooling systems based on refrigeration and temperature resistant battery chemistry.

They will use an environmental chamber to replicate the ambient conditions of Indian cities for characterisation and testing of their batteries.

SMART DIAGNOSTICS

Urinary tract infections - UTIs - could be diagnosed in under 30 minutes with a smartphone camera-based test developed by biological engineers at Bath University.

The process can identify the presence of E. coli bacteria in a urine sample in 25 minutes and could make UTI testing more widely available in developing nations and remote regions thanks to its potential to be made portable, and more cheaply than lab-based tests.

As well as a smartphone camera, the test takes advantage of widely available reagents and new micro-engineered materials.

The test uses antibodies to capture bacterial cells in capillaries within a plastic strip, detecting and identifying the cells optically rather than through microbiological methods. ***JF***

Read more about med-tech at www.theengineer.co.uk

BORIS BOOST FOR BRUDERER AFTER GENERAL ELECTION

Management at stamping press specialist Bruderer UK are crediting December 2019's definitive general election result with an upturn in investment.

The company expects a buoyant 2020 with a £3m pipeline of projects including the installation of machinery for clients in the aerospace, automotive, construction and renewables sectors.

Adrian Haller, managing director, said: "We move into 2020 with a very healthy order book, which reflects the positive attitude of our customers following the election results in December.

"Electrification is a market that is due to take off after a number of stalled starts and we are currently in the process of tooling up suites of tools for major automotive suppliers in preparation for EV product launches. 2020 could well be the breakthrough year."

Bruderer UK, which employs 14 people at its headquarters in Luton and at a satellite facility in the West Midlands, weathered Brexit uncertainty and economic volatility with a surge in major rebuilds on existing presses. *JF*

Ministers misled over HS2

Minority report points to major cost overun for high-speed rail project

JASON FORD REPORTS

Parliament has been 'misled' over the cost of HS2 and rail improvements can be delivered without building it, claims a new report that puts the cost of the project at £107bn.

In his report, Lord Berkeley, formerly deputy chair of the Oakervee Review commissioned by the government to evaluate the future of HS2, states that rail services in the Midlands and North can be improved with alternative solutions that are quicker, more economical and would provide commuters in these areas with better daily services. Improvements to the lines to and from London can be delivered without building HS2, which Lord Berkeley said would disrupt and damage businesses, residents and the environment.

First proposed by Lord Adonis during the last Labour administration and brought into being by the Conservative-Liberal Democrat coalition government in 2010, HS2 had an initial price tag of £56bn.

According to Lord Berkeley, HS2's Benefit Cost Ratio (BCR) has fallen below the break-even point of 1:1 and could fall to under 0.6:1, falling short of the 2.3:1 BCR used by HS2 Ltd to get the project through parliament.

In his report, Lord Berkeley said the costs of the HS2 project are out of control, the benefits are overstated and might not be delivered to Leeds and Manchester for another 20 years.

Consequently, Lord Berkeley believes government ministers should acknowledge that the project is over three times over budget and look to approve a new budget estimated at £107bn, with or without a reduced specification, and accept that the benefit cost ratio will be substantially decreased.

Commenting on Lord Berkeley's report, Darren Caplan, chief executive of the Railway Industry Association, said: "Let us be clear: HS2 is vital for the UK as it seeks to boost its transport infrastructure for the whole country in the coming decades.

"It will provide much greater capacity by taking traffic off the current rail network, and transform connectivity between economic centres, cities, towns and communities."

Read more at www.theengineer.co.uk

Fresh funding for hot idea

Mixergy's hot water tank cuts energy bills and balances grid

An Oxford University spin-out whose innovative hot water tanks promise to save up to 20 per cent on hot water bills has secured £3.6m in Series A financing.

Rather than heat all the water in a hot water tank, the Mixergy Tank applies volumetric heating to supply hot water in a quantity specified by the consumer, who can control the system with an app.

According to Mixergy, it does this by exploiting thermal stratification and in doing so delivers hot water five times faster for direct electric tanks and two times faster for indirect gas tanks. As well as saving on energy, the tank provides up to 30 per cent more useable hot water via the use of inlet diffusers that reduce the mixing of cold water that enters the cylinder as hot water is drawn from it.

Mixergy says its tank has the added benefit of being the first hot water product certified to deliver grid balancing services to the National Grid. Through turning on/off when national energy demand misaligns with energy supply, the Mixergy tank can reduce network strain and use renewable energy more effectively.

The company said this has been achieved through developments in sensing and control along with a software platform, which optimises household heating schedules across a national network of smart connected hot water tanks.

Mixergy said it will use the funding – which was led by Foresight Williams Technology – develop the technology and support the national roll out of Mixergy tanks with British Gas. FWT were joined by Centrica, Oxford Sciences Innovation, and IP Group. ***JF***

inspi/stock.adobe.com

High time for hydrogen

With the cost of renewable energy falling and emissions regulations tightening, the time has never been better for hydrogen to fuel heavy duty trucks

WRITTEN BY JASON FORD

The expression 'chicken and egg' crops up repeatedly when researching hydrogen's role as a viable fuel source for heavy duty, Class-8 lorries, and it's easy to see why.

One kilogram of hydrogen has the same energy density as a gallon of diesel, but manufacturers won't invest in the development of fuel cell electric trucks if there is little or no refueling infrastructure in place for customers.

"To encourage adoption, hydrogen faces similar issues to battery EVs – the need for infrastructure and volume manufacture of vehicles to reduce costs. Battery EVs need charging points and sometimes grid reinforcement; hydrogen vehicles need refuelling stations," Mark Griffin, market development manager for clean fuels, BOC told The Engineer.

It's a conundrum that has helped stymie the adoption of hydrogen as a fuel source for heavy-duty vehicles, but this is about to change with tightening tailpipe emissions standards and a drop in the financial - and environmental - cost of producing it.

The EU has mandated that from 2025, heavy-duty vehicles will have to emit 15 per cent less CO2, rising to 30 per cent from 2030. The organisation adds that as a first step, the CO2 emission standards will cover large lorries, which account for 65-to-70 per cent of all CO2 emissions from heavy-duty vehicles. In the UK, the government's Road to Zero Strategy is driving the transition to zero emissions across all vehicle types for public, commercial and private transport.

Speaking at the launch of the Nikola Tre (News, page 6) Gerrit Marx, president of IVECO commercial and specialty vehicles, said, "In order to bring down 15 per cent we need to target 20-25 per cent CO2 reduction versus actual consumption in 2019, which is only possible with 8,9,10 per cent fully electric, emissions free, heavy duty trucks.

"There's only one way to do it, and that's battery electric trucks with a modular toolkit, a modular platform that allows for fuel cell electric range extender technology."

Despite being the most abundant element in the universe, hydrogen must be extracted from compounds including water or methane, and the processes to do this haven't been low-cost or low carbon until quite recently.

The most common production method today is steam methane reformation, which can be a low-carbon process when used with carbon capture or a biomass feedstock, said Griffin. Another is electrolysis, a process that extracts hydrogen from water. In its Path to Hydrogen Competitiveness report, the Hydrogen Council states that electrolysis via renewables is 60 per cent more affordable as low-carbon and renewable electricity prices have dropped and capital expenditure in electrolysis has fallen.

"This is how hydrogen is produced at Europe's largest hydrogen bus refuelling station, Kittybrewster in Aberdeen operated by BOC," said Griffin. "Once generated, the hydrogen is compressed to store it efficiently."

Kittybrewster produces 300kg of hydrogen a day, which Griffin said is enough to refuel ten 42-seat buses, with each bus travelling up to 350km on a full tank.

Addressing the chicken and egg conundrum for Class-8 trucks, Nikola Motor has a target of 700 heavy duty fast-fuelling stations across the USA by 2028 and a more modest 70 across Europe by 2030. These will provide refuelling in 15-minutes on 3-to-4-hectare sites that will use renewable energy sources, supplemented with grid power, to produce a standard 8T of hydrogen per day. Delivered in partnership with Norway's Nel, the stations will provide 7T/day heavy duty fueling at 70Mpa (enough for around 160 trucks), and 1T/day for lighter duty fueling on the SAE J2601 standard, providing fuel for around 200 passenger cars.

"Ultimately, hydrogen fuel cells will be more economically viable than Battery Electric Vehicles because of the power required to pull heavy loads, the space available in the truck cab and the constant use that heavy duty applications require just to make them economical," said Jim Gregory, European business development manager for alternative fuel, at Luxfer Gas Cylinders.

In the long-range commercial vehicles market there is a clearer opportunity for the application of fuel cell technology, added Jeremy Parkes, DNV EV business leader.

"We anticipate that 5-13 per cent of heavy goods vehicles will be powered by fuel cells by 2050, according to our Energy Transition Outlook report," he said. THE ENGINEER

"HYDROGEN FUEL CELLS WILL BE MORE VIABLE THAN BATTERY ELECTRIC VEHICLES BECAUSE OF THE POWER REQUIRED TO PULL HEAVY LOADS"

Could a new generation of innovative propulsion technologies that harness the power of the wind help the shipping industry clean up its act? Jon Excell reports

WINDS OF

CHANGE

Econowind's containerised ventifoil system, installed here on the deck of the DFDS cargo vessel Lysbris Seaways

Commercial shipping - for many years resistant to the low carbon revolution sweeping other areas of transportation - is changing fast.

Faced with a combination of rising fuel prices and an industry-wide strategy to cut greenhouse gas emissions by at least 50 per cent over the next 30 years, the sector (thought to be responsible for around 2.5 per cent of global GHG emissions) is innovating as never before in an effort to boost fuel efficiency and reduce its environmental impact.

From the development of novel hybrid electric propulsion systems to AI driven improvements in operational efficiency, no stone is being left unturned in the quest to slash emissions. But arguably some of the most intriguing advances are being made in a field that harks back to the earliest days of seafaring: wind propulsion.

Whilst no-one's quite proposing a return to the great age of sail - where world trade was utterly reliant on the power of the wind - many believe that a new generation of wind propulsion systems - an eclectic mix of innovative sails, strange deck mounted wings, kites and weird hull designs - could play a key role in the sector's future.

Gavin Allwright, who heads up the trade body representing companies in this field - the International Windships Association (IWSA) - has witnessed this growing interest first-hand. The association has grown from 12 to just over 100 members and partners since 2014: a clear reflection, says Allwright, of the growing seriousness with which wind propulsion is being treated. "We don't see how we can make the speed and depth of the change without wind propulsion taking a significant load," he told The Engineer.

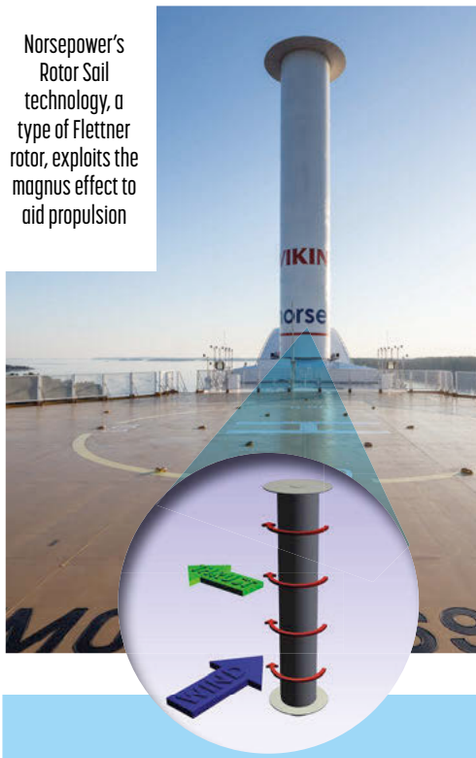
Many of the technologies at the heart of this burgeoning field have actually been around for some time. Flettner rotors, for instance (discussed later in this article) were invented over a century ago. What's changed, said Allwright, is that there are now tangible examples of these systems in action and, in many cases, verified figures to back up the developers' claims.

At the most recognisable end of the wind-assist spectrum are innovations in soft sail systems. The increasing sophistication of automation and route optimisation systems have revived interest in seafaring's original power source, and there are now a growing number of examples of larger vessels using smart soft sails alongside auxiliary propulsion systems. In one notable development, French naval architect VPLP recently unveiled a design for a 121 metre long roll-on/roll-off (RORO) vessel that will be used to transport components of the Ariane 6 rocket from Europe to Guiana. The ship's main propulsion system (a dual fuel LNG MDO engine) will be assisted by four Oceanwings; fully automated wing-sails which are each supported by a 30m high mast and measuring a total of 363 square meters.

There is also growing interest in the use of rigid hard sails, which are sometimes preferred over soft sails because of the potential for incorporating different aerodynamic structures or even photovoltaic coatings.

As with soft sail innovations, there are numerous ongoing initiatives in this area exploring the application of the technology to vessels of various different sizes. In one recent development, Japanese firms Mitsui OSK lines and Oshima shipbuilding received Approval In Principle from marine classification body ClassNK to build a 100,000 DWT bulk carrier equipped with a telescopic hard sail system that the group claims could reduce fuel usage by as much as 8 per cent.

Whilst the ability to automate, deploy new materials, and use data to optimise performance is breathing fresh life into →



Norsepower's Rotor Sail technology, a type of Flettner rotor, exploits the magnus effect to aid propulsion

the use of traditional sails, they do come with some significant challenges as they are scaled up in size. Not only do they take up large amounts of deck space (valuable real-estate in the commercial shipping sector) but they can also induce a significant amount of heeling (or tipping from side to side) in the vessel.

One concept that potentially gets around this problem is an innovative device known as a suction wing, a deck mounted vertical foil claimed to provide considerably more power per square metre than a normal sail at a fraction of the height.

Based on technology originally pioneered by marine explorer and conservationist Jacques Cousteau, these systems use a powered suction device mounted within the wing to suck in the boundary layer around the foil and increase its propulsive efficiency.

One of the key players here is Netherlands firm Econowind, whose so-called Ventifoil technology – a non-rotating wing with vents and a powered internal fan - can either be retrofitted to the deck of a vessel, or deployed within containers that are added and removed as and when required.

