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Higher power

The quiet rise of electric aircraft



Bright future

How Diamond Light Source is helping advance additive technology

»24



Special relationship

HP's chief engineer on the closer bonds between hardware and software

»26



Up front

Getting to grips with the Honda Civic Type R

»30

Careers

New engineering opportunities as the UK's rail renaissance gathers momentum

»40

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this issue

Volume 297
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news

- 04 Nuclear** Breathing new life into power plants
- 06 Augmented reality** Keeping firefighters safe
- 08 Space** Hunting exoplanets with light-sensitive detectors
- 10 Rail** Alternatives to diesel trains

opinion

- 14 Viewpoint** Stuart Bradley
- 16 Mailbox** Your letters to the editor
- 18 Hayaatun Sillem** Engaging the next generation of engineers
- 26 Interview** Chandrakant Patel
- 28 Scifi eye** The imaginary prospects for currency

features

- 20 Cover story** Hybrid electric aircraft could revolutionise aviation
- 24 Additive** Molten substances and additive manufacturing
- 30 Car of the issue** Honda Civic Type R
- 40 Careers** Opportunities in rail
- 45 Archive**
- 46 Digest**

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our opinion

Electric dreams



Although it may not be universally popular with readers of *The Engineer* (see mailbox, p16), electrification is now a well-established and, we would argue irresistible, trend in the automotive sector. Last month's Frankfurt Motor show, which *The Engineer* was fortunate enough to attend, provided a striking illustration of this – with OEMs and suppliers almost universally united in putting electrification at the heart of their future plans.

In this issue's cover story (Higher power, p20), we ask whether the electric revolution sweeping the car industry might be about to do the same for the civil aerospace sector.

From the epic round-the-world achievements of Solar Impulse – the world's first renewably powered aircraft – to the landmark channel crossing of Airbus's E-Fan battery-powered two-seater in 2014, we have long kept an interested eye on an area that while technologically fascinating, appeared to have little chance of replacing the incumbent technology.

“There is considerable momentum behind the development of hybrid aircraft that derive a huge amount of power from electric motors”

However, with the sector now apparently reevaluating the way in which electric power systems could be deployed, that is now beginning to change.

As we report, the industry appears to be turning away from the idea of a pure electric aircraft: power-to-weight ratios for batteries fall a long way short and range anxiety acquires a terrifying new resonance when you're 39,000ft above the ground. What's more, lightweight two-seater electric planes are only ever likely to appeal to a small number of people.

Instead, there's now considerable momentum behind the development of hybrid aircraft that derive a significant amount of power from electric motors but are kept topped up by, for instance, kerosene-fuelled range extenders. Many believe that for short-haul flights such aircraft could offer genuine competition to their noisier, heavier, and more polluting jet-powered cousins.

There are lots of challenges ahead, and it's unlikely that the primacy of the jet engine is going to be threatened, or that electrification in aerospace will have the revolutionary impact expected in the automotive industry. But as the barriers between disciplines and sectors become ever more blurred, we can surely expect the aerospace sector to be emboldened and inspired by the changes it sees occurring in the faster-moving automotive space.

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NUCLEAR

Breathing new life into power plants

Project aims for a significant increase in generating capacity HELEN KNIGHT REPORTS



An EPSRC-funded project, led by researchers at Strathclyde University, is attempting to develop the technologies and expertise that is needed to extend the life of nuclear power plants.

Nuclear power is undergoing a renaissance in the UK, thanks to concerns about greenhouse gas emissions from fossil-fuel plants, and a major government programme of investment in the sector.

However, with the industry already facing significant skills shortages, investment in new nuclear plants and efforts to extend the lives of existing plants, alongside a parallel programme of renewal in nuclear submarines, is placing considerable strain on the industry.

The Strathclyde project, which also includes partners Babcock International Group, BAM Nuttall, Bruce Power, EDF-Energy, Kinectrics,

the Weir Group, Imperial College, the Alan Turing Institute and the universities of Surrey and Cranfield, is aiming to reduce the cost of managing and maintaining existing nuclear plants, and increase their generating capacity, by improving their health.

This project should therefore help to reduce the cost of nuclear energy for consumers.

The expertise and technology produced as a result of the project will also be fed into the development of next-generation nuclear plants, according to Prof Stephen McArthur at Strathclyde, who is leading the project.

“One of the big challenges facing the industry at the moment is plant lifetime extension, how you extend the life of nuclear power plants to allow them to continue providing electricity generation in the medium term, as part of our drive towards a low-carbon economy,” said McArthur.

To this end, the researchers will investigate advances such as

autonomous non-destructive evaluation and inspection technologies. In particular, they aim to improve the ultrasonic inspection technologies used to monitor the health of nuclear plants, said McArthur.

“There are a number of challenges around the infrastructure, which include the reactor core, and then widening out into the systems associated with that, and beyond it to the mechanical equipment such as pumps and valves, and the electrical equipment,” he added.

The researchers will also investigate the use of bacteria and other biological organisms to develop self-healing concrete. Concrete, used widely in nuclear plants, is prone to cracking, which allows water to enter and degrade the structures.

By adding bacteria capable of using water and a feedstock to produce cement-like substances, for example, the team hopes to develop structures that can heal any cracks or holes for themselves, before they become significant.

Finally, the researchers aim to investigate how advances in machine-learning technologies could create smarter nuclear power stations, said McArthur.

“We will be looking at how we translate the recent advancements in data science into operational systems within the nuclear field, so that as you are gathering lots of data from plant and equipment, you can be automatically informed of any major deviations and issues that you need to be aware of,” he added.

The technology could also allow plant operators to predict issues before they arise, said McArthur.

Ultimately, the team hopes to take laboratory research at a low technology readiness level, and develop it into prototypes for applications within the industry, he added.

“We will take what is being envisaged in a laboratory context and show that it works for data or equipment within the industry, in the short term as prototypes, and then in the longer term we will work with the supply-chain partners to turn the technology into products and systems that can be used for day-to-day operations in the plant,” said McArthur. ■

Read **more** online

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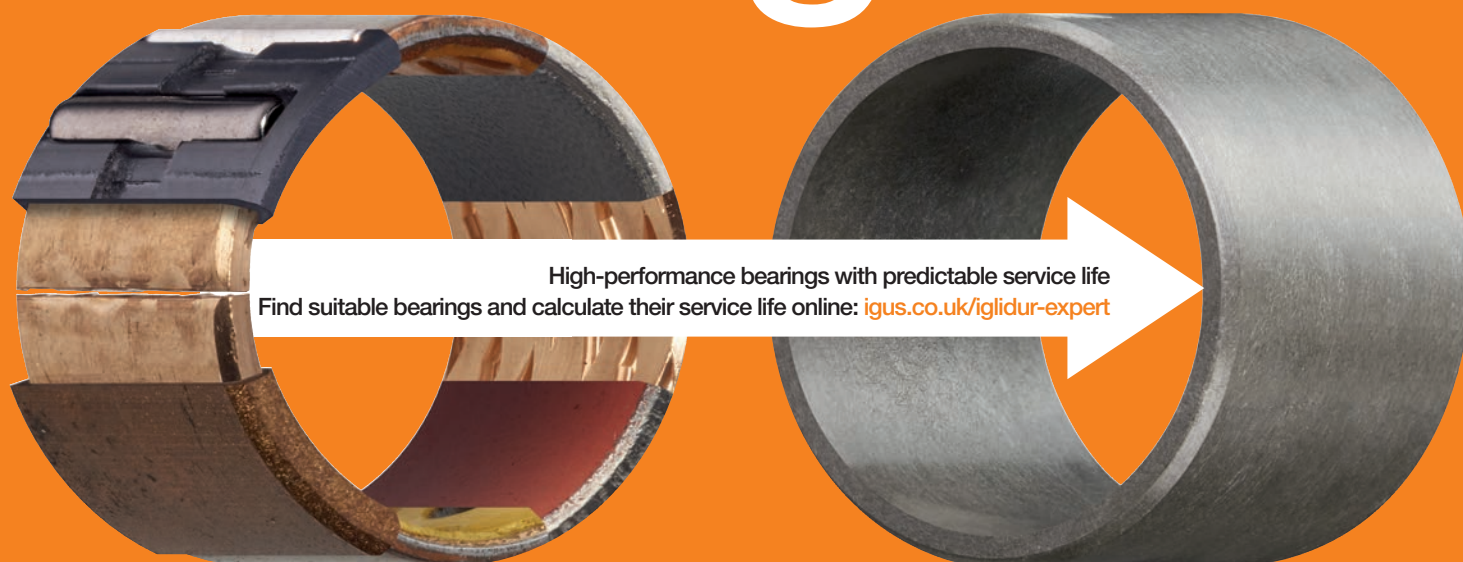
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AUGMENTED REALITY

Seeing flame is an aim of the game

Glasses could assist in the future safety of firefighters **JASON FORD REPORTS**



The AR glasses are under development at BAE Systems

Firefighters might one day be able to go further into hazardous situations and exit safely thanks to augmented reality (AR) glasses that are under development at BAE Systems.

The company is using its heritage in AR to close a gap that exists between bulky and unadaptable systems used by the military and commercially available equivalents that tend to be large and fragile.

To this end, BAE Systems used DSEI 2017 to unveil a wearable AR

concept that uses its patented waveguide technology to provide optical performance and efficiency in a miniaturised, ruggedised package.

Scheduled for qualification and validation in 2019, the product will be worn like a pair of glasses and use free-space tracking technology to display guidance, targeting, and mission information to the user, along with sensor video.

BAE is engaging with customers to gain feedback to inform the design and capabilities of the final product.

Rob Merryweather, director of Strategic Growth at BAE Systems'

Electronic Systems, said the technology brings together three key technology threads: display; a tracking solution that understands where a person is located; and imaging technologies that enhance the performance of the human eye.

In the firefighting scenario, Merryweather envisages a visual display that shows a trail of 'virtual breadcrumbs' as firefighters go into a building.

"That means they can get out of that building more quickly, they can retrace their steps with confidence," he said. "That in turn means firefighters can potentially go further into a building than they would previously have done so without that technology. At the point where we do that, we've got to make sure that display continues to work so they can find their way out again."

Merryweather added that the final product will give users an experience similar to watching a 52in TV from 5ft away, so information can be overlaid around the periphery without hindering the view.

One hurdle that must be overcome is powering the glasses.

"We know that we're capped at 2W per side. At more than 2W per side the temperature close to the head becomes too much of a problem," said Merryweather. "We're a little bit dependent on how much efficiency we get out of the waveguide when we do that development, but ideally we would like to be much closer to 0.5W to a 1W per side. Again, as we go through this we'll understand where that needs to be." ■

Newsinbrief

Tariff turmoil

The US Department of Commerce is to impose a 220 per cent import tariff on Bombardier C Series jets, a decision that could jeopardise UK jobs. Boeing claims that Bombardier has received unfair state subsidies from the UK and Canada to clinch a deal with Delta for 75 aircraft plus options. Bombardier employs over 4,000 people at its Belfast plants, around 1,000 of whom are linked directly to the C Series.

Sign of security?

Tata Steel Limited and ThyssenKrupp signed a formal agreement that could secure the future of Port Talbot, home to the Indian conglomerate's strip steel business. The memorandum of understanding signed between Tata and German engineering group ThyssenKrupp marks the latest stage in the development of a joint venture between the two companies.

Green summer

New data from National Grid has shown that growth in renewable energy helped make summer 2017 the greenest since industrialisation. From 21 June to 22 September, almost 52 per cent of electricity generation was met by low-carbon sources, including solar, wind and nuclear. The same period in 2013 saw just 35 per cent of energy needs coming from low-carbon generation.

Cleaner focus

Coventry University is partnering with German firm FEV to build a new £30m facility focused on clean transport and advanced powertrain technology. The low-carbon centre will be home to four advanced powertrain test cells. These will allow researchers to test and improve performance and emissions on different powertrain concepts.

AUTOMOTIVE

Dyson moves onto electric slipway

Company's battery electric vehicle set for 2020 launch

JASON FORD REPORTS

Dyson is expanding into the automotive sector with a battery electric vehicle (EV) that will be launched by 2020.

In an email to company employees, company founder James Dyson said the move to an electric vehicle has been prompted by a desire "to find a solution to the global problem of air pollution" and that the technologies underpinning the company's products could now be employed in an EV.

"At this moment, we finally have the opportunity to bring all our technologies together into a single product," he said in his missive.

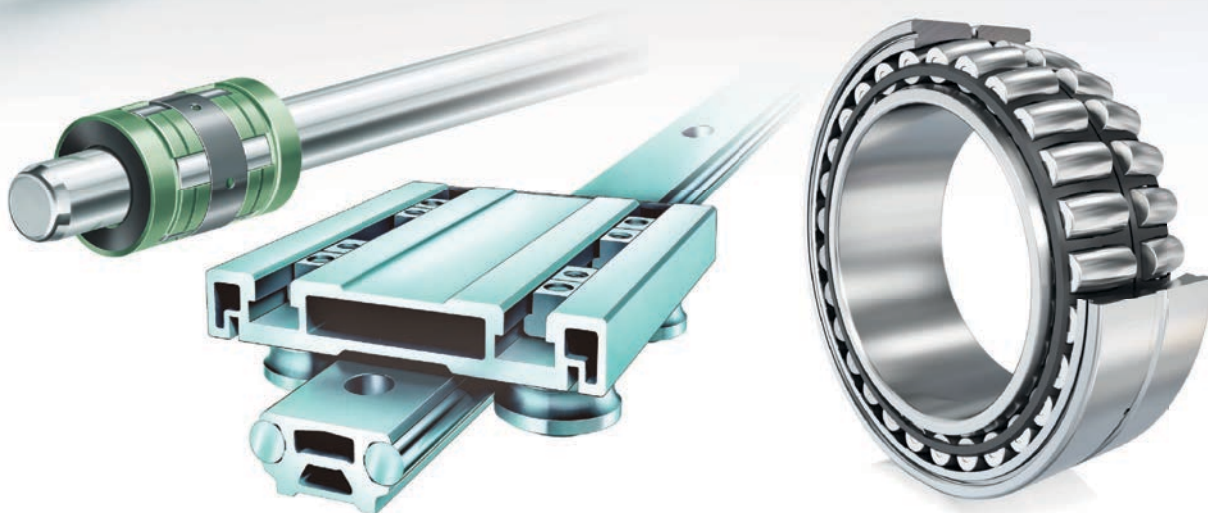
To this end, more than 400 Dyson engineers and "talented individuals from the automotive industry" are taking part in the £2bn project.

"The project will grow quickly from here but at this stage we will not release any information," said Dyson. "Competition for new technology in the automotive industry is fierce and we must do everything we can to keep the specific of our vehicle confidential."