The company's CEO Frank Nieuwenhuis explained that during operation and when the wind conditions are favourable, the system increases the speed of a vessel enabling the captain to throttle back the propulsion system without reducing the voyage time.

Late last year (2019) the firm installed a prototype system, consisting of two 10 metre foils that automatically fold out of a 12 metre container, on the deck of DFDS Cargo vessel, Lysbris Seaways. According to Paul Woodall, director, Environment & Sustainability at DFDS, although a mechanical fault has brought this trial to a premature end, preliminary results show that a positive effect was achieved.

At the time of writing, Econowind was also poised to install a larger permanent system aboard MV Ankie, a 3,600 DWT cargo vessel operated by Van Dam Shipping. Commenting on the potential fuel savings resulting from this application Niewnhuis said: "we expect that on a really good day we will save 20 per cent and over the year we would expect the unit to do between 8 – 10 per cent."

// ON A REALLY GOOD DAY WE WILL SAVE 20 PER CENT AND OVER THE YEAR WE WOULD EXPECT THE UNIT TO DO BETWEEN 8 - 10 PER CENT //

Whilst Econowind's unit takes up a fraction of the deck space occupied by conventional sails, other innovators are looking beyond the deck, and eyeing up the use of giant kites to tap into the potential of the considerably greater wind resource in the skies above a vessel.

One of the most exciting technologies in this area is Seawing, an autonomous system developed by French company Airseas. The firm was spun out of Airbus in 2016 with the express purpose of finding marine applications for modelling and flight control expertise gained in the aerospace sector.

The technology consists of a giant kite that is deployed and refurled at the push of a button, and which, the company claims, can deliver average fuel savings of 20 per cent.

Luc Reinhard, who heads up the firm's business development activities, explained that whilst other kite-based systems have been trialed, Seawing's autonomous operation, and the software tools and flight control systems that underpin its operation set it apart from other technologies. "What is really innovative about our solution is this notion of automation software, digitalisation of the product so it's really simple to use by the crew members onboard ships"

The key components of the system are a mast that allows the wing to be deployed, a winch to roll the 500m long cable, storage for the wing when it's not being operated, and the wing itself.

During operation the wing flies at an altitude of around 150m metres at a 30 degree angle from the ship. A flight control pod positioned directly beneath the wing dynamically adjusts the flight path, moving it through a series of positions and repeatedly dragging it out of what Reinhard describes as "its comfort zone". It's the wing's efforts to return to this position that generate most of the device's traction.

The company has already conducted a number of ground tests and sea trials using scaled down versions of the technology, and is now poised to begin its first commercial installation, which will see a 500 square metre wing installed on an Airbus RORO vessel used to transport aircraft parts. The firm also recently signed a contract with Japanese Ship owner Kawasaki Kisen Kaisha Ltd (aka K Line) to install an even larger 1000 m2 wing on one its vessels, with an option to install upto 50 further systems if this application is successful.

Ship design changes slowly – which is why many of these technologies currently being deployed are retrofittable

Airseas, spun out of Airbus, is commercialising kite-based propulsion systems

solutions.

However, Vindskip, a radical concept developed by Norwegian engineer Serje Lade, offers a glimpse of how future vessels might be designed from the ground up to tap into the wind resource. Lade's aerospace inspired design turns the hull of the boat itself into a wing, a symmetrical airfoil that generates lift that can be used to generate pull.

Lade told The Engineer that the hull works in tandem with the propulsion system and meteorological data to keep the ship at a constant speed. He has also been working with engineers from the Fraunhofer Center for Maritime Logistics and Services on the development of algorithms to calculate the optimum wind angle for the design of the vessel.

Tank testing and wind tunnel tests of scale models and CFD simulations indicate that the design could enable fuel and emissions savings of as much as 60 and 80 per cent respectively, he said.

Whilst concepts like Vindskip are probably many years away from commercialisation, other technologies are already having an impact. And the most widely deployed of the emerging systems is the Flettner rotor, an intriguing concept originally developed almost a century ago, which is now under serious consideration by some of the shipping industry's biggest players.

Similar in appearance to suction wings, Flettners operate on a very different principle, exploiting a curious aerodynamic phenomenon known as the magnus effect, the same force that causes a spinning tennis ball to swerve.

Looking rather like vertical cylinders mounted on the deck of a ship, these powered devices rotate around their own axis. This rotational speed can be adjusted depending on the wind speed and direction, and the interaction between the surface of the rotor and the wind creates a lift force that generates additional thrust.

Whilst a number of firms are actively working on the development of the technology, the leader in terms of the number of installations is Finnish company Norsepower systems, which makes the bold claim that its Rotor Sail technology - if applied to the entire global tanker fleet - would reduce annual CO2 emissions by more than 30 million metric tonnes.

Serje Lade's Vindskip concept turns the hull of the boat itself into a giant sail

Back in 2018, the company was behind the first ever application of the technology to a passenger vessel when a Rotor Sail technology was installed on Viking Grace, an LNG-fueled passenger ferry. Last year, it announced plans to install a 30 metre high system aboard the M/V Copenhagen, a hybrid passenger ferry operated by Scandlines.

The firm also recently announced results of a year-long installation of two 30 x 5m Rotor Sails on the Maersk Pelican , a 109,000 DWT, a tanker. The results of this trial were analysed by Chris Craddock, Technical Advisory & Ship Performance Manager at Llloyds Register, who told The Engineer, "We have independently verified the performance of Norsepower's Flettner rotor system through a 12 month in-service trial - the aggregated total fuel saved for propulsion was 8.2 per cent. This was closely in-line with the expectation of Norsepower."

"WE CAN LEAVE NO STONE UNTURNED IN PURSUIT OF CONTINUED EFFICIENCY IMPROVEMENTS"

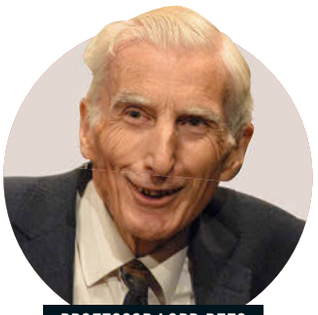
Craddock added that the lessons learnt from this project have been incorporated into a Flettner rotor savings calculator which can be freely used to estimate the fuel savings for many types of ship types sailing on any trading route across the globe flettner.lr.org

Having demonstratable figures like this has, said Allwright, created real momentum in the sector. "Two or three years ago we had very few demonstration vessels out there and there weren't enough reference points for the industry to say 'right now we understand' and get an understanding of what the savings might be."

Lloyds Register's Craddock, though broadly positive about the role that could be played by wind assist systems, warned that there is still a long way to go. " Wind technologies are generally acknowledged as a credible energy saving technology that could be applied to merchant shipping and reduce carbon emissions for certain ship types and sailing routes," he said. "However, since wind technologies are generally at a low level of technology readiness, there is a cautious interest by most of the market, with some of the larger charterers directly investing in technology development programs and pilot projects. As more technology demonstration pilot projects are successfully completed raising confidence in the technology, and new build contracts are placed specifying these technologies, payback periods will drop and there will be a steady increase in the uptake of the technology."

DFDS's Paul Woodall took a similarly balanced view. "We can leave no stone unturned in pursuit of continued efficiency improvements. This must include being available for testing any new technology, including various types of wind assistance. There is no single silver bullet that will bring shipping's GHG emissions down to the required levels, it is a long tough road. Shipping is a multifaceted industry that will require a number of different solutions models."

The technology's current momentum will no doubt lead to a greater number of applicaitons in the years ahead. But it's clear that while wind-assist has an important role to play, it's not going to single-handedly address the shipping sector's ambitious targets. THE ENGINEER



PROFESSOR LORD REES

On the future, a challenge for engineers

Professor Lord Rees Kt OM HonFREng HonFMedSci FRS, Astronomer Royal at the Institute of Astronomy, University of Cambridge

Any effort to forecast the future of Earth and its people is, inevitably, tentative. AI might revolutionise healthcare; human inhabitants of Mars may evolve into a different species; palates may eventually warm to the idea of an insect-based burger. I cannot predict the future, but there are two things that I can say with near certainty: the world in 2050 will be more crowded, and it will be warmer.

Fifty years ago, the global population was 3.5 billion, but this is predicted to rise to around 10 billion by 2050, impacting increasingly on our infrastructure. Food production has largely kept pace with the rising population and, while famines still occur, they are more often caused by conflict and maldistribution than overall scarcity. This may not continue, and the geopolitical stresses are most worrying.

In recent years climate change has acquired global attention, yet it remains chronically under-addressed. It is difficult for people, businesses, and governments to prioritise action that will benefit people elsewhere in the world decades hence. Even those who agree that there is a significant risk of climate catastrophe differ in how urgently they advocate action today.

The Earth has existed for 45 million centuries, but this is the first where the planet's future hinges so heavily on a single species: ours. A daunting task, but there is hope. Consider technologies such as the smartphone or the internet – just 25 years ago they would have seemed like magic. These two innovations transformed the world so greatly, and so quickly, that we must keep our minds open to advances dwelling currently in science fiction.

I recommend maintaining a pragmatic approach, balancing professional optimism and political pessimism. We should evangelise new technology, for without it we won't be able to sustain an expanding population; and we should be wary that politicians are unlikely to prioritise the necessary global and long-term measures unless voters continue to call for them.

Technological advancement has provided people with safer, longer, and more satisfying lives than ever before. However, climate change and unintended downsides of advanced technology are collateral impacts of some of these advances. Consider, for instance, the fires currently burning in Australia, and the growing surveillance of our personal data.

To protect our planet's future, we need wisely directed technology and appropriate investment. Feeding 10 billion people requires more efficient agriculture: genetically modified crops, dietary innovations, and artificial meats.

If mitigating climate change is truly a priority for politicians, then nations should invest in accelerating the development of low-carbon energy generation, and technologies where parallel progress is crucial. The faster these mature at scale, the sooner that national transitions will become more affordable to countries needing more generating capacity, and where there is otherwise pressure to build coal-fired power stations. This will have geopolitical implications, but I struggle to think of a more inspiring challenge for the next generation of engineers than devising clean and economical energy systems for the world.

Tomorrow's challenges are international; managing potential shortages of resources and transitioning to low carbon energy cannot be achieved by nations individually. Lasting change requires integrated discussions about every level of the global ecosystem. Last year's Global Grand Challenges Summit in London, hosted by the Royal Academy of Engineering jointly with the US National Academy of Engineering and the Chinese Academy of Engineering, did just that. It provided a forum for interdisciplinary discussion about solving global challenges such as sustaining 10 billion people and the impact of AI and other transformational technologies. Key decisions about global issues shouldn't be made by one facet of the populace; they should be the outcome of diverse debate.

The Large Hadron Collider epitomises such efforts. It required global collaboration, pushing technology to its limits to investigate the fundamental mysteries of the universe; this is something in which humanity can take pride, and I hope such cooperation is repeated more frequently in our attempts to protect the future.

Scientists and engineers have an obligation to promote beneficial applications of their work and to warn against the downsides. Researchers can use their collective expertise to assess which scenarios can be dismissed as science fiction, and how best to alleviate the most serious consequences. Experts must collaborate to enhance their leverage and amplify their voices through blogging and media engagement.

Extinction is a call that we must heed but there is hope. Half a century ago technologies that we take for granted today were thought to exist only in futuristic fantasy, and daily advances in every field continually push the boundaries of what is possible. If humanity guides itself with rational, global, and long-term thinking, then I should say that we stand a chance. THE ENGINEER

> "TO PROTECT OUR PLANET'S FUTURE, WE NEED WISELY DIRECTED TECHNOLOGY"

Prof Rees' latest book, On the Future: Prospects for Humanity, was released by Princeton University Press in 2019.

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As we begin the 2020's we're entering a new era in Business Performance Automation. Sure, task automation has been building over the last 20 years, but we now have the tools to deliver it business wide. With the Business Technology Platform from SAP you can now have true Intelligent Automation.

Furthermore, this technology is now available for SMEs, not just blue-chip companies. When an ERP system, such as SAP Business One, works hand in hand with the SAP HANA Database you have the engine for Intelligent Technologies and Predictive Analytics to create Business Process Automation.

In most businesses today the processes are complex and still require too much manual intervention. It's this manual input that leads to inefficiencies and errors. However, removing these steps often leads to systems becoming overly complex and integration becoming a weak point. If any one of the integration points changes or is upgraded the system breaks.

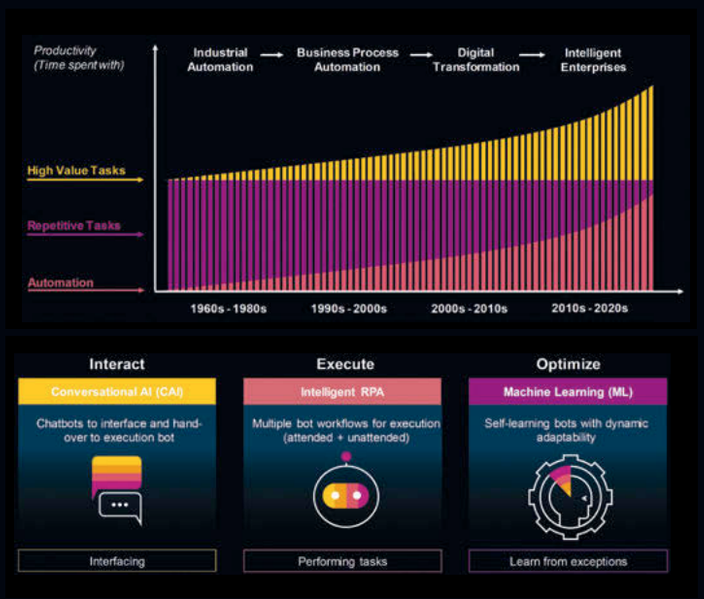
Robotic Process Automation (RPA) accelerates the digital transformation of business processes by automatically replicating tedious repetitive tasks to free up humans for more high value tasks.

SAP's intelligent RPA is able to automate scenarios including SAP and non-SAP applications. This brings the level of business automation possible to a new level and within reach of the average SME in the UK.