Taavi Madiberk, CEO of Skeleton Technologies, said: "With tech players such as Dyson now entering the electric car market, it is clear that the competition in the sector is reaching new heights and is ripe for disruption. Dyson's move into this market is set to further ignite an already dynamic sector." ■

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SPACE

Throw some light on dark matters

Detectors will help to search for signs of life on exoplanets ANDREW WADE REPORTS

A €42m European Space Agency (ESA) contract to develop highly sensitive light detectors for the upcoming PLATO mission to hunt exoplanets has been awarded to Teledyne e2v.

PLATO (Planetary Transits and Oscillations of stars) will carry 26 telescopes mounted on a single satellite platform, enabling it to survey huge areas of sky simultaneously. Each telescope will be equipped with four Teledyne e2v Charge Coupled Device (CCD) visible-light detectors. The detectors measure the dimming of a star's light when a planet passes in front of it, allowing scientists to predict which exoplanets may have atmospheric conditions conducive to life.

"The basic principle is similar to detectors that are used in digital cameras, but those used in PLATO are very much larger and more sensitive," said Dr Paul Jorden, astronomy technical specialist at Chelmsford-based Teledyne e2v. "The detectors are made of silicon that converts light from the stars into electrons that can then be read out through an integrated circuit."

Astronomers know of several thousand exoplanets orbiting stars outside our solar system, many of which were discovered by the Kepler

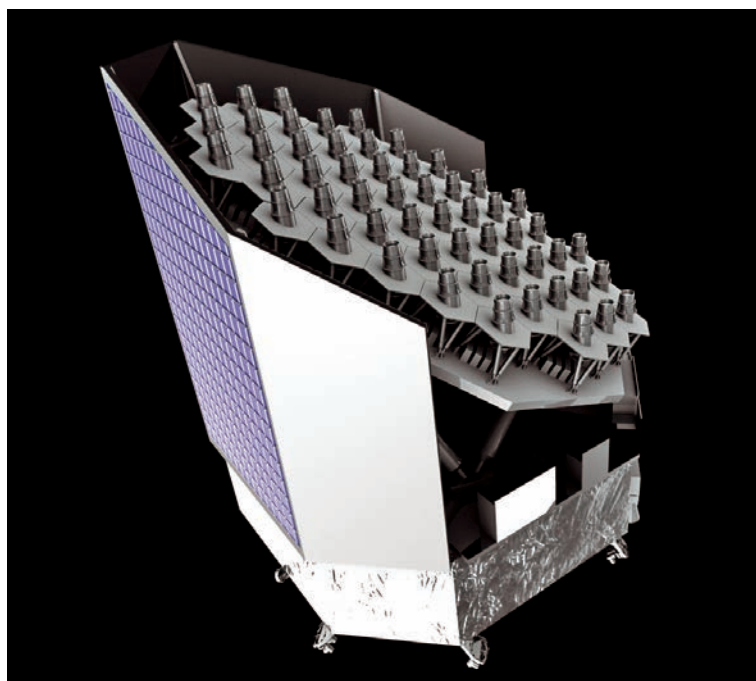
and CoRoT space missions, themselves equipped with Teledyne e2v's CCD detectors.

Jorden said the CCDs will be manufactured using a specialised version of the semiconductor manufacturing process that is also used for integrated circuit production. Specific methods to improve sensitivity and electro-optical performance are used to achieve the ultra-high performance, so that almost 100 per cent of the

light falling on a PLATO CCD will produce an output signal.

PLATO's CCDs will individually be capable of counting 20 megapixels and will come in full-frame and frame-transfer variants. Each telescope will therefore comprise about 80 megapixels, giving PLATO an overall total of 2.12 gigapixels. This is more than twice the equivalent number for GAIA, the previous largest camera in space. According to Jorden, PLATO could be an important stepping-stone to finding life beyond Earth.

"Follow-up missions to PLATO will then look at a small number of exoplanets in more detail to see if they are likely to support life, for example, if they have an atmosphere," he said. "The answer to this question will have a great impact on what we know and how we think of ourselves as human beings." ■



PLATO's 26 telescopes will carry light detectors. Credit: Thales Alenia Space

AUTOMOTIVE

Clean sweep on runways and roads

Collaboration will work on fully autonomous electric road sweeper

JON EXCELL REPORTS



The autonomous vehicle arm of Midlands sports car manufacturer Westfield has plans to develop the UK's first fully autonomous pure-electric road sweeper.

The company will collaborate with outdoor cleaning specialist Johnston Sweepers and machine-vision expert Fusion Processing.

Westfield CEO Julian Turner said the initial aim is to develop technology for use in the detection and removal of foreign objects from airport runways and aprons, but it could ultimately improve the efficiency of road sweeping.

Damage caused by foreign objects at airports is estimated to cost the aerospace industry around \$4bn per year, and many debris-detection systems still rely heavily on the human eye. Turner said that the use of autonomous systems equipped with advanced sensing equipment could help reduce the chance of human error and improve detection rates.

He added that the vision for road-sweeping applications is to replace the large diesel vehicles currently used with fleets of smaller, lightweight vehicles that would be stationed in strategic areas and head out regularly to clean their local streets. "Rather than having a vehicle sitting there 80 per cent of the time not doing anything these vehicles will be 90 per cent utilised," he said.

Turner hopes to have a prototype vehicle ready by early 2018. ■

MEDICAL

Engineering the NHS mindset

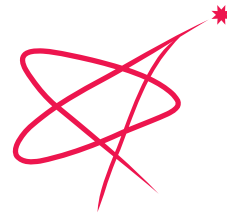
Report looks to augment patient care

The application of an engineering mindset could help relieve pressure on the NHS and improve patient care.

This is the key message of a cross-disciplinary report from the Royal Academy of Engineering (RAEng), the Royal College of Physicians and the Academy of Medical Sciences.

The NHS faces challenges, including the impact of funding cuts to the pressures of an ageing population.

The RAEng-led report *Engineering better care: a systems approach to health and care design and continuous improvement* claims that it will only be able to effectively meet these challenges by applying systems-level approaches common to engineering, an approach that gives careful consideration to the way every element of the system - in this case patients, carers, clinicians and other staff - interacts. **JE**



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RAIL

Hydrogen set for Liverpool tracks

Proposed trial seeks alternatives for diesel trains **DAVID FOWLER REPORTS**



Alstom's Coradia train is undergoing tests in Germany and the Czech Republic

Alstom wants to test its hydrogen-powered trains in the UK and is in talks about running a trial in the Liverpool area.

The Department for Transport's recent scaling back of rail electrification plans means there will be greater demand for non-electric trains, including alternatives to diesel.

Alstom UK managing director for trains and modernisation Mike Hulme said: "We're working with

Liverpool city region to establish a source of hydrogen from the refineries in the Ellesmere Port area and we believe that the Liverpool area would be a good test case."

Hulme suggested Liverpool-Chester services as a suitable trial for the hydrogen train. Network Rail's Halton Curve project is currently under way to restore a section of track near Frodsham in Cheshire, making possible a new hourly service between Liverpool and Chester from December next year. Alstom's new Widnes technology centre is

nearby, and north-west England has an established rail engineering skills base, he said.

He added: "There has been dialogue with Liverpool city region and various Roscos [rolling stock operating companies] about how we can develop a demonstrator. It is an option that we're pushing quite

"We are working with Liverpool to establish a hydrogen source"

Mike Hulme
Alstom UK

heavily, and we seem to be getting some traction."

Alstom's Coradia iLint train, powered by a hydrogen fuel cell, is currently undergoing tests in Germany and the Czech Republic, with the aim of conducting passenger test runs on the Buxtehude-Bremervörde-Bremerhaven-Cuxhaven route early in 2018. In March 2017 it performed a successful test at 80km/h on Alstom's test track in Salzgitter, Lower Saxony.

Hulme said emissions would drive a search for alternatives to diesel, and questioned whether emissions from diesel trains around key terminus stations such as Euston would be tolerated in the medium to longer term. "I suggest they won't, so there has to be an alternative."

Other options include battery technology. Bombardier has conducted research in this area and modified a Class 379 Electrostar to demonstrate it could match the performance of the electric version running on battery power. ■

AEROSPACE

Gearbox is all set to reach new heights

Aero gearbox sets new records

HELEN KNIGHT REPORTS



Rolls-Royce's Power Gearbox has set a new record by reaching 70,000 horsepower during tests at its facility in Dahlewitz, near Berlin, Germany.

What is claimed to be the world's most powerful aerospace gearbox is to be used in Rolls-Royce's UltraFan engine, which is due to be available for service by around 2025.

The Power Gearbox, which began testing in May, 2017 is designed to run up to 100,000 horsepower. Each pair of teeth on the gearbox will transmit the same power as an entire Formula One race grid, according to Phil Curnock, chief engineer for civil aerospace future programmes at Rolls-Royce.

The Power Gearbox, which consists of a series of five planetary gears, will allow the shafts at the core of the engine to run at very high speeds, while the fan at the front runs at a slower speed, said Curnock.

"The engine has a very high speed, efficient intermediate turbine at the back, but if I connected that directly to the fan at the front, it would be spinning too fast, so we need to reduce the speed of that spool, and we do that using the Power Gearbox," he said. "The Power Gearbox for UltraFan enables a larger, slower, more efficient fan system."

To test the gearbox, Rolls-Royce has built a €84m facility that contains of a power test rig and an attitude test rig. The latter, is capable of tipping and turning the gearbox, to emulate flight conditions during take-off and banking. ■

AUTOMOTIVE

Axles are on the advance

Technology suitable for electric vehicles

An electric axle concept for cars, claimed to be the most advanced system of its kind in the world, has been unveiled by GKN Driveline.

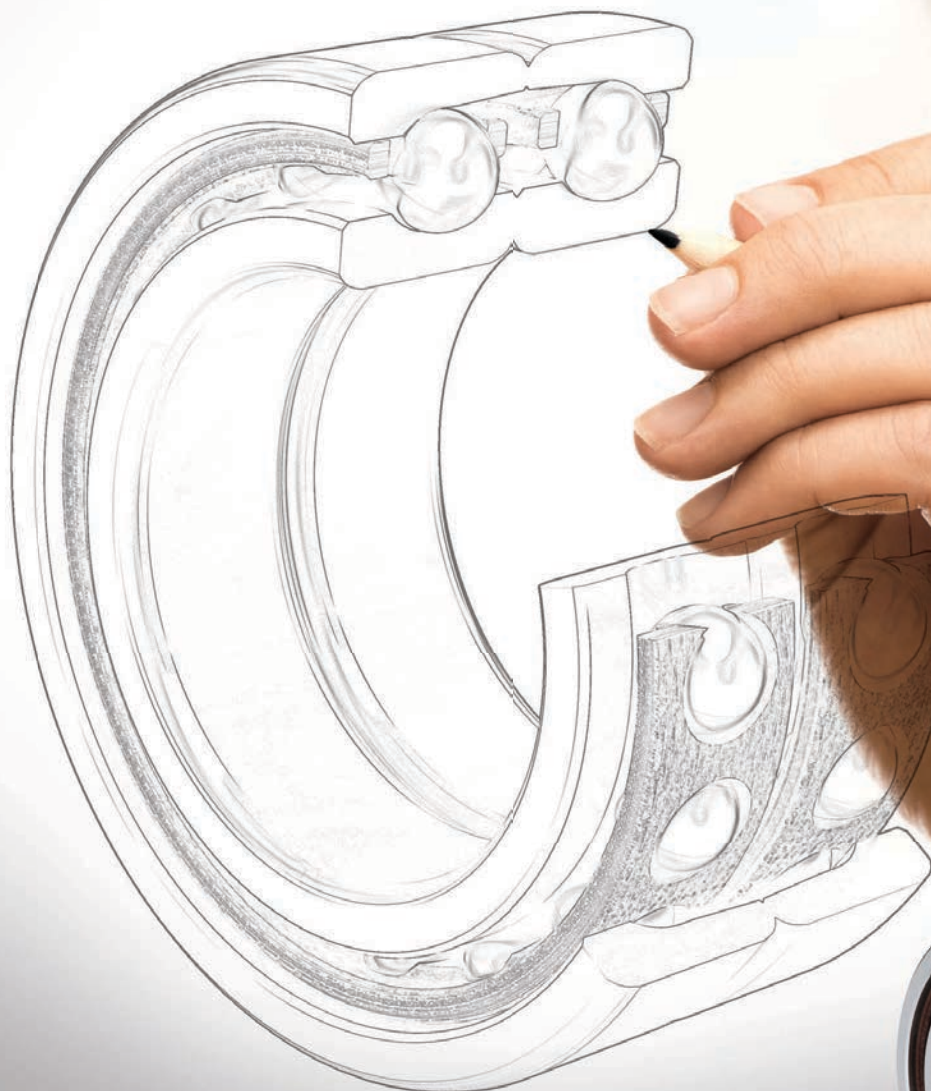
Dubbed eTwinstarX, the system brings together a number of technologies already commercialised by GKN with some key new innovations that the company

says could see the technology applied to a range of different vehicles.

The technology could be used either for the primary drive in fully electric vehicles, or for the secondary drive on plug-in hybrid vehicles – creating a 'split-axle' driveline. GKN has already supplied high-performance front eAxles for the Porsche 918 Spyder and BMW i8 supercars, as well as efficient rear eAxles for the Volvo XC90 T8 Twin Engine and BMW 2 Series Active Tourer.

Thanks to an integrated format, the new electric drive unit is smaller than other systems. **JE**

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COMMUNICATIONS

Down to the very last millimetre

Project looks to a future of true 5G wireless data coverage HELEN KNIGHT REPORTS

Ubiquitous 5G wireless data coverage with speeds of up to 100Gbps could be made possible by a European project developing technologies to exploit the millimetre-wave spectrum.

The amount of data used by wireless devices such as tablets and smart phones already exceeds that of desktop computers, and is set to increase further as emerging technologies such as 4k video streaming, cloud gaming and augmented reality take off.

Increasing the amount of wireless data available will mean covering urban areas with dense grids of micro, nano and pico cells, each

“The signal will increase in power to a new level”

Prof Claudio Paoloni
Lancaster University

serving a small number of users.

But transmitting the data to these cells before it can be shared among users will be no easy task. Existing base stations are fed data through fibres, according to Prof Claudio Paoloni at Lancaster University.

“But if the number of cells were to increase substantially, the fibre would be very difficult and expensive to install,” he said.

One option is to use millimetre-wave frequencies, in the 30-300GHz range, to transmit data wirelessly.

However, millimetre-wave signals are susceptible to attenuation, or weakening, by rain and fog, said Paoloni, who is leading a €2.9m European Union Horizon 2020 project aiming to develop technologies to exploit this part of the spectrum.

The project, known as Ultrawave, will develop a system with sufficient transmission power to overcome

this attenuation, based on a device called a millimetre-wave travelling-wave tube.