This has been made possible thanks to built-in Machine Learning and Artificial Intelligence driven by SAP HANA. It doesn't matter if the process is part automated, for example a digital assistant to a human, or a fully unattended process, the self-learning bots are key to the automation.

The use of Conversational AI means computers can now simulate real conversations across different business areas, from warehouses and production to providing management information. So, it's possible for actions within the ERP system, such as stock re-ordering, to be driven by Conversational AI. However, there are practical environmental restrictions of an office environment that are currently holding this back.

Conversational AI means SAP Business One users can ask for reports in language that makes sense to them. For example, "Show me the top 20 lowest sales margins by product group for 2018 and 2019", could be said in 20 different ways by 20 different people, but that's not a problem to the bot executing the request. The bot may offer several variations of the result, but quickly learns what it is that you want.

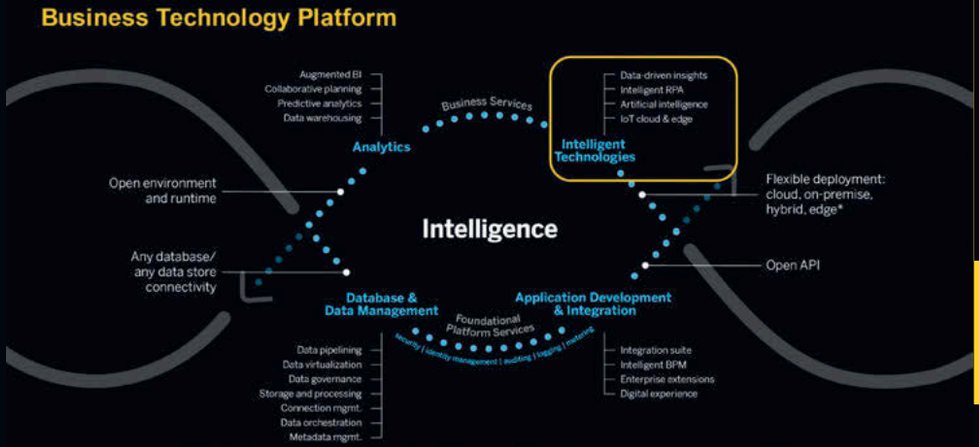


In Attended Mode, the bot is helping human by automatically adding commentary, 360° views, images and data to whatever they are viewing. It's commenting on not just the data on the screen, but the underlying data that isn't seen but that is driving the results.

Unattended bots continuously monitor and perform tasks to learn from the results. This results in semi-automated processes becoming fully automated over a short period of time. This takes automation to a whole new level and SAP Business One users can easily benefit from this technology.

This new decade will see the repetitive business processes that have traditionally been manual, becoming more and more automated within their ERP system. Human intervention will start to become a rarity.

If your business is not currently utilising an ERP product that can provide this level of Intelligent Business Automation then now is the time to consider products such as SAP Business One.



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IN OUR OPINION

On track or off the rails?

Too big to fail or destined for the scrapheap? The UK government's eventual decision on HS2 will cast a long shadow for years to come, writes Andrew Wade

Of all the sectors we cover at The Engineer, none tends to ignite the passions quite so much as rail. From the grand stations and bridges of the Victorian era to the complex, heaving network of today, rail is interwoven into the fabric of British society, a symbol of both towering achievement and modern frustration.

The Victorian heritage is something of a double-edged sword, inspiring with its storied past and engineering marvels, while at the same time impeding the radical overhaul the network clearly requires. For all its former glory, the UK's infrastructure has failed to keep pace with the rest of Europe, never mind the likes of new rail superpowers such as China. Inevitably, this has led to services being squeezed, compounded by increased numbers flocking to the network in recent years.

HS2, or High Speed 2 to give it its full title, was supposed to be the answer. Running north-south from London to Birmingham initially, then on to Manchester and Leeds in a 'Y' route under Phase 2, the project was conceived to relieve capacity on existing lines while also reducing journey times between some of the country's major cities. As well as a new high-speed line and rolling stock, HS2 will see major new stations being built in London and Birmingham, with significant updates to existing stations at multiple other locations.

Perhaps unsurprisingly given the scale, questions regarding cost and value have dogged HS2 from day one. An initial price tag of £55bn was tabled in 2015, followed by parliamentary approval for Phase 1 in 2017. With work at several sites across the country underway, some estimates claim the projected costs have already risen to more than £80bn. A recent report from Lord Berkeley - the former deputy chairman of the independent Oakervee Review in to HS2 - claims the final cost will be closer to £110bn, around double the original budget. The same report says that Phase 1 trains – originally due to start running between London and Birmingham in 2026 – are unlikely to carry their first passengers until 2031.

The sheer size of the figures involved has raised eyebrows as well as the inevitable cries of 'white elephant'. Building high speed rail infrastructure was never going to come cheap, but rising engineering costs and poor ground conditions have seen estimates spiral upwards worryingly fast, leading to calls for the entire project to be scrapped. The ongoing issues with Crossrail – for so long the poster child of UK rail infrastructure – are also a very timely reminder that even when things appear to be going smoothly, trouble is never far away on projects of this magnitude.

Cost aside, HS2 faces a litany of other issues. The visual, ecological and environmental impact of the project have all been cited as reasons to scrap or reroute the line. The most comprehensive study to date, published in January, claimed HS2 would destroy or irreparably damage five internationally protected wildlife sites, 693 local wildlife sites, 108 ancient woodlands and 33 legally protected sites of special scientific interest. Environmental organisations such as Greenpeace have said the project is incompatible with the UK's climate goals, while groups such as 'Stop HS2' have put successive UK governments under pressure to cancel the project.

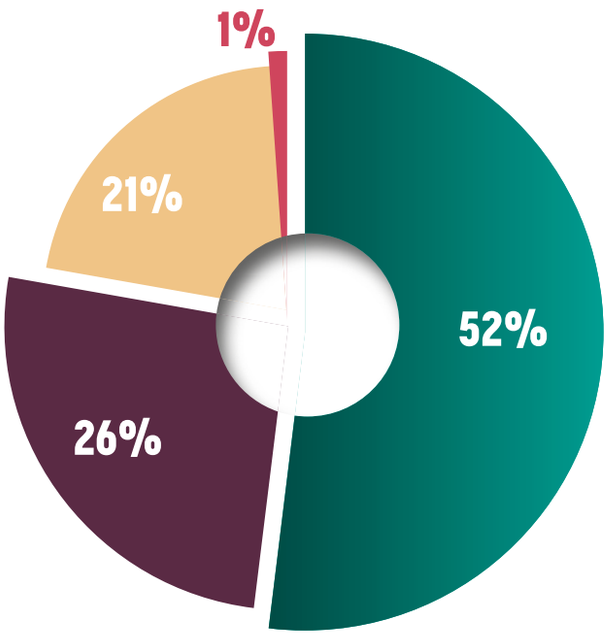
But what of the HS2's supporters? Businesses across the UK, particularly in the north of England, are invariably in favour, claiming it will dramatically improve connectivity between the commercial and industrial epicentres of the country, giving the economy a much-needed boost. Politicians have been largely supportive, seeing the project as an opportunity to help redress the north-south imbalance perceived by many who live beyond the M25.

Politics is fickle, however, and ballooning costs have frightened the herd, leading to the aforementioned Oakervee Review being established in August 2019. According to The Times, an early draft of the report states that 'large ticket price rises' would be required if HS2 does not go ahead. HS2 Ltd, the government-backed company responsible for building the new line, says the economic case for the project is strong and that it will deliver value for money. But in his recent dissenting report, Lord Berkley accused the promoters of HS2 of having 'undue influence' over the ongoing Oakervee Review, skewing the outlook in favour of the project despite evidence to the contrary.

With any project of this size, there comes a point when it becomes too big to fail. A recent freedom of information request from the Local Democracy Reporting Service revealed the total HS2 spend on buying property in London to be more than £1.25bn as of 30 June - no small investment, but undoubtedly a drop in the ocean compared to the final bill. What Boris Johnson and his cabinet must decide in the coming months is whether HS2 is worth the outlay. That decision that will cast a long shadow over this government and indeed many governments to come. THE ENGINEER

Poll: How should the incoming government deal with HS2?

Readers of the engineer are strongly in favour of axing the project, with cancellation (52 per cent) twice as popular as moving ahead with current plans (26 per cent). Around one in five respondents (21 per cent) think that the project should refocus on the northern connections it has promised, while just one per cent chose the 'none of the above' option. A remarkable 3,555 respondents took part in the poll, illustrating what an emotive topic HS2 has become in the engineering community and beyond. Needless to say, some strong opinions were expressed in the comments and the debate raged on below the line for several weeks after the poll was published.



Cancel it

Go ahead with existing plans

Concentrate on northern connections

None of the above

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

SCAN ME

IN YOUR OPINION

HS2 should be abandoned and the money put into east/west links in the North of England thus linking cities like Newcastle with Carlisle, Hull to Liverpool etc. Linking these cities would then give links to the main lines to London, Birmingham, Leeds etc. Just look at the railway maps of the Victorian/pre-Beeching era, that was a reasonably good plan.
David Banks

It should be cancelled and improvements made to the existing system including reopening "Beechinged" lines closed in the 60's and 70's. Increasing the loading gauge to allow lorry trailers to be moved by rail would also cut carbon and reduce traffic on the roads. Both of which could give a better return on investment than HS2.
Cliff

Absolutely HS2 should go ahead with the existing plan. This is a vital project that will allow high speed services to be taken off existing Victorian infrastructure and free that up for local and freight services.
Melanie Osborne

Cramming more and more people in to our already overflowing capital city and surrounding areas seems ridiculous. Especially with the latest technology to support remote working and collaboration I think we would be far better off investing the money to support growth and diversification elsewhere on our tiny island.
Simon Stevens

If the PM and his new government are serious about delivering prosperity to the Midlands and the North, while at the same time achieving a real reduction in carbon emissions, there is only one credible course of action - press ahead with HS2 Phase 1 and bring forward Phase 2a and 2b. It's a no-brainer
Carl Shillito

HS2 was flawed from the start. Stations should have been planned for the outskirts of cities, where land is much cheaper, and everything planned with cost effectiveness in mind.

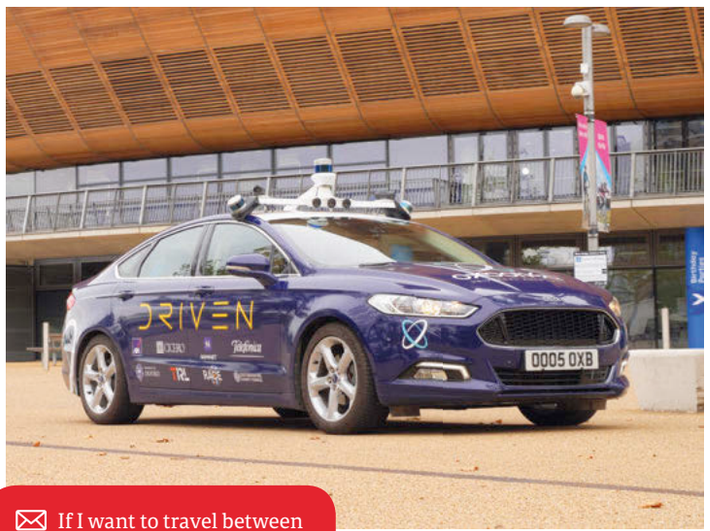
However, it would be foolish to scrap it now, at this late stage, seeing as so much money has been sunk in, and we won't get any of that back (except for workers who at least got paid for this elephant). Sorry for the opponents, but I think it should proceed. One overpriced and flawed rail connection is still much better than spending all that money for nothing.
Robert

It's a good job the Victorians didn't worry about it how much things would cost years ago. If they did we would not have any railway. So let's just get on with it.
Gandy

Cancel it! The stated benefits aren't worth the investment (£60B-£100B??), would be a lot more beneficial and cost effective in putting the money into upgrading the existing infrastructure and rolling stock - across the whole country. I suggest the current Government (same as the old) are not going to make any sensible decisions on this front. Just as BoJo didn't lie down in front of the bulldozers to prevent Heathrow expansion he is unlikely to make any decisions that impact the investments and profits of his rich buddies.
Another Steve

Ambivalent to autonomy

Our report on the public's reluctance to embrace driverless vehicles was matched by reader scepticism



If I want to travel between A and B in a vehicle I don't control I would rather use a bus or a train! I honestly cannot see any rational reason I would spend money on, or travel in these death pods.
Another Steve

These cars will be very expensive for the majority of people and also with cars changing to electric power, they won't have the capacity to go very far with the extra power required. The infrastructure has to be thought out first without rushing into the first idea that comes up! We need something more like driving assistance where the driver is still mainly in control, because it is human nature to be in control of any situation. **Martin**

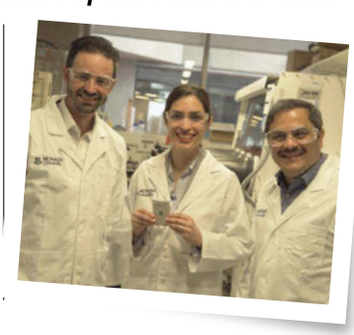
Is the whole strategy crossing the line between feasibility and desirability/utility? This whole area seems to be being hyped up but user acceptance (and insurance issues) could be the killer. **Phil Mortimer**

The pursuit of technical solutions to problems that don't really exist is largely an academic and developmental exercise, often on the grounds of 'let's see if we can make it work'. There is no doubt that the concept has advantages, but as always technical solutions only work within a constrained set of parameters and environments. The biggest problem is that outside the conceived paradigm different rules and circumstances apply and it remains the case that an informed human brain coupled with experience is far more flexible and adaptable and able to deal with unexpected and unplanned scenarios. To ensure the needed flexibility (such as in emergency) full human ergonomic controls are still required, therefore it is questionable if the additional machinery to allow a computer to do the controlling can be optimised without adding additional weight and the ability to override or be overridden as circumstances dictate. If the automatic machine is carrying around passengers who are entirely capable of carrying out the same and more functions ultimately what is the point? And how is a human 'supervisor' to be kept alert and capable of taking over in milliseconds while being chauffeured around?
Nick Cole

A lithium-sulphur battery developed in Australia is claimed to outperform market leading batteries by more than four times.

It would be great to have a factory making these in the UK.
John Hartley

Imagine my electric scooter going 80 miles instead of 20 miles. No more range anxiety.
Anthony Steele



This should / could make many more electric planes viable, due to much longer flights/charge!
Stuart Saunders

Four-times higher capacity sounds exciting, but the devil is often in the detail. What are the costs of manufacture for this new battery design/chemistry?
Gary Williams

We asked where government should target infrastructure investments

I would say local (commuting) rail, and national road infrastructure. National rail travel is too expensive to be attractive but increased local rail services will make a difference around commuter towns.
Chris

Has to be energy (specifically electricity). All coal-fired power stations are due to close by 2025 and we will be down to one nuclear power station (Sizewell B; or two if Hinkley Point C is completed) by 2030. We're going to struggle to match present-day capacity let alone new demands like EV charging and ASHP for domestic hot water and space heating. **Trevor**

Got to be energy (with rail a close second). Preferably renewable, if not then small modular nuclear, designed and built in the country.
Cliff

I voted energy. Let's invest in modern small nuclear reactors. This will benefit the whole country.
Robert Harris-Mayes

I voted Energy but not nuclear. The UK should invest more in the huge tidal resource we have. **Ekij**

PRESSING AHEAD

Mats Rahmström, CEO of compressor giant Atlas Copco, talks to Andrew Wade about how electrification, connectivity and digitalisation are driving innovation at the firm.

Even against the backdrop of London's Square Mile skyline, Mats Rahmström looms large. As CEO of industrial giant Atlas Copco, the big Swede is hosting an event at The Shard to mark the UK centenary of the company, which was founded in Rahmström's homeland in 1873. Its early days in rail construction seem an age away, and today Atlas Copco is one of the world's leading producers of air compressors. According to the CEO, change has always been part of the company's DNA.

"One thing we always speak about is the tradition of always being ready for change," said Rahmström. "It's also aligned with one of our main owners, the investor group of the Wallenberg family. And thus the move to separate the mining from industrial."

Sweden's prominent Wallenberg family has stakes in many of the country's most recognisable industrial firms, including Atlas Copco, Ericsson, Saab and ABB Group. In 2018, Atlas Copco's mining equipment division was spun out of the main business into a new independent company called Epiroc, a change it seems at least partially driven by the Wallenbergs seeking to divest from less sustainable sectors such as mining. It's a move that also fits with Atlas Copco's trajectory towards more electrification across its business lines.

"The most obvious example is the auto sector where we – maybe six or seven years ago – realised that we were heading this way and this was an opportunity," Rahmström explained.

Up until that point, Atlas Copco's primary role in the automotive sector had been powering equipment for final assembly, such as compressors and pneumatic tools for robots and manual workers.

"Then we realised that if you're going to have more battery cars, more environmentally friendly cars in general, then you're going to be dealing with frames made from lighter materials," said Rahmström. "So now if you come to us and you're an assembly company or want to build a new car - it's probably mixed materials today, with composites and aluminium – we have all the technologies to do that assembly. So that's one of the biggest changes, and I think the auto industry at this time is the most interesting to be part of in all the ways that it's changing quite rapidly.

"If you look at tools in the automotive industry, when I started – which was 30 years ago – all the tools were pneumatic. And of course we sell compressors. But for today's car industry, 95 per cent of what we sell is electric tools, smart electric tools, transducerised tools."

"It's a big engineering challenge," said Rahmström, "but it's also a competence and people challenge, because you start out with more mechanical engineers, now you have more electrical engineers, and today, half of the people working in Industrial Technique are software engineers. And then you get to digitalisation and analytics – we've decided that analytics should be a core competence for the future, so we've hired these types of engineers. So the competence journey is as important as the engineering journey."

Though at its core the company is still very much a nuts and bolts engineering firm, digitalisation is playing an increasingly important role. Rahmström understands some of the frustrations engineers have around the hype of IoT and Industry 4.0, often failing to deliver on oversold promises. Nonetheless, the right digital tools in the right hands can be a powerful thing.

Virtual and augmented reality are part of the company's wider digital strategy

Today the company is divided into four business lines, or 'Techniques'. Compressors are still very much at its heart, making up roughly half of revenues. The other half is split between the remaining three Techniques, namely Vacuum, Industrial and Power. The transition from diesel equipment to more electrically driven machinery across all the business lines is one of the key challenges Atlas Copco is facing.

"It can be very abstract, but in some areas it's very tangible for us," he said. "If you think of the Ford car factory, they could only build black Model Ts on one line. The way they sorted that out was by building in batches of cars or using different lines. But with modern day digitalisation, we can actually build six or seven different models on the same line.

> "I THINK THE AUTO INDUSTRY AT THIS TIME IS THE MOST INTERESTING TO BE PART OF, IN ALL THE WAYS THAT IT'S CHANGING QUITE RAPIDLY"

"And with our smart tools, every time you enter into station, you just scan the operation, you know exactly what parts to pick, we have the human-machine interface to guide where to tighten bolts, for example. So that's a really tangible impact of digitalisation actually working."

That impact is fundamental to Atlas Copco's digital strategy. Adopting technology for its own sake where the benefits are unclear simply adds complexity and can lead to customer frustration. But industrial companies should not be afraid to make the leap when the rewards are obvious. Predictive maintenance is one such area where Rahmström believes digitalisation is clearly working.

"We've got 130,000 connected compressors," he said. "But you need to know what to do with the data. I'd say we're in the midst of being able to predict what will happen. Since we've designed the asset, we know the asset and we can learn quicker than anyone else what will fail. We now have five digital centres for compressors around the world where people with service contracts have this service with us where we can start to make more proactive calls if something is vibrating or there's heat or whatever.

"We cannot predict which part it is yet, we are not quite on that level, but predictive is getting more and more tangible for us. We've taken it down to what is valuable instead of what is cool or what is possible. When you work with the semi-conductor industry and the auto industry, they are very demanding, so that keeps us on our toes makes sure what we bring to them is valuable."

VR and AR tools are more niche, said the CEO, but should by no means be ruled out simply on that basis. VR can have a role to play in the design process, while AR could assist in field maintenance of industrial equipment, as demonstrated by software providers such as PTC in recent years.

"It's still a niche tool and I think the ones who are leading it is service, for example on portable compressors," said Rahmström. "If you are out in the field somewhere you can use your camera and get guidance from an operator or an engineer that can look at the same thing and have see-through drawings. I don't think it will be for everyone, but it's something that could be extremely valuable with time."

That type of innovation is important for Atlas Copco to continue attracting young engineers. By Rahmström's own admission, the company may not initially be as appealing as other employers it competes with for engineering talent. But when people see the

variety of technology that underpins its operations, Atlas Copco becomes a more enticing prospect.

"Many young engineers don't realise all the cool technologies being implemented in this big industrial company," Rahmström said. "Normally we are not so attractive, looking from the outside. But when we've had people come to us and learn what we're doing and the opportunities, then they stay." THE ENGINEER

Kaylee McNally
Arlington Automotive

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Enginuity

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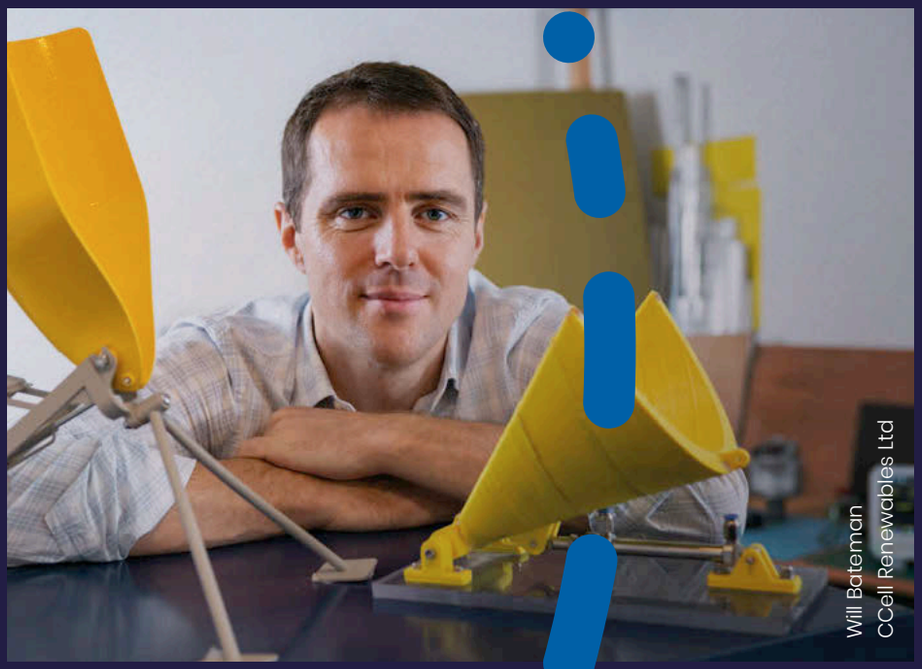

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GROWTH INDUSTRY

Vertical farming startup LettUs Grow is one of a number of UK firms developing technology that could help shore up the UK's food security. Andrew Wade reports

Between the UK's EU exit and the growing threat of climate change, food security has become a headline topic. The supply lines from farm to fork that many of us take for granted can be more fragile than we think, as illustrated by recent weather events in the UK.

"At the height of the heatwave that we had last summer, (the UK) was importing lettuce by plane from California, importing around 30,000 heads a week just to keep food on our shelves," explained Charlie Guy, managing director and co-founder of agritech startup, LettUs Grow.

Set up in 2015 while Guy was still at Bristol University, LettUs Grow is one of several emerging UK businesses focused on vertical farming, where plants and crops are grown indoors in upright stacks, typically without soil, using LED lighting, climate control and targeted nutrient delivery. Although still a relatively niche enterprise, it's attracting plenty of attention, with grocery retailer Ocado recently announcing a £17m investment in the sector.

For its part, LettUs Grow has just secured £2.35 million in seed funding, which Guy says the company will use to scale up and invest in new products. Currently, the business has two major components: its aeroponic nutrient delivery system and an integrated farm management software platform called Ostara. According to LettUs Grow, its aeroponics equipment can boost growth rate by 70 per cent across a range of crops compared to other vertical farming methods such as hydroponics, as well as reduce water usage by 95 per cent versus traditional agriculture.

"At LettUs Grow we've developed two key technologies," Guy explained. "The first is a new aeroponic method where we irrigate the crop roots with a very fine mist using a patent-pending method that we've developed over the last few years. It has massive benefits in terms of how scalable the technology is and controllable and optimisable it is.

"It's all about the amount in the root zone that plants experience. Everyone knows that healthy soil has good pockets of oxygen and nutrients and is well aerated. So this is really what we're maximising. By having no soil and an air gap you've got bountiful oxygen and carbon dioxide for plants to perform at their biological optimum."

Somewhat misleadingly, LettUs Grow is primarily a technology provider rather than an actual food grower, supplying its equipment and software to farmers and entrepreneurs seeking out new opportunities. According to Guy, the return on investment of aeroponics takes just two to three years, while the more widely used hydroponics takes between four and five.

But nutrient delivery is just one part of the vertical farming picture.

Vertical farming sees trays of produce stacked under LED lights

> **"WE CAN OPTIMISE THE PHOTOSYNTHETIC PERFORMANCE OF A PLANT"**

Advances in LED lighting, coupled with a reduction in cost, have played a key role in the sector's boom. Rather than simply replicating sunlight, LEDs can be finely tuned to different wavelengths for various crops. Combined with carefully controlled climate conditions, LEDs and aeroponics can enhance every aspect of growth, maximising crop yields.

"All of these are effectively ways that we can optimise or tune the performance of a plant so that it's most photosynthetically efficient and working at its optimum," said Guy.

The second pillar of LettUs Grow is Ostara, a bespoke software platform that can monitor and control indoor growing in greenhouses as well as vertical farms. Sensors throughout the growing environment feed back to the software, which collates the data and provides crop growth analysis. On top of this, Ostara also incorporates tracing of crop history, something that Guy believes has become more important for retailers and consumers given events of recent years.

"The real importance of this was seen in 2018 with the romaine lettuce scandal in the US, where contaminated produce was on shelves and nobody knew where it had come from," he explained.

"One of the massive benefits of indoor and controlled-environment agriculture is that we can really know where our produce has gone and what it's experienced after it was produced and grown."

The elephant in the room remains cost. Swapping sunshine and soil for LEDs and aeroponics may deliver a host of benefits, but is also comes at a price. The energy inputs currently required for vertical farming make it difficult to turn a profit on anything but high value →

herbs and leafy greens. Basil, parsley, and watercress grow quickly and sell at a premium, making them the perfect candidates for vertical farming in terms of competitiveness.

"To date we've grown around 60 different crops in our facility," said Guy. "We're mainly focused on the high-value herbs or lettuce and leafy green crops, but we've also grown things like carrots, radishes strawberries and a whole host of things like tobacco and propagation for trees."

Seasonal demand sees peaks and troughs in the price of things like cress and lettuce, and carefully choreographed growing at scale could allow vertical farms to be profitable in these types of markets. Whereas traditional agriculture has been pushed to the limits of its productivity, this nascent farming method has plenty of headroom to make leaps in efficiency as it scales up and technology improves. Urban farms that supply on demand to high-end city restaurants is one business model that Guy thinks could work, but knowing your market is key.

"There's no point growing crops that are fashionable but you don't know where you're going to sell them," he said.

"We've been working with a company who supply 20 or so of the best restaurants in Bristol - Michelin Star quality. So quality is definitely one of the biggest selling points."

Ultimately, the produce also has to be able to match conventional agriculture on price.

"Food grown in these systems has to be competitive with traditional methods...and we're building tools and features into our software that will enable efficiencies in labour and energy as well," said Guy.

One of those features is integration with renewable energy. LettUs Grow recently partnered with Octopus Energy to optimise power usage throughout the day, avoiding times of peak demand. In a controlled indoor environment, day and night can be variable concepts that reflect the vagaries of the energy market rather than the rising and setting of the sun.