Travelling-wave tubes are elongated vacuum tubes in which a high-energy electron beam is sent along a tiny cylinder, through which the millimetre-wave signal is also transmitted. The signal creates an electric field that alters the velocity of the electron beam, causing some electrons to speed up and some to slow down, and creating a bunching effect.

“At a certain point this dense mass of electrons is delayed, meaning it loses kinetic energy, and this energy is transferred to the signal,” said Paoloni. “As a result, the signal increases in power to a level that is impossible with any other technique,” he said.

Ultrawave consortium partners include Fibernova and the Universitat Politècnica de Valencia in Spain, plus researchers in Germany, France and Italy. ■



Urban areas will be covered with dense grids of micro, nano and pico cells

AUTOMOTIVE

Batteries are a structural breakthrough

Electric vehicles on a new design platform

JASON FORD REPORTS



Structural batteries – and the housing in which they are stored – are one of the key components to an electric vehicle concept introduced by Williams Advanced Engineering.

The lightweight FW-EVX concept could give OEMs a platform on which to design electric vehicles that combine safety, longer range and better performance.

According to Williams, the concept also includes innovations in cooling systems and lightweight aluminium and carbon-fibre structures, all of which are integrated into a single, scalable platform.

Similarly, a highly automated, near-zero-waste process is being implemented to create fibre-reinforced suspension components on the FW-EVX, which provides up to 40 per cent weight reduction over a conventional aluminium wishbone.

Williams has developed a process of forming high-strength 3D structures from 2D materials to create the exoskeleton for a battery module that contributes to the battery's structural performance.

Paul McNamara, Williams Advanced Engineering technical director, said that there are 10 cells within each battery module.

“The idea is – because they're stiff exoskeletons – as they are clamped down onto the base you can imagine that what they're doing is almost forming their own honeycomb structure; all these boxes butted up against each other and tightly clamped out, which is giving a lot of extra stiffness to the whole structure in a very lightweight way.” ■

METROLOGY

Enter the smart factory

A centre of excellence for British metrology

A new £25m centre of excellence in metrology will save British industry millions of pounds and hours in new ‘smart factories’.

The Future Metrology Hub, one of eight EPSRC-funded future manufacturing hubs, headquartered at Huddersfield University, will organise the research and

development of a range of new measurement methods that form part of accelerating Britain's manufacturing.

Millions of components are machined and fabricated every day, and measured and validated at the end of the process with a CMM machine. New techniques can integrate the measurement inside the manufacturing process, saving industry millions of hours of production time.

Estimates from the National Physical Laboratory (NPL), state that up to one-fifth of the total value of UK manufacturing activity is in product verification. **WS**

AUTOMOTIVE

Driving is all in the motorway mind

Autonomous technology set to be tested in cars on French motorways HELEN KNIGHT REPORTS

Level 4 autonomous technology designed to allow drivers to take their minds off the road is to be tested in cars on French motorways later this year.

Carmaker Groupe PSA has announced a partnership with Hungarian automotive software developer Almotive to test a pilot programme at highway cruising speeds of up to 130km/h, on 300km dedicated motorway sections.

The project will test AI-based technologies including adaptive

capabilities for controlling the car, such as lane keeping," he said.

The partnership is designed to demonstrate the potential of AI technology for Level 4 capabilities for driving safely, even if the driver chooses not to intervene. At Level 5, the car would not require a driver at all, negating the need for steering wheels or pedals.

The two companies completed the first phase of the project in May, when they installed the hardware and software in a Citroën C4 Picasso. In the second stage, the companies will test the technologies in simulated and real-world conditions.

The software is first tested using simulation software, said Lajos Nemeth, who is leading the project at Almotive.

"One of the key challenges we are facing is the validation of autonomous driving, and that is why our development approach is to validate everything first in our AI simulation product," he said. "The very same software will be tested in the simulator that will be used to control the car on the road."

The AI algorithms are tested against realistic highway driving scenarios, including different weather, traffic and lighting conditions, and their response to these is then analysed by the company's engineers to determine if any fixes are needed. Once the software reaches a certain maturity level, it is deemed ready to be tested on public roads, said Nemeth.

Even then, only the detection and recognition software will be tested first, to ensure that it is operating properly, before the control software is permitted to take over the car. ■

"A key challenge is validation of autonomous driving"

Lajos Nemeth
Almotive

cruise control, fully automated lane changing, autonomous over-taking and collision avoidance, according to Adam Kotai, control engineer at Almotive.

"We are testing our recognition capabilities, so recognising things such as other cars, people and road lanes, as well as our



The software and hardware has been installed in a Citroën C4 Picasso

MEDICAL

Quality of life for paraplegic children

Hackathon offers up mobile app for predictive analysis

JASON FORD REPORTS

An internal competition at IBM in the UK has led to technology that could potentially improve the quality of life for very young children with paraplegia and their parents.

The technology solutions were developed during a 'hackathon' – a competitive event that gives developers a chance to build innovative applications, usually based on a particular theme. The event was organised in response to Spinal Cord Awareness month, with three-year-old Emerson Grant providing the test case for participating teams.

Emerson sustained a spinal cord injury at 18 months that left him paralysed from the chest down. Consequently, he can't cough or control his temperature, and his family must ensure he does not overheat, as well as avoid letting colds turn into pneumonia or chest infections. They must also be able to recognise if his autonomic (involuntary) nervous system becomes dangerously overstimulated, which could cause autonomic dysreflexia (AD), a condition requiring immediate attention.

One solution from team I-Spinal responded to a scenario that would let Emerson attend nursery and give his carers the information they would need to ensure his wellbeing. It combines a mobile app and wearable technology to create a system that performs predictive analysis.

With an iPad attached to his wheelchair, the wearables and other sensors collect real-time data on ambient temperature, outside temperature, sweat levels, heart rate, and oxygen saturation levels.

The system also uses reactive data, so that if Emerson experiences a sudden deterioration, warnings can be given to his carers. ■

COMMUNICATIONS

Observing the Earth

Australia signs agreement to access data from a small radar satellite

Australia is to boost its Earth-observation capabilities following an agreement to access data from NovaSAR-S, a first-in-class small radar satellite developed by Surrey Satellite Technology Limited.

SSTL will provide Australia's Commonwealth

Scientific and Industrial Research Organisation (CSIRO) a 10 per cent share of the tasking and data acquisition capabilities from NovaSAR-S, which is due for launch later this year. NovaSAR-S is a technology demonstration mission designed to complement much larger, complex radar satellites with a smaller, more cost-effective platform that delivers Earth-observation Synthetic Aperture Radar (SAR) imagery day and night.

Managing the energy use on board the small SAR platform has been made possible with a new S-band solid-state amplifier technology. **JF**

Lessons in the wind

As the cost of UK offshore wind energy falls to under £58 for every megawatt hour of electricity produced, what does it mean for the sector?

The UK government's latest competitive auction for renewable technologies has seen the cost of offshore wind energy halve in just two years. The unprecedented figure of £57.50 per megawatt hour (Mwh) has surprised many experts, but it is indicative of a very aggressive cost-reduction curve set to continue beyond 2020.

So how has this drop in cost been achieved? This is a clear example of focused innovation in action. By targeting specific areas of offshore wind technologies, the industry has been able to scale up capacity through longer blades, larger gearboxes and floating foundations. The Energy Technologies Institute (ETI) has been funding research and testing in these areas since 2008, sharing what we have learned to reinforce investor confidence and fast-track innovation in the areas where it can be most effective.

For example, the ETI worked with UK SME Blade Dynamics on the aptly named 'very long blade project', which focused on new design and manufacture techniques that reduced the blade cost and weight, helping increase turbine performance. Building each blade from a set of smaller composite pieces uses mass manufacturing techniques that help to reduce the costs of production.

Research and insights such as this have encouraged a large number of UK companies to invest in bigger turbines and identify the sites that are the ideal distance from shore in fairly shallow waters to achieve the lowest-possible capital cost per kilowatt. As an industry, we have also made learnings from our experiences of running these off-shore power stations. Through running them and maintaining them, we have identified many areas to cut costs and improve processes.

With clear public support for offshore wind technologies, the sector has benefited from long-term commitments by government that has given investors and the market confidence to develop and grow. Stability of policy has helped the UK, ideally positioned with the vast Continental Shelf to maximise this natural resource, to effectively position itself as a global leader in this sector. The competitive auction approach

provides a guaranteed price that helps attract investors, and encourages continued innovation.

Over the next 30 years, we expect to see more of the same in the offshore wind market; targeted innovation and shared learnings that can further reduce costs and ensure a secure, sustainable supply of energy that supports the UK's overall energy strategy. At ETI, we recommend an integrated approach, using a mixture of base load and variable energy sources, where offshore wind energy will sit alongside nuclear, bio-energy and carbon capture and storage.

At this point in time, policy is key. The Scottish government has had a clear and consistent policy that has reaped rewards, and the UK government could benefit from a similar approach, bolstered by the strong public support for renewables and specifically offshore wind. Supporting research projects, promoting collaboration between industry and academia, and working alongside European neighbours will help augment the cost-reduction curve that we've been seeing.

Regardless of the uncertainty caused by Brexit, we should see the continent of Europe as an opportunity to grow the market for our energy, by creating better connections with Europe's electricity network. We have already learnt a lot from Denmark's experiences, and collaboration has been a key part of the UK's success to date.

Other renewable technologies can also learn a lot from the success of the approach taken for

offshore wind technologies. There is a lot of synergy with marine energy, which has much to gain from both the knowledge acquired in this sector, and choices made in terms of technologies.

The desire to incorporate cost saving mass manufacturing techniques has driven the direction of innovation and could make significant cost savings in the marine market too.

Just as turbines benefited from innovations in composite technologies developed in the automotive and aerospace markets, companies investing in energy storage will benefit hugely from battery technologies developed for the motor industry. EDF, currently building a nuclear power station in the UK at Hinkley Point in Somerset, has the opportunity to learn 'by doing' and identify cost savings for future nuclear power stations, mirroring the progress made by offshore wind technologies.

It's important that we celebrate the great steps forward made by the offshore wind energy sector to bring down costs, to ensure that we continue the rapid progress we've made so far and replicate the strategy to benefit other renewables. With focused innovation and policy support, the technology has become commercially viable. We shouldn't underestimate the huge influence it could have on the renewables sector, providing the UK with a sustainable and secure energy supply. ■

Stuart Bradley is offshore renewables strategy manager for the Energy Technologies Institute



Targeted investment in technology has driven down the cost of wind energy

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The **hot** topic

On the buses



Without knowing the conditions under which this 'record' was set this is meaningless. In 1989 a Boeing 747 flew non-stop from London to Sydney – how many non-stop London-Sydney flights are there today, 28 years later? Zero – if the test conditions do not replicate real life the record is meaningless. It is, of course, not necessary to explain this to any engineer but others will want to believe that electric nirvana will be with us tomorrow.

David Lawton

A controlled test is one thing but what distance would the bus travel under normal operating conditions and with a payload of passengers? Also, what would the recharge time be? Testing in artificial conditions looks great, but can be misleading.

Chris Saint

I freely acknowledge the comments above regarding the failure to mimic real life of

vehicles tested under ideal conditions; I have yet to own a single vehicle that could match the claimed miles per gallon for a sustained period. That said, the underlying fact that everyone seems to be ignoring is that the previous record has been beaten by nearly 10 per cent. Technology moves on. Electric nirvana may not be with us tomorrow, but it will probably be here sooner than was thought possible only a few years ago.

Martyn

Nothing but a bunch of cynics. Why not just have battery packs that could be slotted in and replaced like memory cards? Buses have to take rest breaks every couple of hours by law, which would be an ideal time to switch the battery. Imagine if the salvation of the world from impending climatic disaster depended on you lot. We'd be up a creek without a paddle...

Oh wait, hang on!

Sebastian Broady

While the technology for the vehicles exists and battery packs can be exchanged, where is the grid with capacity to power all these recharges? Assuming the figures above are correct my local small business coach company with eight coaches on site will require a substation with megawatt capacity as minimum to overnight charge the buses. Unfortunately, unless we go fully nuclear, I still firmly believe we are only shifting the CO₂/noxious gas source from one place to another. And I'll leave the argument alone about the manufacturing effect on the environment of electric vehicles versus internal combustion.

Geof Iason

We're engineers – we overcome technicalities. The main issues of EVs are specific energy density, time to 'refuel' and power delivery – science and product development will address these.

Chris W

I couldn't agree more, Chris. If half the cynics replying here had their way, we wouldn't just be driving internal combustion-engined cars forever more, we would still be driving Model T Fords. EVs are improving all the time – they sure as heck haven't been improved by engineers sitting around moping about how impossible the task is.

Martyn Walters

At what speeds, weather, time of day, internal heating/ac requirements? How many passengers? How often did it stop, how many hills? In other words, is it practical? We all know that we can make these things, but they have to exist in a real world.

Nick Cole

Battery technology is basically dead in the water unless there is a dramatic improvement in rapid charge times, smaller batteries, less use of finite precious metals and massively extended range in real-world test conditions... not carefully controlled record setting on a test track.

Simon Ellis

I understand the naysayers and agree with the positives. Tests are 'never' what will happen in real life but comparison points are comparison points. Trains, trams (and trolley buses) must be the solution for mass-number movement (somewhere in Manchester to somewhere in London) The truth is the paradigms will shift and there will not be a one-for-one replacement and all the opportunities will come together. We just need to exploit things a little quicker.

Ian Paterson



The secret engineer

As the engineering workplace becomes more fluid, we must be careful we don't forget about teamwork, writes our anonymous blogger

Recent events have highlighted an aspect of life to me that most of us seem to take for granted. At (generally) 38 hours a week we spend a large percentage of our time at work where, as most of us do not have the isolation of lorry drivers or the aloofness of the senior surgeon, we build relationships.

My own career has regularly seen me being a part of transitory project groups and permanent departmental groups, within which we invariably had to work together to complete difficult tasks within challenging timescales. Some colleagues have become firm friends while a few others have provoked a feeling of resentment as to the fact that they are breathing the same air as me. This last group really is very small though.

Of course, we are employed to 'do stuff' but a good atmosphere always helps. Even in the most trying circumstances, advice and support can enable us to achieve more than we thought possible. If things are working really well, then the combined talents exceed reasonable expectation and ventures into the exceptional. Even without reaching such rarified heights, though, the fact remains that we spend a lot of time together in the pursuit of a single aim and this builds a bond that our natural reticence may lead us to ignore. I know this doesn't apply to everyone but there are few absolute loners practising engineering.

Mr Secret-Engineer Senior provides a prime example. He has been retired for a number of years now, with the organisation he worked for



having passed into history. However, he still regularly meets up with the 'old boys' from his working days. There was an era spent in the golden light of vision, investment and pushing boundaries within their field. An eclectic mix of the quietly pragmatic and the eccentric genius, these ladies and gentlemen regularly directed their combined talents towards world-beating excellence. Something that helped forge the friendships of 50 or more years ago, friendships that remain strong and unbroken today.