"We've already shown around a 15 per cent reduction in energy through this," said Guy. "And with energy being one of the biggest contributors to most crops in an indoor facility, this is pretty significant."

Co-founder Charlie Guy inspects some leafy produce
Energy inputs make up the the bulk of crops' final cost

As well as herbs and leafy greens, the company has identified a more niche area with potential for profit. Research sectors, including the pharmaceutical industry, often require exotic plants or novel strains of crops. The closely controlled environment of vertical farming can not only guarantee provenance, it can provide tweaks and adjustments in growing conditions to produce an abundance of different outcomes on demand.

"We've been working with a company testing crops that could be used for vaccine production," Guy explained, "so there's all sorts of novel uses where you really want that tight level of control."

Despite the produce being endorsed by high-end restaurants and big pharma, the nature of the growing method has also brought some unexpected hurdles.

"At the moment we aren't able to certify as organic, even though our sustainability credentials are arguably better than organic," said Guy. "This is a bit of a sticking point, because we don't have any soil, and without any soil it's hard to certify that soil as organic."

As much a philosophical problem as a technical one, the absence of soil is nonetheless preventing vertical farming from achieving the same certifications as traditionally grown food. It's symptomatic of an industry still coming to terms with a new method and its impact. As the sector expands, these growing pains will no doubt be overcome, allowing vertical farming to play an important role in agriculture's 21st century tech revolution. THE ENGINEER

"WITHOUT ANY SOIL, IT'S HARD TO CERTIFY AS ORGANIC"

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Engineering a skills shortage solution

Employer led skills body Enginuity, formerly known as Semta, is on a mission to reshape the way that industry attracts and nurtures key skills. Jon Excell spoke to the organisation's CEO, Ann Watson.

JON EXCELL REPORTS

As the boundaries between once distinct sectors become ever more blurred and new technologies transform the way that engineers work, UK industry's skills demands are changing fast.

Add to this the fact that the sector is increasingly competing with other areas of the economy for expertise in emerging areas - such as data analytics and AI - and it's clear that when it comes to tapping into the best available talent, engineering employers face some considerable challenges.

Unsurprisingly, these challenges are also a key priority for the various organisations committed to helping industry get the skills it needs, one of which is newly launched employer-led body Enginuity – formerly known as Semta – which is on a mission to

revitalise the way that industry nurtures and attracts expertise.

The Engineer caught up with Enginuity CEO Ann Watson ahead of its relaunch to discuss the nature of industry's skills challenge and find out how the new organisation plans to address this head on.

CEO since 2015, Watson has had a front-row seat on industry's changing skills requirements in recent years. "It's a really challenging time for employers," she said. "Skills have been top of the priority list for a number of years, and as we move into the world of Industry 4.0 those skills challenges are changing. The need for data and digital skills is increasing and we're seeing a huge upskilling challenge. Sixty per cent of the manufacturing workforce of 2030 have already left school, and these are the individuals that we've got to upskill."

The difficulty employers face addressing all of this is, she added, compounded by the speed of the change. "Employers are telling us that whilst in the past job roles might have changed every 10 years, they're now changing every 3 years, and this requires constant upskilling and reskilling of the existing workforce."

Against, this backdrop, it's also becoming increasingly difficult for employers to second-guess what skills they're likely to need in the future, said Watson. "What they're telling us is that in five years' time we don't know what an engineer's going to look like but what we need is someone that's got a broad range of skills that can be applied to different situations and technologies."

The launch of Enginuity is, she said, a direct response to this situation, and borne of a realisation that to be fully effective the skills sector itself needs to embrace the same technologies that are reshaping industry. "We need to recognise that this is the world our employers are in and if we don't join that world we'll be left behind. From our perspective, we've got to be running alongside the employers – if not running faster – if we want to help them in terms of their future skills"

For Enginuity, this has meant investing in an internal data science capability which, Watson claims, has helped the organisation become much better placed to anticipate these emerging skills requirements. "We looked at how can we use the tools and techniques of industry 4.0 to create something quite special in the skills world," she said.

Expanding on exactly how the organisation can help, Watson explained that it's typically through a mixture of softer messaging – such as case studies on emerging engineers and the coverage generated by its annual awards competition – and more direct practical measures.

Here, Enginuity is particularly heavily involved in the apprenticeship arena, and along with partner organisation EAL (the awarding organisation for industry) is working closely with employers to help them develop their apprenticeship standards and also to refine the apprenticeship assessment regime. "Better data will only improve [these solutions] moving forward," said Watson. "Making these solutions even more responsive to current and future needs, an even better user experience, and even easier to integrate and measure."

Alongside apprenticeships, another priority area for the body is helping industry upskill existing employees, and it works with employers and skills bodies on the development training programmes to do just that. Whilst much of this is, inevitably, focused on the cutting edge technologies of Industry 4.0, Watson stressed that sometimes, improving an company's digital awareness, can involve something as fundamental as ensuring that staff know how to use an Excel spreadsheet.

"WE LOOKED AT HOW WE COULD USE THE TOOLS OF INDUSTRY 4.0 TO CREATE SOMETHING QUITE SPECIAL IN THE SKILLS WORLD"

Another way in which the organisation hopes to move the skills dial is through a recently launched online apprenticeship matching service.

One major problem, frequently noted by The Engineer, is that whilst big name employers don't typically struggle to attract the skills they require; less well-known, smaller companies do face significant challenges.

The Engineering Talent portal, which Enginuity has been piloting since April 2019, aims to address this by helping to funnel unsuccessful apprenticeship applications with larger companies through to SME recruiters. "The very large organisations are inundated with applications from young people for their apprenticeship vacancies," said Watson. "BAE, one of the engineering talent partners, last year sent out 1300 rejection letters. At the other of the spectrum you've got the SME who may have a great opportunity but doesn't have the brand name and can't attract the young people".

The new portal, which pulls in data from employers as well as all apprenticeship vacancies from the national apprenticeship service, points these unsuccessful applicants – many of whom would otherwise be lost to the engineering sector – at related opportunities elsewhere in the sector.

There's no doubt that the blurring of boundaries between once distinct disciplines and sectors, and the widespread need for expertise in new emerging areas create some significant challenges for employers.

But, concluded Watson, it has also created the opportunity to be more strategic about skills, and to encourage both skills bodies, and the different engineering sectors to work together in a way that they haven't before. "The skills sector's not been great at collaboration in the past," she said. "It's very fragmented. There are something like 620 different initiatives focused on schools, and 36 professional engineering institutions. The future world gives the opportunity to bring a bit more strategy and structure to things."

To this end, a key focus of the new organisation is encouraging the different skills working groups, and employers from different sectors to collaborate on the challenges they face.

"In the new digital world the skills that the aerospace, rail, and defence sectors need are becoming very common," said Watson. "We've now got people like Network rail sitting on our board because they're seeing that when they move into the world of digital railways the skillsets they need are more akin to the aerospace and defence sectors, skills they've never needed before. This creates the opportunity to get employers to collaborate, particularly on the data and digital skills agenda, and to work together, supported by Enginuity, on developing some of the digital skills solutions. We're not going to see government come in with a lot of money for skills, so it's very much down to the employers working together." THE ENGINEER

Semi-active suspension

Engineers are increasingly turning to semi-active suspension systems to optimise the seemingly-conflicting balance between ride and handling

CHRIS PICKERING REPORTS

We often talk about cars defying physics. That's perhaps something of an oxymoron. But when a high-riding 2.4-tonne SUV can dance through a set of S-bends like a sports car, it really does feel like it's bending the laws of nature. And yet that's precisely what active and semi-active suspension systems can achieve.

By adjusting the suspension to suit the prevailing conditions – or, in some cases, even pre-empting them – it's possible to blend ride comfort and dynamic ability in a way that simply isn't possible with passive systems.

One of the most effective ways of doing this is to use adaptive anti-roll bars. Unlike conventional anti-roll bars, these devices can vary the amount of load that resists the car's body roll. This allows the roll stiffness to be tailored to different use cases. For instance, the system might detect a large steering input and react accordingly or it might adapt its behaviour to different vehicle speeds.

EASY GLIDER

The Bentley Bentayga V8 uses an electric anti-roll bar system coupled with twin-chamber air suspension

Schaeffler and Continental are among the suppliers who offer systems that work on this principle. The two companies offer separate products, but they collaborated on the underlying technology, which sees the anti-roll bar split into two halves, connected by a three-stage planetary gearbox and a 48-volt electric motor. By rotating one way or the other, the motor can apply up to 1300Nm of torque to each half of the anti-roll bar, resisting wheel movement on that side of the vehicle. The torque is measured precisely with the help of a non-contact sensor and full actuation can be reached in 0.3 seconds.

One advantage of this approach is that it's relatively easy to integrate into a chassis that's been designed for traditional anti-roll bars. It's also quite energy efficient as the system only consumes energy when the motor

"ADAPTIVE ROLL BARS CAN VARY THE AMOUNT OF LOAD THAT RESISTS THE CAR'S BODY ROLL"

is applying torque (and only a small amount if it's maintaining an existing load).

The other option is to do away with the anti-roll bars completely. Mercedes' Active Body Control system uses hydraulic servos on the suspension struts to generate forces that oppose unwanted movement. Recently, the firm has taken things a step further with its Magic Body Control system, which uses a lidar scanner to analyse the upcoming road surface and pre-empt the required spring and damper characteristics.

Other cars use hydraulically-interlinked systems, where displacement of one wheel forces fluid into the dampers on the other side to resist body roll. The basic concept here is not new. Citroën and BMC both had passive interlinked systems more than half a century ago (although initially both were only linked fore-and-aft). Recently, however, Tenneco has revived the concept with its Kinetic system, which is believed to be the basis of the Proactive Chassis Control system on McLaren's Super Series cars.

Where McLaren's application of this technology takes things to a whole new level is its control. A series of solenoid-operated needle valves limit the flow rates – side-to-side and front-to-back – to continually adjust the bump and roll stiffness at both ends of the car. It's phenomenally effective and allows these cars to blend genuine comfort with the sort of cornering performance that was only available on the race track until recently.

The potential applications of these systems extend far beyond supercars, though. With the continuing SUV craze and the move towards electric and hybrid powertrains, everyday cars are getting heavier. That makes it harder than ever to control their mass while still providing a comfortable ride. The technology also complements connected and autonomous vehicles, allowing the suspension to adapt itself to the road ahead.

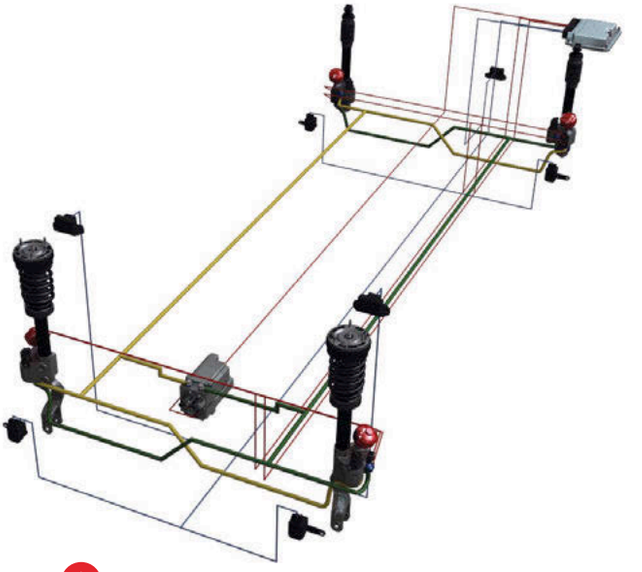
ON TEST: BENTLEY BENTAYGA

And so we head back to those S-bends. At more than 1.7 metres tall and weighing 2,395kg, the Bentley Bentayga V8 is not a natural athlete. Or at least, it shouldn't be. But flick the rotary controller on the transmission tunnel into Sport mode and it will carve through corners with barely a hint of body roll. Even in this stiffest setting, however, it glides imperiously over rough roads.

Bentley uses an electric anti-roll bar system coupled with twin-chamber air suspension. As with any semi-active system, the great benefit is that it only firms things up when you need it to – the anti-roll bar can be softened or even completely decoupled the rest of the time. In some cases, the motor is left connected and the 48-volt system can actually harvest energy from the suspension movement.

Speak to the Bentley engineers and they'll tell you that the Bentayga has the broadest remit of any of their cars. In fact, possibly of any car on the road. With its sporting heritage and 180mph performance, the big Bentley needed to deliver a genuinely dynamic driving experience. On the other hand, it also needed to offer limousine-like comfort and even a degree of off-road ability.

It's doubtful that many owners will venture off the beaten track in their Bentayga, but it nonetheless manages to provide 245mm of ground clearance and 500mm of wading depth (despite the electronics mounted on the chassis). Meanwhile, decoupling the anti-roll bar allows the wheels to reach full droop for maximum wheel articulation when driving off-road.



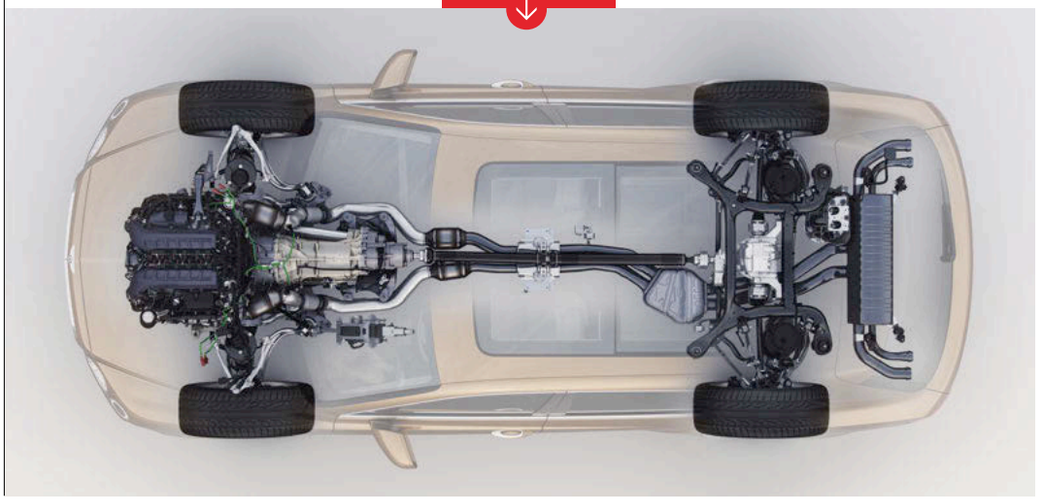
FLUID POWER
Tenneco's Kinetic intelligent suspension system uses hydraulic dampers to resist body roll

Given the focus on refinement, it was imperative that the motor-driven anti-roll bar system should be silent and seamless in its operation. There were also other challenges, such as providing cooling and managing the mind-boggling complex interaction with the other chassis systems.