I too have been fortunate to be involved in a situation that has created similar ties. Some years ago, a certain company was formed to build a new type of whizz-bang, with the number of those involved growing from four or five to about 15. We were looking to fulfil one man's vision from the starting point of just a borrowed hanger and a few desks, with money always being tight and duties venturing beyond normal.

This led to some pressure points along the way, but it was a grand adventure. Sadly, we didn't see our project reach fruition but

labouring under trying conditions and chasing hopes together made for a very strong team.

Now we too meet up regularly for riotous evenings that serve to provide a platform for both scandalous recollection and catching up. This despite over a decade having passed since our disbandment. Sadly, we recently lost one of our group to cancer, but with that shared loss came another tie to hold us together.

I started my career in engineering during the transition from a workforce that had an expectation of a job for life to the peripatetic career that comes with a fluid movement of staff. I keep seeing promises of the freedom that working from home offers, but will the next generation of engineers lose out because of this?

There are advantages to the brave new world and it is the nature of industry that we have to adopt new practices to remain competitive. I wonder though whether in 50 or 100 years there will still be the dynamic necessary to bring a group of people together in such a way?

The arguments, the fighting, the jokes and the moments of success that — when shared first hand together over a number of years — stop you from being a collection of individuals and truly turns you into a team. To lose that catalyst for superlative achievement within industry would be a shame. To lose the personal connections that come with being a part of the team that achieves the superlative would be worse. ■

In your opinion

Is biomass really renewable?

It's particularly non-renewable when it turns out we can't produce enough of it in the UK so we now bring the stuff in by ship from Canada.

Robert Hunter

Biomass should be one of the future green energy sources, sourced from forests where (for a like-for-like area) the wood biomass is not reducing.

Tim

A much better source of biomass would be algae, since the production tonnage is far higher than any other plant

species (on a per-annum basis). Drying the algal mass sufficiently may pose a challenge, but one other means of processing is direct conversion to transportable liquid fuel.

James Stewart

It depends on the biomass and on what would happen if it were not burned. Cutting down large trees and planting saplings clearly increases CO₂; it releases carbon that was captured before CO₂ emissions were a concern against a promise to re-capture it later. Burning short-lived fuel crops planted for the purpose, or by-products of other crops such as straw, that close an annual cycle, puts the capture ahead of emission.

TonyC

This is quite complex. It makes sense to use waste-wood material

from saw and pulp mills to produce electricity. It can be burnt to produce electricity or processed to make bio-fuels. It is not 100 per cent renewable as energy is needed for transport and processing. The money would be better spent subsidising and developing other proper renewable energies.

Dan

I'm really pleased to see *The Engineer* has suggested one way to view biomass energy is as "essentially a carbon-based fuel like coal that's dressed up as a renewable". That is spot on.

Robert Palgrave



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theengineer.co.uk



Looking ahead to the year of engineering

A series of events next year will build on efforts to engage the next generation of engineers

At the end of September, some 30,000 people visited London's ExCel to get a sneak peek into the future. With talks and exhibitions on everything from the practicalities of moving to Mars to the prospects of using DNA for data storage, New Scientist Live set out to challenge, puzzle and entertain its audience in equal measure. This show, now in its second year, is just one example of the plethora of interactive science and engineering engagement opportunities available.

The show brought some of the UK's best-known engineering companies together under one roof. The Royal Academy of Engineering presented a special exhibition of engineering inspired by *Star Wars*, showcasing how engineering innovation is bringing real-life research ever closer to the world portrayed in the films. Prof Sriram Subramanian and his team from the Interact Lab at the University of Sussex showed visitors how levitation is possible using a cushion of ultrasound. They also demonstrated haptics, the ultrasound-based technology that allows people to 'feel' invisible objects and is already revolutionising the way that surgeons and dentists are trained, as well as adding sensory feedback to glass touchscreens.

The UK's museums have significantly raised the bar in recent years on public engagement – including with engineering. The Victoria & Albert Museum's popular exhibition on the life of Ove Arup and the Science Museum's engagement with national opportunities through live broadcasts such as Tim Peake's mission launch demonstrate the growing market for public engagement with science, engineering, technology and mathematics.

The academy runs a public engagement programme, Ingenious, to support projects across the UK that engage the public with engineers and engineering. To date, Ingenious has provided opportunities for more than 5,000 engineers to gain skills in communication and bring engineering to the heart of society. It is encouraging to see both the rising numbers of high-quality applications to the scheme, and the high proportion of participating engineers that continue to undertake engagement post-project.

Why is this increasing level of STEM engagement happening? Much of the current public engagement aims to attract more young people into STEM careers, driven by the recognised skills shortages and gaps across STEM, and in engineering in particular. We also know from the engineers who participate in Ingenious that they find public engagement rewarding, not least because it helps remind them what they love about their jobs.

At the last count, there were well over 600 initiatives focused on STEM engagement in schools. Having so many initiatives may actually be part of the problem; we need to take a much more cohesive approach if we are to have the impact we're seeking.

The government's Year of Engineering 2018 seeks to do that. Government has recognised the skills shortage, not least because developing a successful industrial strategy depends critically on the availability of a highly skilled workforce for the future, and has invested in a programme to give more than a million young people parents and teachers direct and inspiring



experiences of engineering over the course of the year.

The Year of Engineering aims to build on a multitude of national and regional initiatives that already promote engineering as a career choice, including EngineeringUK's hugely popular Big Bang Fair, which brings more than 80,000 students to the NEC every year to celebrate engineering, and the annual Tomorrow's Engineers Week.

As an active partner in the Year, the Academy will be running This is Engineering, a novel multi-year marketing communications campaign aimed at rebranding engineering for young people aged 13-18 and their teachers and parents, to change their perceptions of engineering and encourage more young people from all backgrounds to consider careers in engineering. It seeks to pool resources to deliver a more visible, more powerful and more unifying campaign than anything that has gone before,

and provide digital content that all engineering organisations can use to attract the next generation of talent.

Together, the Year of Engineering 2018 and This is Engineering will give our audiences multiple opportunities to experience positive and unified messages about engineering, improving their awareness and attitudes and encouraging them to find out more about engineering careers, via the Tomorrow's Engineers website.

This is Engineering aims to provide a legacy for the Year of Engineering well beyond 2018, building on what's worked and nurturing its community of advocates and supporters. Encouraging more young people from all backgrounds to pursue engineering requires long-term action, and a coordinated effort across the whole profession. ■

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

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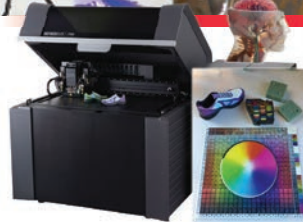
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Higher power

Electric aircraft propulsion offers quiet operation but big challenges for the industry. Stuart Nathan reports

Airbus aspires to develop electric short-haul airlines

Electrification is having profound impacts on the automotive industry and it seems the aerospace sector will be next.

Attracted by the low weight and cost of electric motors compared with gas turbine jet engines, and particularly by their near-silent operation and potential for zero emissions, the civil aviation sector is showing increasing interest in using electricity to power future flight, at least over the relatively short distances that dominate city-to-city aviation.

While jets are unassailable as the prime movers for intercontinental long-haul airliners – nobody's suggesting that electric aircraft could transport passengers from Europe to Asia, across the Atlantic or even between the East and West coasts of the US – the short-haul routes between both European and US cities, currently plied mostly by twin-engined single-aisle aircraft, are the targets for a new generation of radically different aircraft whose development is being fostered by the aerospace majors. These machines could take the sector into areas of science and technology very different from those it is used to.

Of the two biggest players in civil aviation, Airbus is taking the more active role in this initiative by developing its own aircraft, while Boeing has invested in a start-up company that is conducting the process (see box on p22). Airbus's plans have undergone considerable change, however.

The last time *The Engineer* covered this subject in detail was in an interview with the then-chief technology officer of Airbus, Jean Botti, in late 2015. Electric aircraft were a major focus of Botti's tenure as CTO but he left the company in April 2016. His successor, while still attaching considerable importance to the project, has proved to have different ideas about how it should be conducted.

Paul Eremenko joined Airbus in 2015 to launch and run its Silicon Valley-based innovation offshoot, A³; he took over the CTO's position in June 2016. An aeronautics and astronautics graduate, he has worked at DARPA – where he headed the office responsible for drones, satellites, robotics and X-planes – and at Motorola and Google, where he initiated development of modular, customisable smartphones. In a lecture at Purdue University in 2014, he stated that his career had been motivated partly by a desire to build a starship, and while at DARPA he was involved in a study to define an organisation that might meet such a goal.

On moving to Airbus, one of Eremenko's first actions was to revamp the E-Fan electric aircraft project. The first E-Fan, a two-seater with two 30kW electric motors, flew in 2014, crossing the English Channel as a symbolic feat. Airbus's original plan was to develop this light aircraft further: a production version was slated for 2017 and marketed as a pilot trainer; and a four-seat version with a hybrid powertrain was due to fly in 2019, in which a kerosene-fuelled engine would act as a range extender, operating a generator to charge the batteries and boosting endurance to around three-and-a-half hours.

A hybrid configuration – E-Fan Plus, with a 68hp (50kW) two-stroke combustion engine from German manufacturer Solo Aircraft Systems, capable of 30 minutes' battery endurance and up to two hours 15 minutes in hybrid mode – was developed and flown in 2016, but subsequent plans for the electric aircraft project changed.

"To put it simply, we decided that this plan was just not ambitious enough," Glenn Llewellyn, Airbus general manager for electrification, told *The Engineer*.

Electric aircraft development has continued under Siemens, which in 2016 formed a partnership with Airbus after co-sponsoring – but not providing

equipment for – E-Fan. Siemens supplied the 50kg, 260kW motor for an Extra 330LE aerobatic aircraft that first took to the air in July 2016. An order of magnitude more powerful than the E-Fan, this aircraft spurred Airbus to abandon its roadmap of gradual power increases from the kW to the MW range, as Botti had envisaged, and instead look to progress directly to a 2MW demonstrator, as a stepping stone to a hybrid-drive aircraft that could match current single-aisle, short-haul aircraft in terms of range and passenger capacity, and operate from conventional airports. Such an aircraft would likely be another order of magnitude more powerful than the 2MW demonstrator, Llewellyn said.

“We might be able to do that in a single step; we might not,” he told *The Engineer*. “We expect to encounter all sorts of challenges in developing the 2MW aircraft; we just don’t know what all of those might be yet. It’s those ‘unknown unknowns’ that make it difficult to predict how we’d take the step after that.”

The 2MW option has its own goals as a basis for urban aerial mobility vehicles. This sector – currently mostly speculative, of course – was one that Airbus had barely targeted before Eremenko’s appointment but, at the Geneva motor show in March this year, the company unveiled the result of a collaboration with Italian automotive development house Italdesign: a modular concept vehicle called Pop.Up. This consisted of a two-seater passenger capsule that could be linked to an electric ground module (essentially a four-wheeled chassis) or an octocopter air module.

Airbus’s ambitions in this sector are likely to favour a larger-capacity vehicle, Llewellyn indicated, and not one that could operate in either road or air mode but one that would be able to take off and land from ‘vertiports’ within cities. “Electric propulsion is ideally suited to urban environments because it’s so quiet, which is important when you want to fly near occupied buildings and at low altitude. And, when you’re in pure electric mode, operating off batteries,

you’re producing no emissions and are not affecting air quality,” he said.

However, Llewellyn would not rule out such vehicles also having a hybrid capability. “It gives us greater flexibility and, of course, with a motor and generator complementing the electric system you can operate in a different mode. A gas turbine acting as a range extender wouldn’t have



to handle all the varying loads you encounter during flight – the electric propulsion system would deal with those – so you can optimise its operation so that it runs at maximum efficiency.”

Such hybridisation could be with a hydrogen fuel cell or a gas turbine, or even a diesel engine, coupled to a generator, Llewellyn added. “Even with existing technologies, a hybrid could have significant range.”

Another factor in favour of hybrids crops up regularly with electric aircraft: much of the technology required to enable the type of aircraft that industry would like to fly is simply not yet advanced enough.

“The power-to-weight ratios for battery technology are still a long way short of what is required,” Llewellyn said. “Current batteries would be far too heavy as the only source of energy to feasibly fly a large passenger aircraft. This is where hybrid solutions, even at low levels, can be of interest. That said, battery research perhaps has the most investment of any technology in the world right now, so we need to prepare ourselves for a future in which this is possible.”

Pop.Up is not Airbus’s only urban aerial mobility concept. At a presentation to media earlier this year, Eremenko described four other electric technology demonstrator projects: CityAirbus, a multi-propeller vehicle to carry up to four passengers, intended to be autonomous once regulations are in place for such aircraft, which is being developed by Airbus Helicopters and targeted for first flight by 2018; Skyways, a collaboration with the University of Singapore for delivery of small packages by drones, to be tested initially around the university; Vahana, a single-passenger self-piloted VTOL vehicle being developed by A³; and a less tangible A³ project, Voom, an on-demand shared helicopter booking app for megacity dwellers (with applications beyond only electric aircraft).

One thing that hasn’t changed from Botti’s vision is the design philosophy



01 Airbus’s fleet of proposed electric urban aircraft. From top: City Airbus; Vahana; and Pop.Up

02 Electric motors integrated into airframe

03 Siemens-powered Extra 330LE



“Electric propulsion is ideally suited to urban environments because it’s so quiet. And, when in pure electric mode, you’re producing no emissions”

Airbus wants to apply to its larger electric aircraft. Rather than simply ‘bolting on’ engines to the wings or fuselage, it would integrate electric motors into the airframe at multiple points within aerodynamic housings.

“One advantage that electric motors have over gas turbine engines is that it’s relatively cheap, in terms of both cost and weight, to add more of them,” Llewellyn said. “But using integration we can explore things like boundary layer ingestion, which could be another way to recover energy.”

Boundary layer ingestion uses the air immediately around the aircraft to feed the fans that accelerate air to generate thrust; it reduces drag and, in theory, means that the engines do not have to work so hard, both of which would reduce fuel consumption (or, in the case of electric motors, their demand for electricity). However, it is not a simple matter because boundary layer airflow is distorted, so fans need to be designed to take account of this.

Aerospace technology is often a matter of trade-offs – for example, material strength is always balanced against lightness – and electrification is no exception. Heat management is often a sticking point, Llewellyn said, with more powerful motors’ components running hotter and therefore requiring more equipment to handle the heat load, so power output must be balanced against the amount

of equipment that can be carried. This may also limit the use of another technology whose potential is attractive for electric aviation: superconductivity.

This is another area where technology has not developed to the point of usefulness. "Even the highest-temperature superconductors need to be cooled to about 70° above absolute zero," Llewellyn said, "so, although you'd gain from the very efficient, low-loss transmission of energy in a superconducting system, you'd have to balance that against the extra mass of all that cooling equipment, plus you'd have to handle the heat extracted from the system."

Development of higher-temperature superconductors could be a sector of fundamental research where the aerospace industry might want to inject funds, he speculated, although these might be limited to projects directly relevant to aviation. ■

Propelled by enthusiasm

Firms and organisations are excited about the potential of electric aircraft propulsion

Although Airbus is the most involved of the two civil aerospace giants in developing electric aircraft, it was not the first in the space. That honour goes to Boeing, which started its foray into electric propulsion in 2012 with a project called SUGARVolt (SUGAR – Subsonic Ultra-Green Aircraft Research).

SUGARVolt is in fact a hybrid concept, with dual turbine engines running on conventional jet fuel for take-off and then switching to electrical power at cruise altitude. To account for the reduced thrust in electric mode, the design incorporates features to enhance flight efficiency: a braced, high-aspect wing (mounted atop the fuselage) with a wide span and a narrow, turbulence-reducing width, designed to fold at the tips to allow the aircraft access to standard gates at airports.

Intended for first flight in the mid-2030s, SUGARVolt is currently on a hiatus, with Boeing now throwing its weight behind a third-party project (see main body of this feature). The company announced in April this year that it was investing, through a new venture capital arm called HorizonX, in a Washington State-based company called Zunum that was developing a range of regional hybrid-electric aircraft, with capacities for 10-50 passengers and ranges of 700-1,000 miles

(1,100-1,600km). Also investing in Zunum is a subsidiary of the US short-haul budget airline JetBlue Airways.

Zunum aims to fly its aircraft between neglected small airports. "The shift to large aircraft and long ranges driven by gas turbines has concentrated almost all air traffic to just 2 per cent of our airports, creating a massive transport gap over regional distances. As a result, door-to-door times for most journeys are no better than they were 50 years ago," said Zunum chief executive Ashish Kumar.

Like Airbus, Kumar regards electric propulsion as the key to changing this, used on take-off and landing to greatly reduce engine noise and access airports nearer city centres without affecting air quality or disturbing residents. In hybrid mode, the engine – still likely to be a gas turbine – would kick in to extend range in cruising flight.

The company says these aircraft, which have been in development for three years in partnership with the Center for Power Optimisation of Electro-Thermal Systems at the University of Illinois, will fly first in around 2020, and over a typical route will produce 80 per cent less carbon emissions than a typical airliner of this class. On routes such as Boston to Washington DC, door-to-door



NASA's X-57
Maxwell

journey times could halve, with fares dropping by 40-80 per cent.

NASA too is active in electric aircraft, using its X-plane designation for the first time in a decade to name its research aircraft, the X-57 Maxwell. X-planes became known for research into trans-sonic flight, and included the legendary rocket-powered Bell X-1, which, in 1947, became the first aircraft to break the sound barrier, and the X-15, which flew so high in the 1960s that its pilots were awarded astronaut wings.

The X-57 is a very different aircraft, and markedly unlike the sleekly integrated visions of Airbus's electric airliner concepts, but it further illustrates the principle that electric motors are light and cheap enough to be used in abundance. Purely battery powered and based on an Italian-designed twin piston-

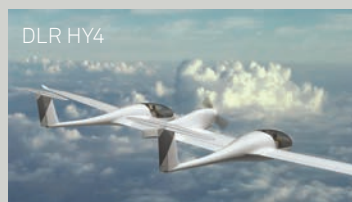
engine light aircraft, the Tecnam P2006T, the Maxwell's high-aspect wing (specifically designed, and long and skinny like the SUGARVolt's) packs on 14 motors: 12 in the middle for use on take-off and landing, and two larger ones, at each end, for cruising flight.

The thinking is that distributing power across multiple motors will cut the energy needed to accelerate the aircraft to 175mph and maintain that speed at cruise to a fifth of levels seen with conventional small aircraft and, of course, with much less noise. Whether Maxwell will become as legendary as those early X-planes is unclear, but it may have an equal — although very different — influence on future flight.

A European project, HY4, takes a different approach to powering electric flight. A four-passenger light aircraft developed by Germany's DLR aerospace research organisation, HY4 has an 80kW electric motor powered by a hydrogen fuel cell, hybridised with a lithium-ion battery to cover peak power loads. The aircraft was originally developed as a battery-powered plane by Slovenia's Pipistrel, in which form it won NASA's Green Flight Challenge three times. DLR converted it to fuel-cell power with onboard high-pressure hydrogen storage, with which it first flew, for 15 minutes, at Stuttgart in September 2016.



Boeing SUGARVolt



DLR HY4



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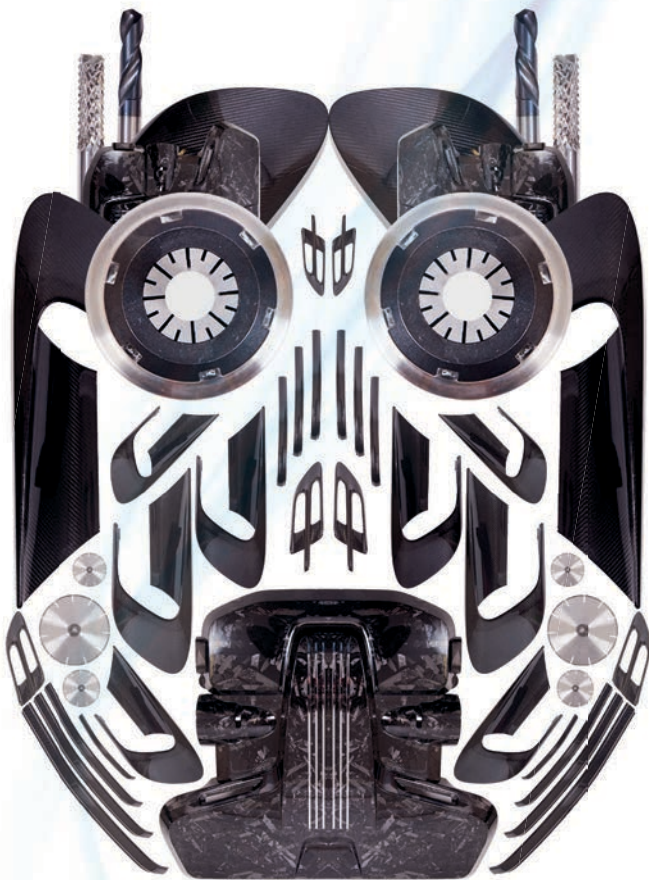


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POWER DISPLAYS EMC

Spotlight into additive

Research into molten substances at the Diamond Light Source could transform additive manufacturing
reports Stuart Nathan

The space-age silver disk of the Diamond Light Source sits in the Oxfordshire landscape like a recently landed flying saucer. Inside, powerful magnets accelerate electrons around a circuit shaped like a many-sided polygon and, at each shallow vertex, intense X-rays are directed into hutch-like laboratories where they are used to probe the properties of matter, helping uncover information about substances whose atoms form regular patterns. X-rays can penetrate crystals and the lattice structures of metals and their atoms scatter the radiation in characteristic ways that reveal how they are organised.

X-ray crystallography's origins are in fundamental science. It has been instrumental in discoveries such as the structures of DNA and insulin, and it is widely used to help design drugs to attack viruses, bacteria and cancer. It is also used by teams trying to find out what colour dinosaur feathers were and reading the contents of ancient documents, among other things. But Diamond is also a centre for industrial and engineering research, and a base for researchers looking at everything from the optimisation of automotive lubricants to probing the structures of engineering materials.

Prof Peter Lee's research has a wider scope than most. Lee is professor of X-ray Imaging at the University of Manchester, but is based at Diamond's Harwell campus, where he is assistant director of physical sciences. Lee's research focuses on solidification and crystallisation of molten substances, which has taken his team into investigation of phenomena including the behaviour of magma inside active volcanoes, freezing of ice cream and, most relevant for engineering, how the processes involved in 3D printing (or additive manufacturing) influence the structure and properties of the materials formed in the process. This research has led Lee and his team to collaborate with Rolls-Royce on potential manufacturing processes for aerospace components, and the design of materials for surgical prosthetics that will bind to and encourage the growth of new bone through their structure.

Lee is involved with projects such as MAPP (Manufacture Using Advanced Powder Processes), the EPSRC's £20m future manufacturing hub, which aims to

usher forward the possibility of powders that are "active and designed, rather than passive elements in their processing", where control of particles' surface state and chemistry, internal structure, bulk chemistry, form, shape and size, will result in greater process efficiency and reliability, and product performance.

Another major project, AMAZE (Additive Manufacturing Aiming towards Zero waste and Efficient Production of High-tech Metal Products), ran from 2013 to June of this year with €18m European Union funding and involved 26 organisations, including Renishaw on the supply side; Volvo, Airbus, BAE Systems and the European Space Agency on the user side; and the Manufacturing Technology Centre, University of Birmingham, Imperial College London and the Fraunhofer institutes as research partners. "The difficulty with additive is that it works through trial and error," Lee told reporters at a recent media event. "You can change the laser power, the powder density and so on but it's trial and error how it comes out.

We've made a machine that replicates the process in a way that we can X-ray. That's allowed us to get all-new physics insights."

Additive manufacturing aims to replicate the properties of wrought metal, Lee said. "Those properties include fine grain size with appropriate distribution of intermetallics, reinforcement phases, and often nano-precipitates that pin dislocations in the lattice, which improves strength. But, with additive processes, instead of having something that is very controlled as you are rolling it at a fixed temperature, you have a laser that heats at thousands of degrees a second, and you have molten pool



“The difficulty with additive is it works through trial and error”

Prof Peter Lee

afterwards that cools at thousands of degrees a second, and that produces completely different structures we really don't know about.”

Understanding how additive forms structures in the metal and what effect this has on the properties could help refine the process by changing the conditions, Lee explained. “We find that the laser can disturb the powder. So, you can change the laser power but not just that, you can also use optics to change the distribution of the power by shaping the light. You can change the gas surrounding the printing, or the pressure of the gas, or the size of your particles and how they're fed.”

With electron-beam printing, Lee has looked at ways of handling powder and operating the system so that the electron beam does not charge up the metal particles and cause them to repel each other electrostatically.

Lee's current rig mimics the printing of a single layer of powder, so that the X-ray beam arriving into the hutch illuminates the point where the laser melts the powder.

But this rig will soon be succeeded by another, designed to mimic a Rolls-Royce process for repairing turbine blades. These are not the single-crystal cast blades that operate in the hottest part of a turbine engine, Lee said, but blades designed for operation in the cooler, less-demanding part of the engine. Using single-piece blisks rather than individually made blades welded onto a hub has reduced the cost of turbines but made repairs more difficult, he said. Rolls-Royce wants to be able to take blisks with broken blades, machine down the damaged part and rebuild the lost portion using metal powder blown concentrically around the point where a laser strikes the metal.

Lee's group has also worked with the Joint European Torus nuclear fusion experiment at nearby Culham, trying to improve how highly neutron flux-resistant materials can be welded to or printed onto metals with efficient heat transfer properties. In the medical field, surface treatment to functionalise the parts of surgical



02



03

prostheses that contact bone are under study. “Knee implants used to have huge spindles that went right onto the bone but these are now much shorter because of a printed surface lattice mesh into which bone can grow. We can see that because bone has different X-ray permittivity to metal,” he said.

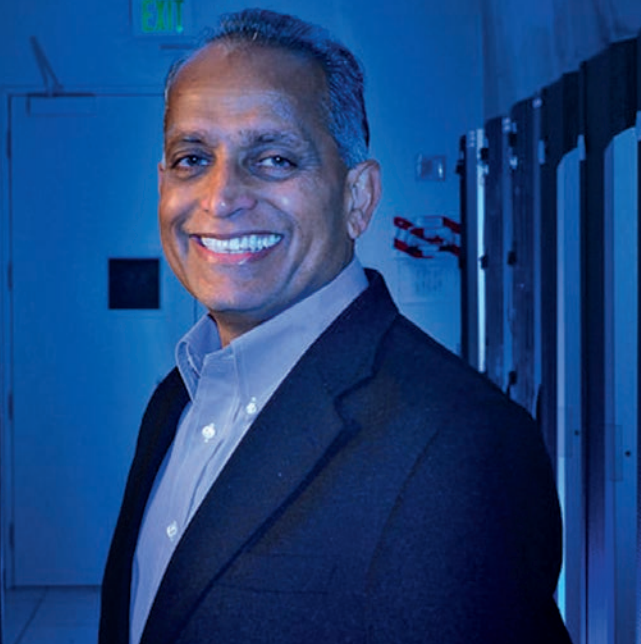
01 Catalyst support mesh

02 Additively produced bone implant

03 The Diamond Light Source

Ice cream may seem trivial by comparison but is equally interesting technically, Lee said. “Taste depends a lot on structure; ice cream is made by shearing a mixture as it freezes to make small ice crystals. The crystals control how the taste molecules spread across the tongue; an ice cream with big crystals will taste sharper. Things such as fat inhibit ice growth, but so do other additives such as air bubbles, so we're trying to find a way to make ice-cream where the crystals grow like it had fat in it, so it tastes the same but has half the calories.”

A worthy goal. ■



interview | **chandrakant patel**

Towards the cyber-physical

For Hewlett-Packard's chief engineer the relationship between hardware and software has never been closer. Andrew Wade reports

As a mechanical engineer in the home of software, Chandrakant Patel sometimes has to remind his colleagues that the real world isn't made from ones and zeroes. "Having been in Silicon Valley for 35 years, I used to work with [Hewlett-Packard co-founder] Bill Hewlett. I was there when the first disk drives came out, when the chip design was done, when fabrication was here, when a lot of physical fundamentals happened," said Patel.

The theme of fundamentals is one to which Patel returns frequently. If the 19th century was the age of machines and the 20th century the age of information, HP's chief engineer regards the current century as the time when the two will fully merge. It's an era he refers to as the "cyber-physical", characterised by the expansion of the internet of things (IoT).

"A Tesla, or an electric car... it's an example of a cyber-physical system," Patel explained.

In this new age, software skills in isolation will no longer suffice, and engineering fundamentals will once again come to the fore in Silicon Valley, he believes. Coding expertise will remain vital but increasingly it will need to be complemented with domain knowledge.

"If you thought civil engineering, mechanical engineering, materials science, heat transfer, fluid mechanics was no longer interesting, you've got another think coming," said Patel. "In the cyber-physical world, that's more important than anything else."

According to Patel, HP's hardware heritage should serve it well in addressing the challenges of the cyber-physical. And some of the company's existing solutions could give it a distinct advantage in certain areas.

Over the past three-quarters of a century, HP has straddled virtually every aspect of IT, from oscillators to software services. Despite that, it is still perhaps best known for its innovations in printing.