Perhaps the most impressive thing about this system is that you never really sense it in action. The handling response feels consistent, whatever the speed and road conditions. It's not even the lack of roll that you notice particularly, but rather a tautness to the Bentley's demeanour and the way it responds to your inputs.

There are even more overtly sporting SUVs out there, but none that can also match the Bentayga's levels of comfort and refinement. It may not truly defy the laws of physics, but it certainly uses them to blistering effect. THE ENGINEER

GOOD SPORT
A top down view of the Bentayga's powertrain



Q&A:

CHARGING AHEAD

An expert panel discusses the charging infrastructure innovations required to support the growing popularity of EVs

JON EXCELL REPORTS

With car makers and government on a mission to bring low-carbon motoring to the masses, the number of electric vehicles on the roads is set to increase rapidly. But is current charging infrastructure fit for purpose? And how will this infrastructure evolve to meet future demand? The Engineer sought the opinions of some of the leading experts in this rapidly growing area of the automotive sector.

Meet the experts

Professor Richard McMahon – WMG, University of Warwick
Matteo de Renzi CEO, BP Chargemaster
Colin Heron - Managing Director, Zero Carbon Future
Dr. Doron Myersdorf - CEO, StoreDot

Is lack of charging infrastructure hampering the uptake of electric vehicles?

CH: There are no studies that correlate the simple number of charge posts with EV registrations. The early adopters are mainly people who live in urban centres and have off street parking. The lack of plentiful affordable EVs is what is hampering the take up of EV. The principle reason for lack of vehicles is a shortage of batteries. Europe has hardly increased installed capacity over the last 6 years and is only now installing large capacity cell manufacturing plants.

MdR: The reality is that there is plenty of capacity in the existing public charging infrastructure in the UK, and there is more being built virtually every day. One thing we need to do better is increase the visibility of the charging infrastructure that is already installed and will be installed in the future. A key benefit of our ultra-fast chargers on BP forecourts is that they will be seen by drivers of other vehicles while refuelling, which will give them greater confidence that the infrastructure is there and it's in convenient, familiar places.

DM: Based on current levels of EV ownership, the existing charging infrastructure is sufficient. However, with EV ownership predicted to increase drastically within the next few years, it is imperative that adequate infrastructure is put in place to meet accelerating demand.

Where is the greatest need for charging infrastructure?

RM: All sorts of forms of charging will be needed to reflect the diverse modes of driving. Home and work charging is great for those who have a home parking place. For those who don't, the charging hub is one model; supermarkets, shopping centres and the like are also in the game.

MdR: Ultimately, we will need the right type of charging infrastructure in the right places. It won't be appropriate, necessary or possible to lay down 150kW chargers absolutely everywhere, but it's also important that we offer these higher speeds and don't assume that everyone will be happy or able to charge at slower speeds.

DM: Having multiple charging options (unlike today when filling a gas tank at a garage is the only way) is key for allowing drivers the flexibility they

> **MULTIPLE CHARGING OPTIONS ARE KEY** Dr. Doron Myersdorf

need. Outside of cities, where driving is characterized by long distances, drivers will have to rely on a combination of home charging and public infrastructure. In this scenario, having access to ultra-fast charging facilities is imperative.

What needs to happen to drive greater levels of installation?

DM: As technological developments such as ultra-fast charging continue to overcome barriers to EV adoption, so governments around the world will have to ensure policy making facilitates rapid deployment of the supporting infrastructure. Meanwhile, simplifying regulations and installation licensing processes reduces overall costs and removes uncertainty for developers and business owners. Charging stations, especially those offering high power, require high capital investment. Therefore, the main goal must be to ensure that private investors in infrastructure projects will maintain a high level of return on their investments.

RM: The current players in charging infrastructure have invested a lot of money into the fledgling networks, but the networks are mostly (so far) unprofitable. It's risky because it's hard to predict peoples' charging behaviour patterns on 1 per cent of early adopters. Sure charging will be needed, but where and at what charging rate remain unknown to a certain degree. It's probably a cart and horse problem – the limited amount of electric vehicles means it's harder for systems to make money, therefore limiting investment in the area at this stage.

CH: The UK has no overall installation plan, and services such as ZAP MAP only find out what has been installed when it is switched on. We have a true post code lottery. There is no model available which calculates how many chargers by type are required per number of registrations (year and cumulative), as the variables are currently too complicated. The current network, with the exception of isolated pieces of equipment, is a financial liability due to the low utilisation. The more chargers that go in the financial viability drops even more, which manifests itself in lack of maintenance and frustration of the current users. The core problem is the uncontrolled installation of charge points where land becomes available and where there is an acceptable connection cost or grant funding.

What is the current state of the art?

DM Interest in EVs for heavy-duty applications and demand for ultra-fast charging are just two of the factors driving rapid development of charging technology. Ultra-fast charging requires high power stations, with the result that we already have 350 kW stations in various stages of implementation. At the same time, new standards are now being developed for even higher-power chargers – so expect to see mega-chargers capable of charging at one megawatt (MW) or more in the not too distant future. Adopting a more strategic approach, infrastructure companies will need to find a way to analyse large amounts of usage data in order to pinpoint and optimise ideal locations for charging stations, and to help standardise their technical specifications. In addition, operators will need to implement 'smart grid' algorithms and intelligent metering systems to balance peak usage and optimize the overall cost of ownership of the entire infrastructure.

CH: Charging technology is sophisticated in terms of the power electronics to talk to a car and deliver power. However, they are also quite dumb as it is the car that determines how the battery is charged. It is the battery chemistry and battery design that determine how long it takes to charge.

Dr. Doron Myersdorf - CEO, StoreDot

Colin Herron
Managing Director, Zero Carbon Future

Matteo de Renzi
BP Chargemaster

Professor Richard McMahon
WMG, University of Warwick

> **I DON'T SEE A DISRUPTIVE BATTERY TECHNOLOGY IN THE NEAR FUTURE**
> **Prof Richard McMahon**

What technologies do you see coming further down the line that will make it quicker and easier to charge EV batteries?

MdR: We would like to see more OEMs bringing vehicles to market that are capable of genuine ultra-fast charging – not just peaking at 100kW or even 150kW for a minute or two. In terms of inductive charging, we have trialled this before and even retrofitted it to previous company vehicles, but we are not seeing a huge amount of appetite for it from the OEMs.

CH: Inductive charging as you drive (dynamic) will, I believe, never happen due to the cost involved in basically digging up our main roads and installing equipment, as well as installing a power supply. Static induction charging on peoples' drives is a possibility. Outside on the street is expensive and requires dedicated charging bays.

With regard to battery technology, the current lithium ion format will get better by about 30 per cent but there will be no step change for 6 to 8 years. The current Holy Grail is solid state, which is not productionised or costed.

DM: Innovative battery technology, in addition to battery cost reduction, will play a crucial role in making EV charging both quicker and easier. With range anxiety a major inhibitor to EV adoption, the ability to charge a battery quickly whilst on the move is a critical factor to overcoming this challenge.

RM: I don't see a disruptive battery technology in the near future. If it existed, it would probably be obvious by now. However, batteries will get better but how that is cashed in is moot – smaller or cheaper packs hence cars, or longer range or ability to take higher charge or longer life?

Static wireless charging has some attractive use advantages – no cable to handle, no getting out in the rain, personal security issues and accessibility for the disabled are all valid considerations. The initial steps are being taken to demonstration, but the OEMs are still on the sidelines. THE ENGINEER

APPLICATION DETAILS

ABB drives helped cut a Madrid hotel's energy usage by 40 per cent

Q&A:

Driven by demand

Industry leaders from ABB, Rockwell and Siemens reveal customer requirements and overall trends that are shaping the evolution of drives

JASON FORD REPORTS

Drives perform different tasks for customers in numerous settings who are starting to demand IIOT compatibility, better data manipulation, more efficiency, and greater process control. The Engineer sought the opinions of experts in this field to find out how they will deliver on these demands.

Meet the experts

Arnold Taddeo, head of global product management – Drive Products, ABB Motion
Jonathan Smith - field business leader - Power & Control Rockwell Automation
Jason Peel, head of motion control business, Siemens UK

What trends / customer requirements are driving developments in your drives products?

AT: We're seeing a continuing demand from our customers for process control and reliability. We work closely with customers to help them choose the right drive, so they can reach their goals to reduce downtime and maximize productivity. Another key trend is energy efficiency, both to contain costs and to reduce emissions that contribute to climate change. Today, one-third of global electricity is converted into motion by electric motors. By 2040 the number of motors in the world is set to double. Typically, a variable speed drive in combination with high efficiency motors will cut energy consumption by 30 per cent to 50 per cent.
JS: Without doubt, the capability for drives to leverage the Industrial Internet of Things (IIoT) is pushing on developments. Customers are expressing an increasing desire to have more control over devices for improved production and quality but additionally to gain actionable, real-time data about what is happening in their plant. Having great motor control with the potential for almost infinite adjustment of speed, torque and position control is expected from a modern drive, but the best products are now capable of much more, including support of predictive maintenance, active condition monitoring and real-time power and energy usage information. Customers expect also that new products should support the latest security protocols.
JP: There is an increasing expectation from customers to gain valuable data from assets to increase productivity/availability. We can meet these expectations, as our fully digitalised factory in Congleton includes: Digital Twin technology, Virtual CAVE (Computer Aided Visual Environment), and 3D glasses-enabled demo of the 'digital factory floor'. Another fast-growing trend is customers requesting more integrated and configured products, meaning additional options to enhance performance are expected to be integrated into one or more products. This means a seamless flow of data from the customer to the manufacturer is critical to ensure fast delivery times as portfolios are now becoming more based on 'make to order'.

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

JP: One of our key customer bases for drives is logistics and intralogistics companies. For instance, in intralogistics, companies are driving productivity savings, picking and moving goods quicker with more accuracy. Similarly, in a varied sector like utilities we see water companies are maintaining reliable supply through the online monitoring of connected assets and reducing energy bills by pumping far more efficiently. This is achieved not just by the drives' components but through Total Integrated Automation (TIA). It is important to ensure that not only is a plant or facility totally integrated in all its hardware but connected through various IoT tools. For instance, our clients use →

> **"THE NUMBER OF MOTORS IN THE WORLD IS SET TO DOUBLE BY 2040"**
> **Arnold Taddeo - ABB**

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JS: A key demand in a modern plant is to maximise the availability of production operations. During downtime the cost of lost production quickly escalates, so keeping the plant online is critical. The latest PowerFlex drives have the capability to provide a detailed condition status in real time, not only of the drives themselves, but also associated motor operations, such as changes in load characteristics. This means is that rather than having fixed maintenance periods (or waiting for a failure) it's now possible to use dynamic planned maintenance.

AT: By installing Variable Speed Drives (VSDs) and electric motors with IE3 energy efficiency classification, we helped cut the energy usage of InterContinental Hotel Madrid by 40 per cent. The equipment reduced energy consumption by 445,000 kWh a year - enough to boil two million kettles of water. ABB's water dedicated drives provided crucial reliability at a key unmanned wastewater treatment plant in Pietarsaari, Finland. The drives have a built-in pump cleaning function to prevent clogging - reducing downtime and saving on manual cleaning costs. The drives can be remotely accessed, ensuring complete control of water levels to prevent the risk of flooding.

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

AT: Our ultra-low harmonic drives are designed to combat the harmful effects of harmonics that may cause electrical equipment to run erratically and increase equipment failure. These VSDs produce exceptionally low levels of harmonics, reducing electrical losses in systems and making them more efficient and reliable. We have also developed variants of the ultra-low harmonic VSD specifically for the HVAC and water and wastewater markets. These drives have been installed in mission critical facilities like hospitals, data centres, and water treatment plants. They keep power networks clean, stable and compliant with the strictest harmonic standards.

JS: An ongoing trend is for customers to be evaluating their energy usage [and] how to minimise losses in their electrical supply network. Electrical disturbances have the potential to disrupt supplies

PRODUCT DETAILS
Rockwell Automation's PowerFlex 755T has been designed to eliminate harmonics at source

[that] can lead to additional losses, resulting in extra costs from energy suppliers and increased capital costs in terms of larger supply items such as transformers or switchgear. A common electrical disturbance is "harmonics" where non-linear loads (such as conventional drives) provide a cumulative impact on the plant electrical supply network. The use of the low harmonic technologies within drives such as the PowerFlex 755T help mitigate harmonics at source.

> **"AN ONGOING TREND IS FOR CUSTOMERS TO BE EVALUATING THEIR ENERGY USAGE"**
> **Jonathan Smith - Rockwell Automation**

JP: Our Sinamics G120X drive, which we launched in 2019, meets all the latest and upcoming UL, NEMA and EN/IEC standards for 2019 and beyond, and offers up to 100kA short-circuit current rating (SCCR), ensuring enhanced product safety and energy efficiency. This drive has been developed to meet the needs of the infrastructure market competitively, having dedicated features that enable pump / fan and compressor solutions to be installed more cost-effectively and specific safety-related modes to ensure

PRODUCT DETAILS
Siemens' Sinamics G120X drive is suitable for a range of industrial environments

building heating / ventilation systems perform in all conditions. The easy-to-use drive is applied across a variety of industrial environments.

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

JP: I can see there being more integration with robotics, with drives controlling robots. Businesses will get faster operational insight as we move to 5G and overlay artificial intelligence, and software will play an increasingly important role, interpreting insight from data and proving plant improvements in the virtual world. New modelling tools combined with additive manufacturing techniques will have greater impact in new product designs, helping customisation and individualisation reach the market much quicker. Customers are also starting to request more integrated and configured products, meaning additional options to enhance performance are expected to be integrated into one product.