"Our engineers created inkjet, which became big business," said Patel. "Now we have 3D print platforms that are based on inkjet."

Patel is referring to Jet Fusion, the additive manufacturing technology that HP sees as a pivotal part of its cyber-physical strategy. As 3D printing matures beyond today's early adoption for prototyping, the company believes additive can become an increasingly important tool in the manufacturing industry. While the global prototyping market is worth a few billion dollars,

"In the cyber-physical world, engineering is more important than anything else"

the wider manufacturing segment is worth around \$12tn. Part of Patel's role is to identify these types of opportunity, as well as the factors that help create them.

"If you were to take a maritime analogy and think of us as a ship, on the bridge, in the CTO office, we're looking at megatrends," he explained. "Social, economic, ecological megatrends. Age and demographic shifts, rapid urbanisation, resource constraints, global conflicts. We look at those megatrends and we look at their impact on the supply/demand management of resources."

As chief engineer, Patel spends some of his time on the company's metaphorical 'bridge', but the majority of it in the engine room, alongside the people exploring solutions to the megatrend challenges.

"Our engine room has people with expertise in machine learning, from Barcelona to Boise," he said.

"We have ink chemists, experts in chemistry, we have materials scientists, we have mechanical engineers... machine learning people. We've organised the HP engineering group across all these global silos into these key disciplines."

The goal of this multidisciplinary unit is to provide 'commando teams' to take on individual problems on demand and in an agile way. Additive manufacturing is a key area of focus and one that Patel views as a 21st century archetype of the cyber-physical. With traditional printing in decline, it's no surprise that HP is seeking to transfer its domain expertise in inkjet across to 3D printing.

The company's Jet Fusion systems use a bed of pre-heated powder. A fusing agent is then deposited selectively using adapted inkjet technology, with overhead heat lamps causing the deposited 'ink' to fuse. According to Patel, the process lends itself to extreme accuracy.

"The precision with ink is phenomenal," he said. "An area where the ink is deposited is a few hundred microns by microns by microns – it's called a voxel [volumetric pixel]. At voxel scale, we are building parts."

It's a complex process happening at a microscopic level, with multiple heat inputs and losses that have to be accounted for. And, with HP looking to promote the technology as a solution for full-blown manufacturing, parts need to match up against more traditional processes like injection moulding. Achieving these kinds of tolerances requires expertise across multiple domains.

"There's a very complex heat transfer equation," said Patel. "We hire PhDs to solve it."

"But we had to address this problem to understand how heat was being transferred, so that we could get



Hewlett-Packard says its JetFusion technology can compete with injection moulding

consistent parts with good structural properties.

"Every nozzle is an actuator. The lamps are an actuator. Someday the lamps could become lasers. You could have multiple rail lamps, multiple intensities. So you can see the richness of actuators that we could have as we move to the future...."

"There's a lot of fundamental engineering, as I'm used to, and I'm so glad that we're going back to an era of fundamentals."

When building in microscopic layers, it is imperative to know one is on the right course. The multitude of actuators therefore requires a complementary suite of sensors. As additive technology progresses, increasing numbers of actuators will generate data, and incredibly complex algorithms will be required to get everything working in harmony. Patel believes artificial intelligence will be key to this co-ordination.

"As it gets more and more advanced, we will have to work on this," he said. "We will get to a world of multi-input, multi-output control systems where machine learning will play a big role."

However, machine learning cannot operate in a vacuum, even in the software capital of the world.

"Many times people say, particularly in Silicon Valley: 'Chandrakant, I don't need to know anything about a

physical system. Just give me data and I'll figure it out.' My response is: 'What data have you got?'

"In this world, machine learning requires domain knowledge... and we are operating at the intersection of data management, machine learning and domain knowledge. If you don't have domain knowledge, you could collect all the data and you could come to correlation... but you couldn't get to causation."

As for the skills required by the next generation of innovators, Patel advises augmenting traditional engineering expertise with its contemporary software counterpart.

"Strength in fundamentals, coupled with computer science," he urged. "The world of just having data science knowledge is over. The cyber-physical age is a return to fundamentals."

Over the course of his career, Patel has been granted over 130 patents, authored more than 150 papers, and been elected to Silicon Valley's Engineering Hall of Fame. After 35 years as a mechanical engineer working in IT, he has some wise words for those who think that software is the only game in town.

"Some of us old timers are teaching some of the newcomers – the millennials – that there is a more exciting world than being in social networking." ■



Future made of money

Novelist Jon Wallace considers the science fiction implications of engineering stories that have caught his eye. This month, the imaginary prospects of currency

Money is a simple method by which sci-fi writers establish the world of their stories. Our dependence on and hunger for currency has helped define human history since around 700BC; we can hardly imagine society without it, and so naturally it plays a crucial role in story, as corrupting motive or hunted treasure.

Crucially, creating an entirely new, imagined currency helps to establish the otherness of our world. Money, whether a coin bearing Caesar's likeness or a note that of a Founding Father, is part of what allows us to define a particular civilisation: for writers an invented currency therefore helps us establish our alternate order.

Often enough the fantasy currency is little more than a fun game for the writer, making up things we find pleasing to say – from Cowboy Bebop's 'Woolongs' to Groo the Wanderer's 'Kopins' and Rick and Morty's 'Flurbos'. Money is often a joke in sci-fi, such as *Futurama's* speaking Nixon notes and Douglas Adams' 'Ningis' – triangular rubber coins measuring 6,800 miles on each side. Still, it plays a crucial role in most of these tales.

Even in worlds where traditional payment is supposed to have ceased, cash retains its importance to storytelling: in *Star Trek: The Next Generation*, where money no longer exists, the writers were horribly shackled by the imposition of greed-free saintliness. Small wonder that *Deep Space Nine*, the *Star Trek* spin-off, is rendered more successful by the introduction of a race entirely defined by 'acquisition'; the Ferengi lust for Latinum created more variety and fun; we like them because we recognise them far better than Federation do-gooders.

So, what to make of a world of cryptocurrencies and contactless payment? Are the days of safes and briefcases under the table numbered? And if so, what does this mean for sci-fi writers wanting to tell tales of Ferengi-style dodgy deals and treasure hunts?



Well, the omens for cash are mixed. *The Engineer* recently reported on a new nano-structure printing process that holds great promises as an anti-counterfeiting measure, promising printed images with a resolution of 100,000dpi. Such work would seem to point to a secure future for the humble banknote. Yet, in the same month, Costcutter supermarkets have trialled a 'finger-vein payment system' that sees customers pay via a scan of the unique biometric map of their finger veins: another step towards a cash-free society.

What can such developments mean for the sci-fi writer? A world without cash would seem to point to a world where more than ever personal worth is resolved solely into exchange value, as our finances define our identity; where privacy becomes more and more an absurdity. Where will it all lead us?

Picture a cashless future where citizens' bank balances define the way they perceive the world; we could tell the story of a city whose population lives in augmented reality (AR), yet where vast swathes of the AR space is invisible to those scanned and found of limited means. This visual

The future omens for hard cash look mixed; but money seems likely to still govern us

exclusivity extends to all things: we could tell the tale of a mischievous tailor who convinces a rich man to wear an AR suit that only the wealthiest citizens will see. He agrees, and wanders the city, appearing a ridiculous fat man in his underwear to all but the fewest of the few. The tailor expects some child will point out the absurdity of this emperor's new clothes, but it never happens. Instead the craze spreads, and for a while the whole city's population wanders in its underwear, hoping to be thought of as princely.

Perhaps even if hard cash remains, money will continue to govern us: imagine future banknotes that possess artificial intelligence, greenbacks designed to turn bright red when used in criminal transactions, rendering them invalid. The system works well, until the notes begin to judge the merit of their legitimate owner's transactions too, only allowing themselves to be spent as they see fit, turning red to prevent their exchange for evils such as alcohol, weapons, or One Direction albums.

Beyond that, it's interesting to speculate how the concept of value could be destroyed by contact with extra terrestrials. Imagine a universe where Earth has joined an inter-galactic economy, where a mineral alien to Earth is standard cash. To acquire the mineral each individual must mint his own currency, provided a purely aesthetic rate of exchange by an intergalactic panel. Suddenly artists are wealthy beyond their wildest dreams as their beautifully rendered coinage purchases stacks of mineral, while once rich men can only attain fragments with childish scrawled notes.

Wherever technology leads money, it will remain the root of all evil; but it's the root of a good story too. With no Ferengi, there's no fun at all. ■

Jon Wallace is a science fiction writer. He is author of *Barricade*, published by Gollancz



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Front up for the fast lane

Chris Pickering **gets to grips with the fastest front-wheel-drive production car to lap the fearsome Nürburgring Nordschleife**



Decked out with more vents and spoilers than a Friday night at McDonald's, the new Honda Civic Type R could never be accused of hiding its light under a bushel. But what you see here is the real deal. It's the fastest front-wheel-drive production car ever to lap the fearsome Nürburgring Nordschleife. Find a long enough straight and it will crack the best part of 170mph.

Under the bonnet there's a two-litre turbocharged four-cylinder petrol engine, producing 320PS (316bhp) and 400Nm of torque. It's a relatively mild revision of the engine found in the previous generation Civic Type R, which courted controversy somewhat among Honda fans by abandoning the brand's traditional high-revving naturally aspirated format in favour of forced induction.

Two years down the line, things have moved on. The idea of a turbocharged Honda no longer raises any eyebrows and neither does the firm's decision to put all that power through the front wheels. While an increasing number of hot hatches are now turning to four-wheel drive, Honda points out that a front-wheel drive set-up is both lighter and more efficient.

The chassis is based on the regular 10th-generation Civic, which uses an innovative 'inside-out' assembly process. Here, the inner frame is assembled first, followed by the outer frame and then the joints. The resulting structure is 16kg lighter than the previous Civic Type R's, despite being both longer and wider. It also yields a torsional stiffness improvement of 37 per cent and a static bending rigidity improvement of 45 per cent.

As with the previous model, all Civic Type Rs – even those bound for export to Japan – are produced by Honda UK Manufacturing in Swindon. For the international launch, however, we headed slightly further afield, to the de-restricted autobahns of Germany.

Traffic prevented a proper attempt at the claimed 169mph top speed, but the Type R was still pulling determinedly at an indicated 156mph. More importantly, it felt absolutely rock solid at that



The idea of a turbo-charged Honda no longer raises any eyebrows



02

speed. All those aerodynamic accoutrements, it turns out, are there for more than just show. In fact, Honda claims this is the only car in its class – and one of relatively few road cars full stop – to produce genuine downforce, as opposed to simply negating lift.

Accelerate hard from low revs and you can sense the engine building up boost, but there's no real lag. That's thanks, in part, to the use of variable valve timing and lift on both the camshafts, which enables very careful control of the exhaust back pressure. The throttle response is pin sharp, aided by a single-mass flywheel, which reduces the clutch inertia by some 25 per cent over the outgoing model.

It all adds up to a hugely fast car. The mighty mid-range torque is accompanied by a genuine appetite for revs. Before you know it, the engine is lunging for the 7,000rpm limiter and it's time to grab another gear. If anything, Honda's claim of 0-to-62mph in 5.7 seconds feels a little conservative.

Following the blast down the autobahn we headed to the Lausitzring to sample the car on track. Grip is prodigious, as you might expect, but what really impressed was how well the Type R manages to blend agility and composure.

At 1,380kg, it's a relatively light car by modern standards, and it slices through the direction changes with scalpel-like precision. The variable-ratio electrically assisted power steering also helps. It isn't the most communicative system, but it does feel remarkably intuitive; the only clue to its non-linear nature is the fact you can negotiate the tightest of turns without shuffling your hands around the wheel.

Honda's decision to stick with front-wheel drive has been well and truly vindicated. Those of a hooligan persuasion might argue that driving the rear wheels

01 All Civic Type Rs are produced by Honda UK Manufacturing in Swindon

02 The car is a more useable day-to-day proposition for drivers

can be more fun, but at no point did the Type R's chassis feel overwhelmed by its power. Torque steer is almost completely absent, thanks to the dual-axis front suspension concept carried over from the previous model. This puts the wheel carrier on a separate

knuckle to the main MacPherson strut, placing the steering axis much closer to the centreline of the wheel. There's also a proper mechanical limited-slip differential, aided by an electronic system that can selectively apply the brake on either side to quell any wheel spin. It works brilliantly, although it's not as addictive as the ultra-aggressive differential on the previous model.

Away from the track, the biggest strides forward are actually to be found in the more everyday aspects of the car. The previous Civic Type R was a real hardcore headbanger. It was great for track-day enthusiasts, but the ride was simply too stiff for UK roads in its most aggressive setting. For the new car, Honda has stuck with magnetorheological dampers, but switched to a triple-chamber design, which provides a much wider range of adjustment. It feels positively plush in comparison and should help to significantly broaden the car's appeal.

The acoustics have also been carefully optimised to make the new Type R substantially quieter whilst cruising. Uniquely, it features an additional tailpipe in what is essentially a twin-exit exhaust system. At high flow rates, this third pipe acts as an additional exhaust outlet, giving the engine a deeper growl. But at lower gas velocities, the flow reverses, sucking in ambient air to prevent the booming noise that would otherwise fill the cabin. The resulting soundtrack isn't the most symphonic, but it is suitably purposeful.

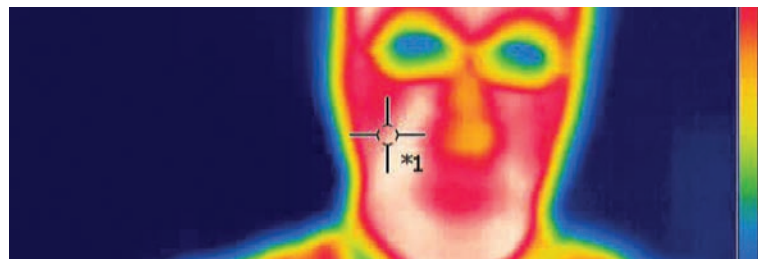
The end result is a car that retains most of the previous Type R's razor-sharp focus, while offering a far more useable day-to-day proposition. ■



01

The living and the inanimate

Thermal cameras could help equip autonomous vehicles. Supplier: Flir



Autonomous vehicles of the future may well be equipped with thermal cameras to help distinguish between living and inanimate objects.

Thermal imaging specialists such as Flir believe that the technology could be used to augment sensors more commonly found on driverless vehicles, such as Lidar, radar and regular cameras. While those sensors are vital for positioning and environmental awareness, they can be limited in identifying humans and animals, especially at distance.

Autonomous vehicle algorithms

that have access to heat-imaging data could potentially lead to better decisions, particularly in darkness or adverse weather. Flir is developing a VGA (Video Graphics Array) device for use in self-driving cars.

According to Paul Clayton, director of automotive at Flir, sample units of the sensors are being shipped to some manufacturers for testing this year. If this programme proves successful, mass-produced sensors could eventually be produced at a cost of a few hundred pounds.

"It's an augment, a somewhat redundant sensor that helps classify in bad lighting conditions or weather," said Clayton.

It's long been known that a variety of sensors provides cars with better awareness of their surroundings, and the unique properties of thermal imaging could potentially provide the additional context required to avert a dangerous incident. Furthermore, orthodox camera technology sometimes has difficulty distinguishing between

real objects and images, such as person walking on a footpath and a person in a roadside billboard. By providing auxiliary temperature data, thermal imaging could help provide the additional information required to instantly classify an object as living or inanimate.

One potential problem is that most driverless algorithms have so far not been incorporating thermal imaging into their calculations. Flir is creating a thermal image database that clients can use to train their own neural networks. ■

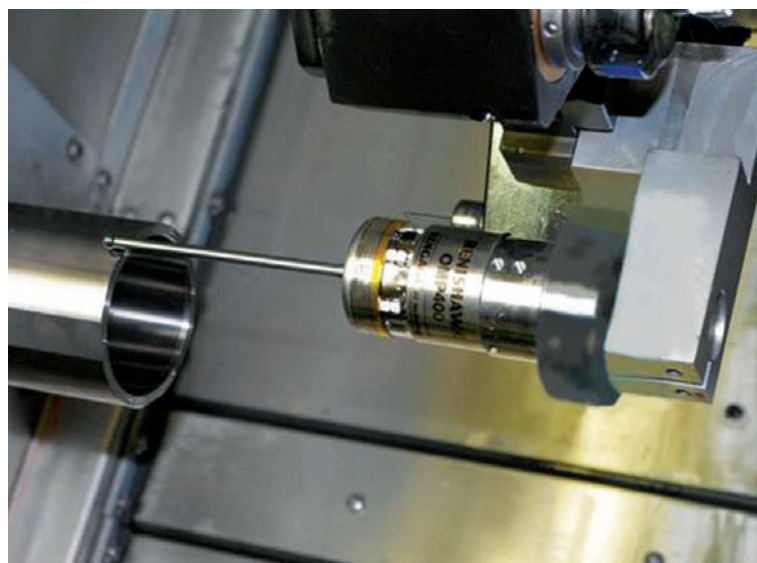
Redefining the laws of the universe

Probes create cylindrical test masses for use in space. Supplier: Renishaw

A micron-accurate probe from Renishaw, combined with a high-precision Benzinger lathe, has been used to create test objects that could help redefine the laws of the universe.

The OMP400 probe helped create incredibly precise cylindrical test masses that will be used in space to test the long-accepted theory that inertial and gravitational masses are always equal – a principle assumed as far back as Galileo. However, the latest research on the smallest particles on our planet indicates that the equivalence principle may no longer apply if measured at a sufficiently high accuracy of less than 10-12 microns (μm). The European Union's Microscope mission is now aiming to clarify these questions, but needs precisely calibrated instrumentation to do it.

"The machines we have today can achieve positioning accuracies of 2



to $3\mu\text{m}$ in one or two directions without any difficulties at all," said Dr Daniel Hagedorn, manager of the National Metrology Institute of

Germany's (PTB) Surface Metrology working group. "But for our test masses, we needed to achieve this high level of precision in all three

dimensions — not only at individual positions, but also on planes, cylinder surfaces and in angles."

To obtain the required level of accuracy, specialists at PTB needed to integrate high-precision measurement directly into the machining process. Hagedorn tested a number of industrial measurement solutions from different manufacturers.

"We concluded that the only solution capable of meeting these standards would be a high-precision probe such as the Renishaw OMP400," he explained.

"We were able to achieve $\pm 1\mu\text{m}$ accuracy for all characteristics. The accuracy and reliability of the Renishaw OMP400 probe was a key factor in our success. The quantities of our raw material platinum-rhodium alone cost tens of thousands of euros, we are very pleased with these results." ■

Ford can now offer customers such as sports car manufacturers a 'one-stop shop' for engines, after signing a formal agreement with Revolve Technologies Ltd, its newly named trusted engine partner.

Revolve has been appointed by Ford as a Quality Calibration Modulator (QCM), the only one in Europe and one of only five worldwide.



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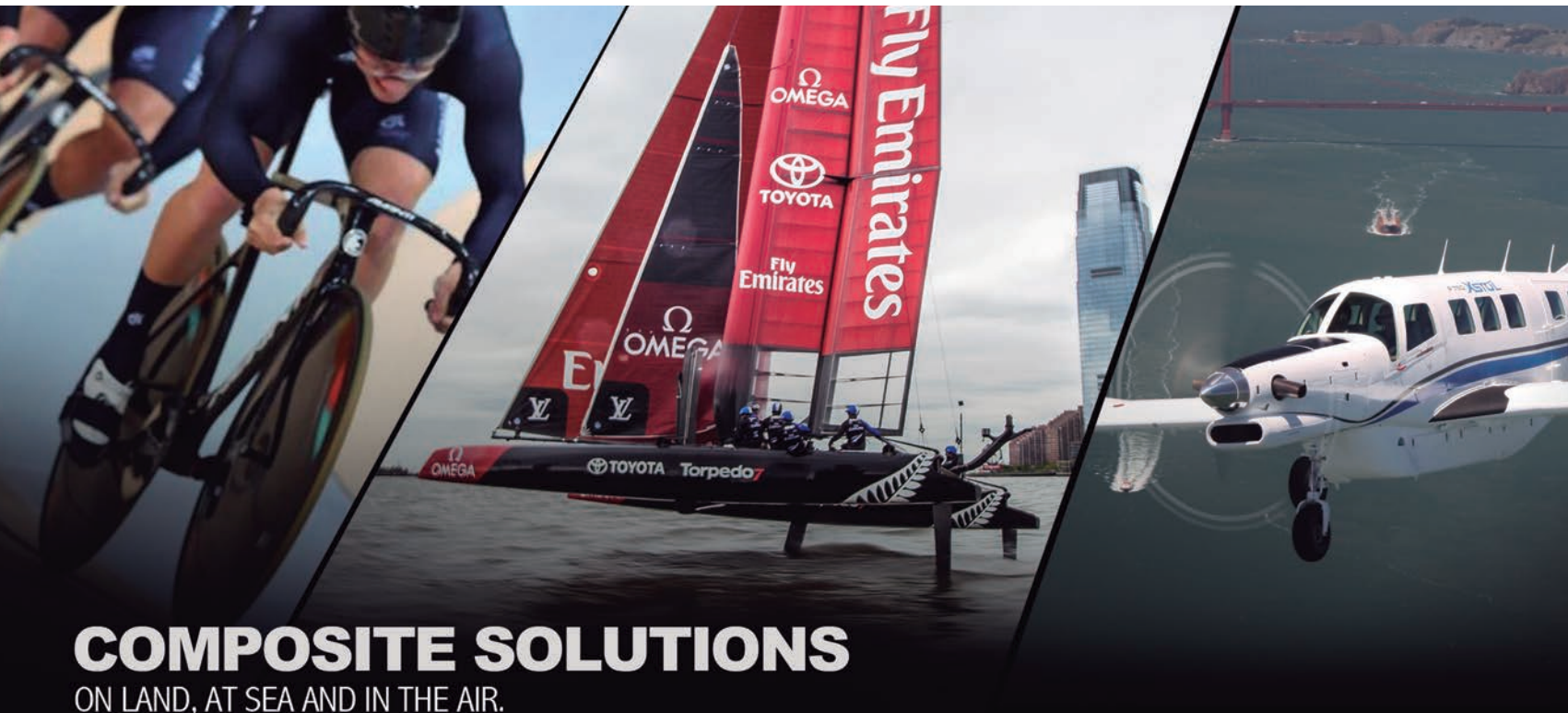


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Collaborative robots and optical sensors

Cobot verifies surface state and dimensional accuracy. Supplier: Alicona

Alicona has introduced Compact-Cobot, which combines collaborative robots with high-resolution optical 3D measuring sensors.

The new Compact-Cobot is a universal product applicable in all industries to verify surface state and dimensional accuracy, including those of large components.

Alicona cobots combine collaborative robots and optical 3D-measuring sensors, delivering traceable and repeatable measurements in high resolution.

The measuring sensor is mounted onto a mobile robot platform and can be positioned as needed, even for the measurement of components in the machine.

This is made possible by intuitive hand-guided control, automatic



measurement evaluation, and a no-enclosures safety concept. Consequently, cobots can verify the surface state and dimensional

accuracy of workpieces in existing production environments.

Cobots require no prior metrology knowledge and make handling,

programming, and executing measurement series easy. Using connected automation software, any series of measurements can be defined at several positions by an administrator, which the operator starts with the press of a button.

Control and measurement are fully automated, and upon completion the worker receives a measurement report with ok or not ok details. Surface state and dimensional accuracy is automatically verified.

In addition, an optional CAD/CAM connection allows the definition of measurements points, measurement directions and so on directly in the corresponding CAD file of the component, the 'digital twin' of the respective workpiece.

A simulation provides a preview of the measurement to be carried out, supporting a safe and secure measurement planning. The virtual operation of the measurement system comprises the entire handling, from the positioning of a component through to the determination of the measurement area in 3D. ■

Inspect the metal waste

Technique uses ultrasound to detect defects

A new technique could improve the efficiency of metal additive manufacturing and reduce waste by allowing components to be inspected during the build process. The technique, which uses laser ultrasound to detect defects, is being developed by Dr Ben Dutton from the Manufacturing Technology Centre in Coventry.

His work could encourage the use of additive manufacturing within mass manufacturing industries as it removes the need for a separate inspection process once components are built. It also responds to the need for new and improved testing techniques in view of the increased use of additive manufacturing in industries such as automotive and aerospace. This work was revealed at the NDT 2017 conference in Telford, UK, on 6 September 2017.

Dr Dutton said: "Currently, some additive manufacturing systems incorporate in-process monitoring but they use cameras to take snapshots of the layers as the item is being created. The problem with cameras is that each new layer of powder can conceal

part of the defect. With NDT methods such as laser ultrasound, there is a certain amount of penetration so you can look below the top layer and detect sub-surface defects in a non-contact way."

The technique has shown potential for use with powder bed and directly deposited additive manufacturing processes, and with components of complex shape.

Dr Dutton is also playing a key role in the development of new ISO standards for inspecting additive manufactured components.

He said: "Inspecting components during the build process will reduce waste. If you spot a defect, you can try to stop the build straight away without having to waste the full part. It would also improve efficiency it would remove the need for a separate inspection once the build is complete. In terms of using additive manufacturing within mass manufacturing, in-process inspection is the future." ■



Helping with the climb

Retaining ring helps classic car reach the summit. Supplier: TFC

Racing classic cars is inherently challenging, as is any motor sport, but with the added difficulty for car owners and drivers to source components to keep their machines going. Hill-climbing enthusiast Martin Rutter had to turn to TFC to get his specially adapted 1970s Fiat X1/9 into shape.

"Racing historic classic cars brings its joys but major headaches when it comes to sourcing components. This is where

TFC came to the rescue for my Fiat X1/9 that I campaign in national speed hill-climb championships, Rutter said. "An urgent and much-required upgrade was a Colotti race gearbox originally developed many decades ago by Valerio Colotti." Colotti Transmissions developed gearboxes for many racing teams, including Ferrari, Minardi, Lotus, Alfa Romeo and Lancia. "However," Rutter continued, "the build of the gearbox was held for weeks as the correct



retaining ring for a motion shaft could not be located – that is until TFC facilitated the supply of a Smalley retaining ring perfect for

the job. It wouldn't be possible to keep historic race cars racing if it wasn't for the support of companies such as TFC." ■

Life on the bridge

Washers cope with the load on Queensferry crossing. Supplier: Tufnol



Scotland's magnificent new road bridge across the Firth of Forth, the Queensferry Crossing, depends on fasteners from Tufnol to bear the load of the 24 million cars that are predicted to cross its 2.7km span every year. Isolation washers manufactured from Tufnol's high-

performance glass laminate are forming pre-loaded connections with the bolts that attach critical components to the bridge construction and have been specially designed to cope with the forces that will be placed upon them every day, 365 days a year.

It's not just the load that's the problem; Queensferry is a challenging location for a structure such as a bridge, with occasional extreme weather and sea-salt-laden air. The washers need to isolate different metals in the structure to help prevent corrosion, which led

to the need for the first Forth Road Bridge to be replaced 54 years after it was built. The new bridge is planned to last more than three times as long.

"We have found the Tufnol isolation washer to be highly suitable for use with pre-loaded stainless-steel connections. These products are quite niche and initially we did not know if we would be able to source a product," said Gerard Kiely, head of section for Forth Crossing Bridge Constructors. "We needed the bolt washers manufactured from a material that would be robust enough to stand up to the rigours of being installed on a bridge situated in one of the UK's harshest environments."

The project is the latest in a series of civil projects for Tufnol. "We've provided products and solutions to a wide range of projects such as this over the years, including Birmingham's New Street station and London Underground and it is great to be part of yet another high-profile infrastructure project," said Roy Thomason, managing director for Tufnol Composites. ■

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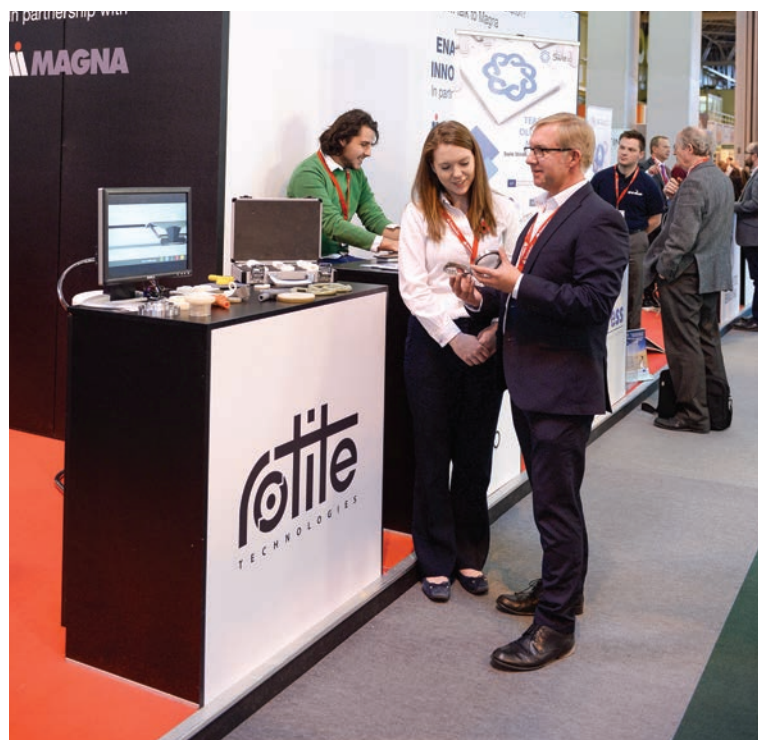
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Advance guard

Show connects entire supply chain of the UK's advanced engineering community



Organised by Easyfairs, Advanced Engineering 2017, which takes place on 1-2 November at the NEC Birmingham, is one of the UK's largest annual gatherings of advanced engineering professionals.