JS: The vision of a full IIoT platform is still quite difficult to achieve as true interoperability between multiple vendor platforms is not there yet. At Rockwell Automation, within our Logix environment we get very close to the sort of Plug-and-Play approach that people expect with personal devices. We call it Premier Integration, and it works by giving each device a dedicated profile which adapts it within the automation system and allows the users and programmers to concentrate on the automation and process control, rather than the configuration of individual items.

AT: Digital solutions allow us to make it easier for customers to use our products. For example, digital user manuals allow customers to quickly and easily access graphical and animated instructions right from their smartphone. By simply scanning a QR code located on our product, the customer has all the relevant information at their fingertips. Soon, it will be possible for customers to use their smartphone to connect their drive directly to our support team. This will allow us to quickly diagnose and resolve any issues. Fast and efficient troubleshooting will help customers maximize production uptime. THE ENGINEER

ISAMBARD KINGDOM BRUNEL: NATIONAL ENGINEER

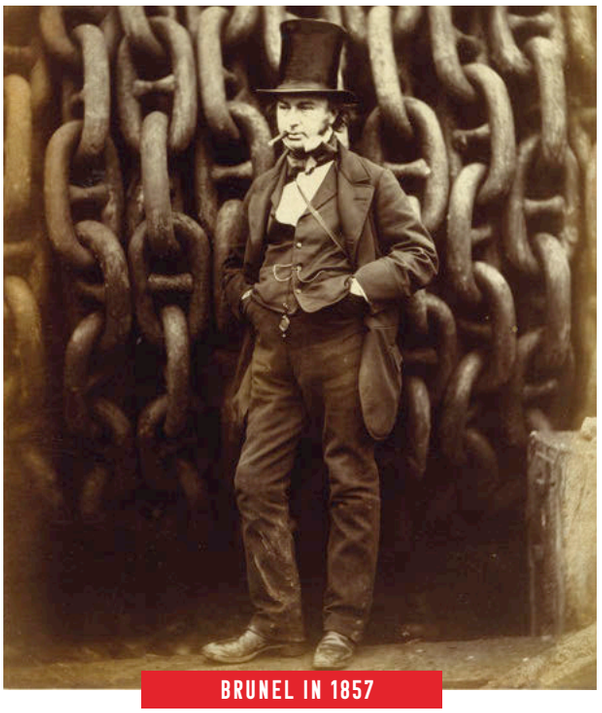
One of the best-known engineers of the 19th century, Isambard Kingdom Brunel achieved greatness in railway, civil and maritime engineering.

WRITTEN BY NICK SMITH

In 2002, the BBC conducted a poll of the '100 Greatest Britons'. While there can be few eyebrows raised at the winner – statesman Winston Churchill – to have an engineer sit in second place, above the likes of William Shakespeare, Captain James Cook and Queen Victoria, seems to say something about just how highly the British prize their Industrial Revolution heroes. The engineer in question was Isambard Kingdom Brunel.

These days, Brunel's fame is greater than our knowledge of his achievements. While those within the engineering community will know that he designed the Clifton Suspension Bridge, Paddington Station and iron transatlantic ships, it's unlikely that those outside will remember Brunel as the man behind the Great Western Railway, and even a hospital in the Crimea that was to establish the blueprint for how field medical facilities are built to this day.

Isambard Kingdom Brunel was born in Portsmouth on 9th April 1806 during the reign of George III, shortly after the creation of the United Kingdom of Great Britain and Ireland. It was a time of social and political unrest across Europe, with Brunel's father, French civil engineer Marc Isambard Brunel (a royalist sympathiser) forced to escape the French Revolution by fleeing to the United States, while his mother Sophia Kingdom was arrested as an English spy during the Reign of Terror. The couple were eventually reunited in England where they started a family shortly after the turn of the century. Their son was named Isambard, a Germanic name of Norman origin meaning 'iron-axe'.



BRUNEL IN 1857

By the time Brunel junior was eight years old, he was fluent in French and familiar with Euclidian geometry. Following a stint at boarding school in Hove (where he learned classical languages), he continued his education at Lycée Henri-IV (now the University of Caen Normandy) in Paris while his father languished in debtor's prison with a liability of £5000. On graduating, Brunel studied as an apprentice to the leading clock maker Abraham-Louis Breguet, after which he returned to England in 1822. His first appointment was with his now released father, working as assistant engineer on a River Thames tunnel project to connect Rotherhithe with Wapping, during which time he was nearly killed in a flooding incident. The tunnel eventually became part of the London Underground and remains in use today.

Although his public recognition rests heavily on one of the most significant feats of Victorian bridge building, the idea that Brunel designed the Clifton Suspension Bridge is contested. It is a matter of record that Brunel submitted four designs for the bridge (all of which were rejected by the 'Colossus of Roads' Thomas Telford in favour of one of his own designs). It is also beyond doubt that further designs by Brunel eventually won a competition (and more importantly, public opinion) to reinstate him as the designer. But the bridge itself, that would not be completed until 1864 (five years after the engineer's death), substantially differs from Brunel's original vision. Less controversial are the Hungerford Bridge – a suspension footbridge close to Charing Cross station in London – the Royal Albert Bridge in Saltash near Plymouth, the Somerset Bridge, the Windsor Railway Bridge and the Maidenhead Railway Bridge, the last of which was the widest brick arch bridge in the world and is still in service, despite today's trains being ten times heavier than they were in Brunel's time.

By 1833 Brunel was chief engineer of the Great Western Railway, a company that had been founded to reinforce Bristol's prominence as Britain's second port and primary point of departure for merchant trade to America. Brunel's largest project to date, the London-Bristol line received its enabling Act of Parliament in 1835, with the first trains running in 1838. Brunel chose a 7 ft (2,134 mm) 'broad gauge' for his railway, based on his calculations and trials for stability and comfort at high speed (later increasing this by a quarter of an inch to reduce friction in the wheel sets while negotiating curves). But with the Birmingham and Gloucester railway operating on a 4 ft 8 1/2 in (1,435 mm) standard gauge, the ensuing incompatibility meant that passengers travelling from south to north needed to change trains to continue their journey. The so-called 'gauge war' led to the appointment by Parliament of the Gauge Commission that reported in

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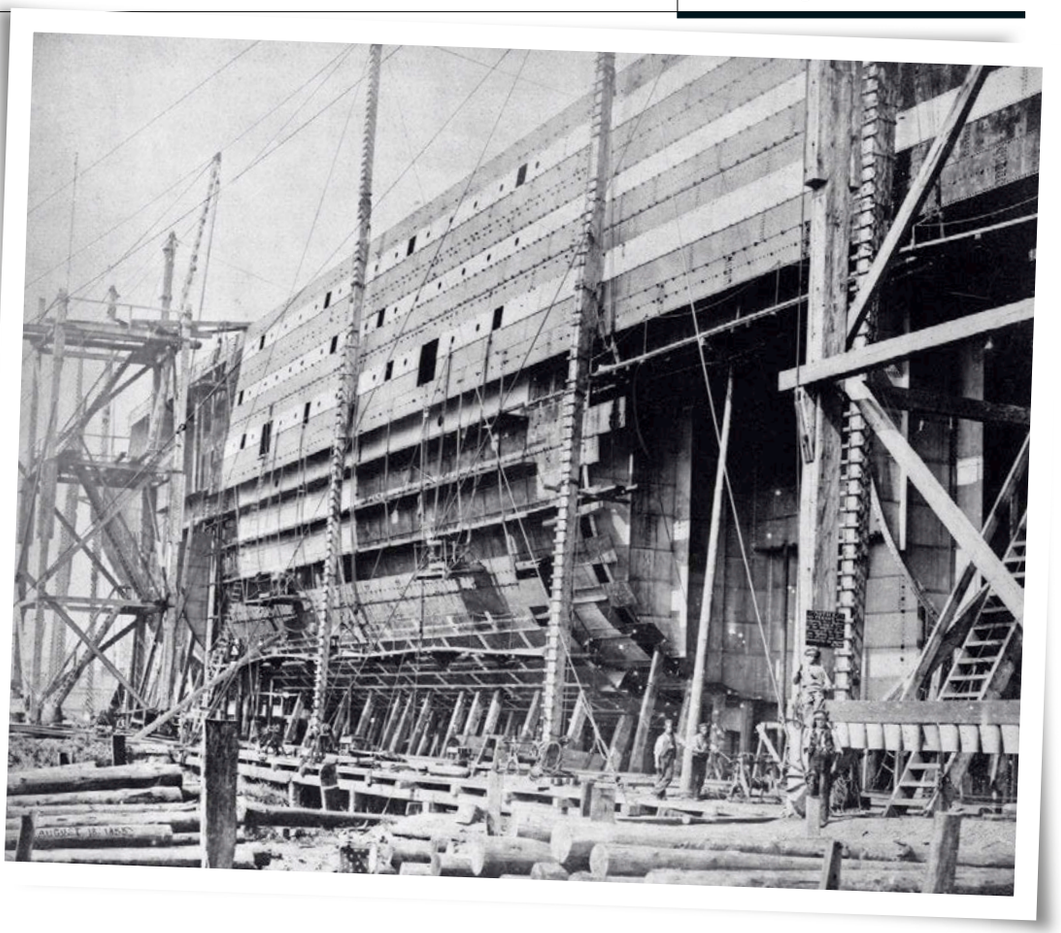

The Great Eastern under construction at Millwall

favour of the standard gauge and, apart from exceptions made for parts of the GWR, the broad gauge was phased out entirely.

The gauge war has done little to overshadow Brunel's achievement in designing the Great Western Railway's London terminus at Paddington. Influenced by Joseph Paxton's Crystal Palace that housed the Great Exhibition of 1851, it remains one of the capital's most important stations and, despite being extended and rebuilt after sustained bombing throughout the Second World War, is still recognisable as Brunel's design. A life-size bronze statue of Brunel by John Doubleday is located between Platforms 8 and 9. The same sculptor has a standing statue of Brunel in Bristol, at the other end of the line.

One of Brunel's lesser successes was his 'atmospheric railway'. The 'vacuum traction' system was intended to provide an alternative to steam power, in which locomotives were propelled along the track by means of a continuous jointed cast iron slotted pipe that lay between the rails connected to a pumping station, with pressure maintained by a longitudinal leather flap along the slot. The patented system came from shipbuilders and engineers Joseph and Jacob Samuda who, along with gas engineer Samuel Clegg, were able to produce encouraging tests in London. When put in practice on a section of the South Devon Railway, there were reliability problems with the seals and valves. The whole enterprise is described in 'The Iron Road: The Illustrated History of Railways' as an 'expensive flop.'

Brunel's vision for the Great Western Railway had always been to extend Britain's rail network across the Atlantic Ocean to America via a sea route from Bristol to New York. The technical issue facing Brunel in the mid 1830s was based on the assumption that ships powered purely by steam weren't capable of making commercially viable voyages of such magnitude. It was a matter of practicality, as the fuel required would take up all the space available in the cargo hold. However, Brunel managed to prove that while the amount of cargo a ship could carry increased by the cube of its dimensions, the resistance it experienced only increased by the square. The implications were obvious: the bigger the ship, the less fuel proportionally required. Brunel offered his services to the Great Western Steamship Company pro bono and was rewarded with the commission to design their first vessel, the Great Western, a predominantly wooden craft with steam-powered paddle wheels, the longest ever built at 236ft (72m). The ship went into regular service – 64 crossings between 1838 and 1846 – and was so successful that Brunel was asked to design another.

Great Britain was even bigger at 322ft (98m). But, more significantly, was propeller-driven and built of metal: as such, widely regarded at the first modern ship. Success was short-lived, with Great Britain meeting misfortune only one year into service, when it ran aground off the coast of Ireland due to navigation error. It was subsequently sold for salvage and is now a ship museum in dry dock in Bristol. The third of Brunel's ships – the Great Eastern – was larger still, carried a complement of 4,000 passengers and was capable of cruising from London to Sydney and back without refuelling. The ship failed to become commercially successful as a passenger vessel and was repurposed as a sub-oceanic telegraph cable-layer, so playing a role in opening up telecommunications between Europe and North America.

// BY 27, BRUNEL HAD BECOME CHIEF ENGINEER AT GREAT WESTERN //

While Brunel was working on the Great Eastern, Florence Nightingale was tending the military sick and wounded of the Crimean War at the British Army Hospital at Scutari, notorious for its unsanitary conditions that caused outbreaks of cholera, dysentery, typhoid and malaria. Nightingale wrote to the Times to force the government to provide a solution. The task was handed to Brunel, who in the space of five months managed to assemble a team to design, build and ship a pre-fabricated complex of wood and canvas buildings to the Dardanelles in 16 ships. The resulting hospital at Renkioi was an overwhelming success, with a 90 percent improvement on patient recovery compared with Scutari.

Brunel died on 5th September 1859 at the age of 53, shortly after the ill-fated maiden voyage of the Great Eastern, during which it was extensively damaged by an explosion. THE ENGINEER

FEBRUARY 1955

Top deck

The Engineer took an in-depth look at the USS Forrestal, a pioneering warship hailed as the world's first supercarrier

WRITTEN BY JASON FORD

The program to deliver the US Navy's next generation of aircraft carrier is well underway with the most recent Ford-class carrier – USS John F. Kennedy – ready for final completion and outfitting.

The 10 Ford-class carriers on order will replace USS Enterprise, which was the world's first nuclear-powered carrier, and Nimitz-class carriers that have been in service since USS Nimitz entered service in 1975.

With a ship's company of between 3000-3,200 and able to embark over 60 aircraft (and 1,500 air wing personnel), the Nimitz-class carriers were designed to have a service life of 50-years with the requirement for a single mid-life refuelling.

The Ford-class will embark over 75 aircraft but will operate with fewer crew members, saving US taxpayers almost $4bn over its 50-year service life.

A shared feature of these vessels is the canted – or angled - flight deck and the first to introduce this innovation to the US Navy was USS Forrestal, a surface ship acknowledged as being the world's first supercarrier that was launched at the yard of Newport News Shipbuilding, Virginia, on December 11th, 1954 and covered by The Engineer the following February.

Our correspondent noted that the 59,900-ton vessel – which had an overall length of 1,036ft and an extreme width across her flight deck of 252ft – would be able to 'accommodate the fast new jet fighter and light bomber aircraft, some of which will be capable of delivering atomic bombs to any part of the world.'

The canted flight deck – which had been evaluated aboard the carrier USS Antietam – covered nearly four acres, enabling aircraft to land at a slightly oblique angle to the fore and aft centre line of the ship.

"Thus, a pilot who has made a bad approach can "gun" his aircraft for another try without endangering aircraft and personnel on the forward flight deck," noted The Engineer's American Section editor.

The canted deck arrangement also provided the advantage of handling take-off and landing operations simultaneously.

"This cant or angle on the flight deck is one of the reasons for the extreme width of the present vessel," our correspondent noted. "The other advantage is that on the starboard side of the ship outboard of the island aircraft can be brought up from below without interfering with operations on the centre line of the deck.

"From the air the Forrestal does not appear to be a large ship because of the fact that her length of 1036ft is only slightly more than four times that of her extreme width of 252ft. Her island, which is the height of a ten-storey building, is almost lost on her enormous flight deck."

Another innovative design feature on board the Forrestal was that the flight deck acted as the 'strength deck'.

"Normally, the flight deck is built with expansion joints so that it is not a part of the ship's overall strength girder," The Engineer said. "By contrast, the flight deck on the Forrestal is a continuous fore-and-aft strength deck. The deck is 1¾ in steel plate, which will have no difficulty in withstanding the heat of jet blasts."

New features on the Ford-class carriers will be an electromagnetic aircraft launch system and advanced arresting gear that will help contribute to a 33 per cent increase in sortie generation compared to the Nimitz-class.

Similarly, four steam catapults allowed Forrestal to launch aircraft faster than any other American carrier afloat and 'her heavy-duty hydraulic arresters will stop one of to-day's 70,000 lb jet aircraft within 150ft after it hits the deck at a speed of 100mph.'

"The steam catapults employed were commissioned at the US Naval Air Material Centre in Philadelphia in December, 1953, and are similar to those originally developed by the Royal Navy," said The Engineer. "With an increased launching power estimated at between five and six times greater than current hydraulic models, these new catapults can launch high-performance jet aircraft even when a carrier is headed down wind or is in a dead calm. Operating steam for the catapults is provided by the conventional ship's boilers which eliminates the necessity for special petrol, oil, powder or compressed air facilities." THE ENGINEER

Aircraft carrier U.S.S. "Forrestal" being moved to fitting out basin after launching.

Slingshot

The vessel's four steam catapults enabled it to launch aircraft faster than any other carrier afloat

GARETH L. POWELL

Stairway to heaven

From sub-surface freight delivery tubes, to space elevators for ferrying workers to off-planet manufacturing facilities, resident science fiction writer Gareth L. Powell ponders some of the ingenious transit technologies of the future.

Last month's story on magnetic product delivery caught my eye. It detailed London start-up, Magway's plans to build a nationwide network of pipes along which freight could be moved using magnetic waves of electrical current. The idea is to remove freight from the roads and eliminate tonnes of CO2 emissions.

As a science fiction author, I've heard similar schemes before, from the pneumatic passenger tubes of the 1940s to Elon Musk's Hyperloop. But the difference with this idea is that it doesn't require a vacuum or low pressure in the tunnels, nor is it trying to solve the problem of transporting humans at supersonic speeds. Instead, its pallets trundle along at 31 mph, milliseconds apart.

London already has a low speed tube-based network for transporting passengers. It's called the Underground, and it handles around 2 million people per day. Creating a network for freight makes a lot of sense. Rather than entrust the delivery of your takeaway dinner to a cycle courier, you could order it from a restaurant and collect it, still hot, at your local terminal. And if companies such as Amazon took to the system, you could use it to get almost anything you wanted delivered.

Better yet, if each pallet carries its own RFID chip, you would be able to track its exact postion as it made its way towards you beneath the streets. No more waiting in for delivery drivers who may or may not show up within the time window they've given you. Instead, you can see your new flatpack armchair has just passed under the Thames and will be ready to collect in ten minutes.

Science fiction has always been full of ingenious mass transit systems—some more plausible than others. Larry Niven wrote about moving pavements, which he dubbed "slidewalks," while British author Peter F Hamilton envisions trains utilising a network of wormholes to travel around the globe, and even to other planets!

One of the most mindboggling concepts to have been dreamed-up is the space elevator—an idea used by scores of writers, including Arthur C. Clarke, Iain Banks, Kim Stanley Robinson, and Alastair Reynolds.

First proposed in 1895 by Konstantin Tsiolkovsky, the space elevator is simple to describe but harder to build. It involves a length of extremely strong material—maybe carbon nanotubes - reaching from the surface of the Earth to geosynchronous orbit. A counterweight on the far end keeps the structure taut. Passengers and freight can then be moved up and down in pressurised elevator cars, without relying on the uncertainties of rockets or parachutes.

Such a structure would drastically lower the cost and risk of shipping materials into orbit. Half a dozen towers, placed strategically around the equator, might make it economically feasible to move most of our manufacturing off-planet, cutting down on industrial pollution. It would also open the way for space tourism and travel to the moon and other planets—a true engineering marvel.

> "PASSENGERS CAN BE MOVED UP AND DOWN IN PRESSURISED ELEVATOR CARS WITHOUT RELYING ON THE UNCERTAINTIES OF ROCKETS"

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Can you imagine taking an elevator from an equatorial nation, and then watching as it rises smoothly into the air? The ground drops away, and then the curvature of the Earth becomes visible. And still you rise, until you're 22,236 miles high. This is geosynchronous orbit. A satellite at this height will take the same amount of time to orbit the Earth as the Earth takes to revolve, so the satellite will appear to remain motionless above the same spot. Here there will be a space station. Maybe a luxury hotel, some corporate offices, and a staging area for transfer to some of the nearby stations and factories that share this orbit, strung between the various elevators like a diamond spider's web.

It sounds like something out of Star Trek, but the realities of our strife-based world mean the ownership and operation of these towers would need to be carefully agreed in order to stop one group or nation gaining a monopoly on orbital access—and to stop the towers themselves becoming targets during wartime. In Red Mars, Kim Stanley Robinson depicts the fall of one such elevator after a terrorist attack. The falling cable wraps itself twice around the planet's equator, causing huge amounts of death and destruction. Trust me, you do not want to be standing under one of those when they come crashing down!

Personally, I think I'll stick with the London Underground. It has its frustrations, but also its charms—and unless you fall asleep on the Circle Line, you don't have to travel 22,000 miles to get to work!

THE ENGINEER

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MISSED OPPORTUNITIES FOR ENGINEERING INSPIRATION

It's great that Bloodhound's back on track, but as our anonymous blogger writes there are plenty more projects out there with the potential to get people excited about the dynamic nature of engineering

Now that Bloodhound is finally up and running we once more have a dynamic engineering figurehead in the public eye. However there are other projects that, in the past decade or two, have garnered as many column inches in the general press whilst barely acknowledging our profession's input. That's not to say the technical aspects have been totally ignored but rather that the "human story" behind each one has been very much to the fore.

Prime examples of this are to be found within the railway preservation community via Tornado and Flying Scotsman. When first unveiled, coverage of the former tended to give timescales and personal sacrifice but, excepting a specific documentary hidden in the schedules, little of the engineering aspects that had to be overcome. True, numbers tend to be trotted out – x hours, y tons of steel, etc – but these are simply journalistic shorthand for the commitment required to fulfil the project's goal.

The Flying Scotsman came out of her protracted rebuild to national hysteria with, again, just a couple of notable documentaries by Auntie Beeb shown on secondary channels. Well, apart from numerous items about "Excitable of Winchester who has been waiting 10 hours in the rain to catch a glimpse as the train goes by", inevitably quoting so many millions of pounds, so many years and so on.

Coverage of both missed opportunities for shots of drop hammers beating huge ingots into shape, the flash of acetylene as plates are cut or the raw sparking crackle of molten metal being poured. Missed opportunities too for showing the rising excitement as locos are built up from dead, disparate parts to become something that breathes and lives through fire and steam. The language of the engineer is one that draws on the lexicon of mathematics and physics, illuminated through plan and drawing. The deciphering of these equation heavy incantations, glimpsing the secrets of the dark arts of engineering – surely that is what hooks the next generation and brings them in?

Look around and there are plenty of similar projects on the go with the potential for sustained long term, in depth coverage. Bentley are building a batch of new "1929" 4 ½ litre cars, the DeHavilland Sea Vixen is starting to be repaired after her wheels up landing and – the inspiration for this piece – the Hawker Typhoon Preservation Group is aiming to rebuild RB396 to flying condition.

For those who don't know, the Typhoon was a late World War II heavy fighter which actually came to excel as a ground attack aircraft. A role that, in particular, was critical in allowing allied forces to make headway immediately after D Day. One of the self-imposed remits for the restoration team is to use as much original material in the aircraft as possible and in the latest newsletter there is a very good piece about the work currently underway on the rear fuselage. As well as using basic technical terms it covers aspects such as the annealing and dressing of aluminium. It also briefly explores the idea of aircraft having a design life and the financial consequences of preservation rather than manufacture from new. It has enough basic information to entice the novice whilst retaining enough content to interest the knowledgable and stands as a model of how the work of our profession can be portrayed to the masses.

The internet provides plenty of opportunity to get this kind of article out there but, perversely, that also means so much is out there already its difficult to get anything noticed by those beyond the already engaged. Promotion by an engineering big hitter, be it commercial organisation or institute, would surely help? The ideal would be a broadcaster picking up the baton and really running with it. Coverage of these kinds of projects should not be produced and broadcast as niche or "minority interest". They should not be sidelined while C-list celebrities just being C-list celebrities fill prime time slots on major channels. They are far too interesting, and important for that. THE ENGINEER

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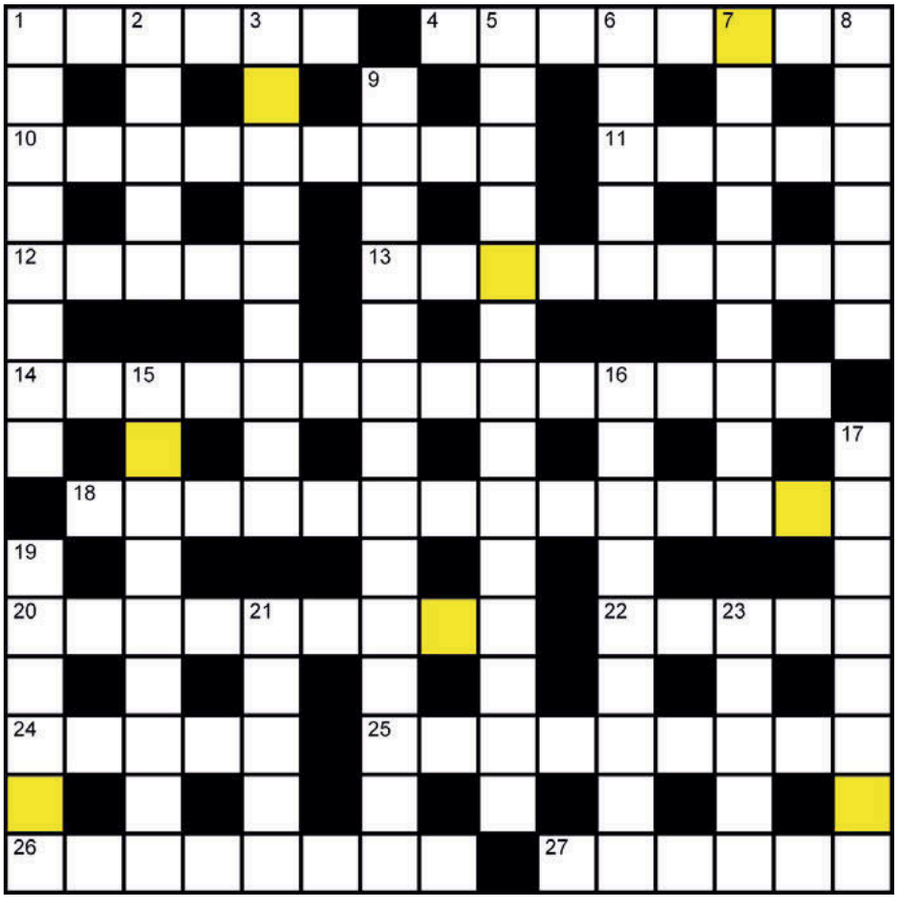

Across

1 Instrument that provides a flashing light (6)
4 Metal fastener similar to a staple (5,3)
10 Structure used to contain an area (9)
11 Compound formed in the reaction of an acid and an alcohol (5)
12 Storehouse for goods (5)
13 Old name for sulphur (9)
14 Whole amounts such as 1,2,3 etc. (7,7)
18 Home appliance for cleaning clothes (7,7)
20 Excess of revenues over outlays (3,6)
22 Enclose with a barrier (5)
24 Reddish brown dye (5)
25 Flows from a leaking tanker (3,6)
26 Trial in realistic working conditions (4,4)
27 In addition (2,4)

Down

1 Pouring out in drops (8)
2 Summarize briefly (5)
3 Burner used in welding (9)
5 Valuable substances like gold and silver (8,6)
6 Creative thoughts (5)
7 Collection containing a variety of sorts of things (9)
8 Given special treatment (6)
9 Motion in which the velocity at any point varies erratically (9,5)
15 Aerial for receiving broadcasts (2-7)
16 Replenishes with excavated material (9)
17 Turning in an opposite direction (8)
19 Fix firmly and stably (6)
21 Undergo a chemical change (5)
23 Small concavity (5)

CROSSWORD PRIZE

When completed rearrange the highlighted squares to spell out a free-standing structure near a main building. The first correct answer received will win a £20 Amazon voucher. Email your answer to **jon.excell@markallengroup.com**

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