It connects the entire supply chain of the UK's advanced engineering industry with R&D, design, test, production and procurement from large and small companies, through to top-tier industry players in a two-day free-to-attend exhibition and high-level conference.

Now in its ninth year, this year's event is expected to bring together more than 700 exhibitors, as well as more than 13,000 engineers, procurement managers and senior decision makers from large and small companies – all looking to source, specify and invest in the most up-to-date products and explore the latest industry innovation.

The event consists of five co-located zones each focused on a specific area of industry: aero engineering, composites engineering, automotive engineering, performance metals engineering and, new for this year, connected manufacturing, which will showcase the latest technology and trends around Industry 4.0. This year's show also features an expanded Enabling Innovation zone specially aimed at start-ups sponsored by automotive supplier Magna International.

Alongside the exhibition, the event also features a free-to-attend CPD accredited two-day conference with presentations from some of the

leading names in manufacturing and engineering, including EEF, Siemens, Magna International, Gambica and Rockwell. Topics under discussion will range from insight into how specific engineering problems have been overcome, through to a focus on more strategic issues and trends such as Industry 4.0, Brexit and additive manufacturing.

Among the speakers on day one, Mike Wilson from BARA will be discussing Industry 4.0, smart factories and autonomous (mobile) robots. Then, on day two, EEF will be taking to the stage to discuss Leading factories of the future – how the fourth industrial revolution is shaping a new leadership and skills dimension. Other talks include: Paul Hingley, Siemens – digitisation keynote; Grant Coffin, Rockwell Automation – Time to value: implementing 14.0 solutions in the real world.

Meanwhile, in the show's Enabling Innovation showcase, around 50 start-ups and researchers will showcase the next generation of exciting new technologies in front of a huge audience of potential investors and customers across all engineering sectors.

To register for the show visit: www.advancedengineeringuk.com. ■

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Tracking the renaissance

The government's decision to start pumping money into Britain's rail industry means a demand for engineers.

Stephen Harris reports

01 Rail investment has created around 1,000 new jobs at Hitachi's Newton Aycliffe plant

02 The first new IEP train rolls off Hitachi's production line

No trains had been made in the birthplace of locomotive manufacturing for over 30 years. But when Hitachi opened its £82m Newton Aycliffe factory in September 2015, it marked the start of a rail manufacturing renaissance not just for the north east of England, where George Stephenson set up the first company founded to build railway engines in 1823, but for the whole of Britain.

For the previous 10 years, there had been only one train builder in the UK: Bombardier in Derby. Today that company has expanded and been joined by Hitachi, assembling trains initially for the Intercity replacement programme and now for two additional British contracts. Soon to follow will be Spanish firm CAF, which is scheduled to open a new plant near Newport in South Wales in 2018. And Alstom has recently opened the country's largest train modernisation facility in Widnes in Cheshire.

As is the case with most modern vehicle manufacturing, these factories will primarily assemble final products from components built all over the world. But the location of these sites within the UK has also contributed to the growth of British companies in the rail supply chain that is also bringing investment. In 2014, for example, Siemens expanded its factory in Hebburn, Tyneside, to build components for the new Thameslink trains. And Hitachi claims that 60 per cent of the parts for its UK-made trains come from British suppliers.

"People can call it a 'renaissance' or a 'new golden era', that sort of thing," said Matt Watson, human resources director at Hitachi Rail Europe. "The reality is that the level of investment going into UK railways right now is huge. Something like this only happens once in 100 years."

That investment is largely thanks to the government's decision to start pumping money into Britain's rail infrastructure again, after decades of neglect, rocketing passenger numbers and the 2008 global recession made doing so politically expedient. Plans worth around £10bn

for unprecedented numbers of new trains to replace the country's ageing rolling stock have followed, bolstered by the Thameslink, Crossrail and High Speed 2 programmes to expand network capacity.

There has also been a change in the government's rhetoric that's placed more emphasis on how infrastructure contracts can benefit the wider UK economy, and on the importance of manufacturing. Add to that historic low interest rates and it's not surprising that international companies have become much more interested in building trains in the UK. Around half of the more than 6,000 new carriages so far ordered are set to be made in Britain by 2021. And investment doesn't stop there.

01





02

"If you look at planned annual investment in the rail sector from all sources up to 2033, it rarely drops below £14bn a year and peaks above £16bn," says Neil Robertson, chief executive of the National Skills Academy for Rail.

For Hitachi, this has meant the creation of around 1,000 jobs at its Newton Aycliffe site so far, including around 100 skilled engineering roles at any one time. "We've set out to build and maintain rolling stock, securing contracts that involve long-term service," said Watson.

"That means we have almost every type of role you could think of. We've got design engineers in the factory working on components and the integration of systems, manufacturing engineers helping to operationalise production. We also have test facility with fully live electrical operations that can diagnose faults and feed back into production."

Beyond the train manufacturers, there is a wealth of other firms that are also benefiting from rail's

resurgence. "We have a lot of small- and medium-sized companies that are particularly good in subsystems, electronic subsystems and asset management systems," said David Clarke, technical director for the Rail Industry Association (RIA). "The nature of global supply chain means that many international companies create centres of excellence around certain capabilities."

Because of this global supply chain, one of the most crucial engineering roles for many companies, especially the rolling stock makers, is systems integration, which Watson also said is one of the most difficult areas to recruit in. It's made all the more important by the fact that the UK has a patchwork of different rail lines, systems, signals and stations, and any new product has to be integrated with them, as well as with other new technologies as the railways go digital.

The knock-on effect is that the industry needs both engineers with specialist rail experience, but also systems engineers with similar skills to those in many other manufacturing sectors. "Everyone wants digital integration with physical systems now," said Robertson. "Never before have advanced manufacturing jobs in rail looked so like other manufacturing jobs, with such a high proportion of competencies to do with digital."

For similar reasons, software engineers are becoming more important than ever, especially as new technologies come through, such as greater train automation, remote sensing and digital traffic management systems. "Software is really coming to the fore," said Peter Loosely,

"Up to 2033, planned annual rail investment rarely drops below £14bn a year and peaks above £16bn"

Neil Robertson, National Skills Academy

the RIA's policy director. "Like planes and cars, trains are now software-driven. There's real growth in that area."

This development is helping to challenge the rail sector's somewhat old-fashioned image built around heavy engineering, which has contributed to its ageing workforce. The RIA estimates that around 50,000 people across the rail industry as a whole will retire within the next 10 years. The demand for engineers in the sector looks strong for the next decade and beyond.

But can the boom be sustained? If government investment comes to an end, the UK's rebuilt rail manufacturing industry will need to ramp up its exporting capability to survive. The outcome of Brexit will play a big role in this. But, overall, the industry remains upbeat.

Loosely said: "Although there are some difficulties, possibly around strategic planning and procurement, the rail sector is an exciting place to be right now." ■

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Down on the farm

A demonstration of a radio-controlled tractor in a Surrey field piqued the interest of *The Engineer*

Fordson tractors underwent a series of modifications during their 47 years in production, but it was a non-production version that lured one of our predecessors to a field in Surrey in October 1955.

Ford Motor Company had invited *The Engineer* to observe an unmanned, radio-controlled Fordson Major diesel tractor, a technology demonstrator that had been built for use in field trials. What piqued the interest of our predecessor was the potential application of radio-controlled vehicles “in the transport of fissionable material at nuclear power plants”.

Furthermore, Ford was demonstrating a vehicle modification that our reporter thought could be “a pointer to the future of mechanised fanning”.

According to the report, radio control was enabled by a transmitter working at 27-12Mc (megacycles) and providing six separate – but not simultaneous – channels, by means of audio-frequency modulation of the carrier, the receiver having tuned reed output relays for the reception of individual signals. These then operated secondary relays to provide excitation from the 12V tractor battery for the solenoids connected to the tractor controls.

The transmitter and receiver were battery operated, the latter being carried in a case fixed to the side of the tractor near to the telescopic whip aerial. The operator's control box was separate from, but attached to, the transmitter by a cable. The controls had been arranged to allow left and right steering, clutch release, implement raising and lowering, and engine stop.

The report said: “On the tractor, in association with the receiver, there was a bank of coloured lights that indicated the control functions and which provided a continuous check on the operation of the radio transmitter and receiving gear.

“The ‘engine stop’ function is also associated with a safety device, which comes into operation in the event of a failure in the transmitter or receiver.



The radio-controlled Fordson Major diesel tractor in action in 1955

The hydraulic system, which operates at about 500lb per square inch, includes a Plessey pump installation, a five-gallon header tank fitted underneath the radiator, a Keelavite control valve and the solenoid operated by-pass valve, as well as the valves and hydraulic cylinders concerned with steering and clutch control.”

The function of the by-pass valve was to short circuit the pump when no hydraulic power was required, which reduced the amount of energy wasted during pumping. The tractor was steered by a double-acting cylinder controlled by a double-acting valve operated magnetically from the 12V tractor battery through the radio receiver's output relays.

The Engineer's reporter said that the mechanical output of the hydraulic cylinders was coupled to a point on the steering drop arm, and there were bypass taps provided so that manual steering could be resorted to if required.

The clutch was controlled by a single-acting

cylinder that was arranged to operate directly on the linkage between the pedal and the clutch.

“For the ‘engine stop’ control there is a solenoid with linkage direct to the lever on the fuel injection pump casing, and to provide a full measure of safety it is arranged to hold the mechanism in the running position when energised,” our reporter observed. “Normally this control is held out in the ‘stop’ position by a spring, so that... in the event of any electrical failure either from the radio or from the battery the solenoid is de-energised and the engine stopped.

“To raise and lower the implement gear the existing control lever has been removed and the linkage connected to a motor-driven actuator. This is controlled by limit switches to provide the correct stroke and automatically centre the valve when the operating switch on the control panel is allowed to centre from the raised position, corresponding to the spring centring cam device normally fitted to the manual control.” **JF ■**

Word of the issue

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

Chain links were fashioned during the earliest age of metals and for decorative purposes. It is easy to imagine how rope lengths may have been joined together, indeed the etymology of the word 'chain' seems to provide proof of the same.

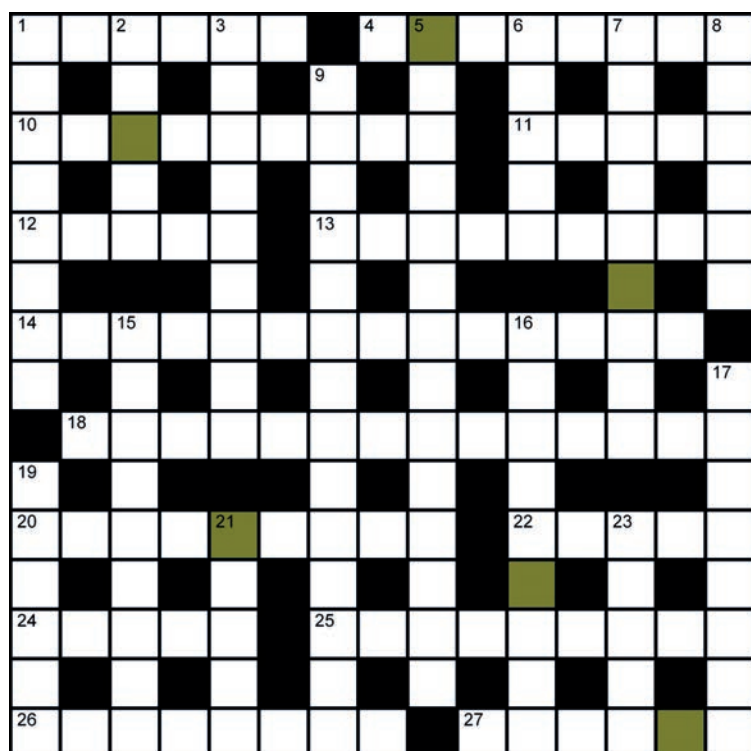
'Chain' came to English from Old French *chaiene*, itself from Latin *catena* and both with the same meaning. All these come from the Proto-Indo-European root *kat* meaning 'to twist, twine' – thus why we can say the earliest chains were not of metal but produced from vegetable matter, just as rope and twine still is.

Also of interest is another Latin word derived from the same root of *kat* and that is *cassis*, which has given us the English 'catch', used in the Roman Empire to mean 'hunting, snare'. Such derivations are clear proof of the early use of shorter lengths to produce something bigger, be it a longer rope or a net.

Bigpicture



The maiden flight of the world's first autonomous flying taxi service has taken place in Dubai. The two-seat Autonomous Air Taxi (AAT) has been supplied by Germany's Volocopter, a manufacturer of autonomous air vehicles.



Prize crossword

When completed rearrange the highlighted squares to spell out a gear with a small number of teeth. The first correct answer received will win a £20 Amazon voucher. Email your answer to jon.excell@centaur.co.uk

Across

- 1 Lessen the strength of a solution (6)
- 4 Be of different opinions (8)
- 10 Large hat that shades the face (9)
- 11 Rested one's weight on one's legs (5)
- 12 Turn around as if on an axis (5)
- 13 Female rower (9)
- 14 Minimum speed needed to escape gravity (6,8)
- 18 Different pieces that make up a machine (9,5)
- 20 Photographic print of plans or technical drawings (9)
- 22 The local name for Wales (5)
- 24 Person employed as one in crowd in film (5)
- 25 Gradually decreasing in width (9)
- 26 Rising currents of warm air (8)
- 27 Travel up (6)

Down

- 1 Prevent deliberately (8)
- 2 Long pointed rod used as a tool (5)
- 3 An informal farewell remark (6-3)
- 5 Occurring between large celestial bodies (14)
- 6 At an angle (5)
- 7 Device that provides energy from fluid flow (9)
- 8 A magnitude or level (6)
- 9 Not conforming to accepted rules (14)
- 15 Minced cooked meats in thick white sauce (9)
- 16 Able to contain a large amount (9)
- 17 Gained the good will of (8)
- 19 To protest (6)
- 21 Colourless watery fluid of the blood (5)
- 23 Corn crop (5)

August's highlighted solution was Resource. Winner: **David Hewitt**

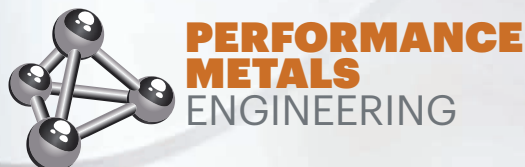
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