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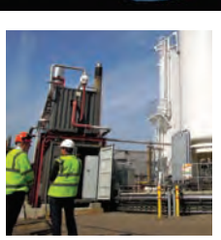

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Prized invention

As this issue of *The Engineer* went to press, the Royal Academy of Engineering named Prof Robert Langer of the Massachusetts Institute of Technology as the second winner of the Queen Elizabeth Prize. The announcement is covered in our news section on page 6, and our columnist Paul Jackson of Engineering UK mentions it in his piece on page 16.

Langer's award recognises his invention of sustained drug-delivery systems; he was also instrumental in developing the fields of tissue engineering and lab-on-a-chip devices. His win will hopefully help to illustrate the variety of sectors in which engineering can play a role, and that role can directly save lives. As many members of the public may not be aware of this type of medical engineering, it's a worthy decision.

Elsewhere in this issue, we look at more traditional engineering sectors, but with a focus on the ways that cutting-edge technologies can change them. Our cover feature (page 18) explains how digital technologies such as virtual reality can be combined with ergonomics and additive manufacturing processes to not only change the types of products that sectors such as aerospace and automotive build, but also have an effect on the very production lines used to build them — directly influencing the working environment of manufacturing employers.

In our interview (page 26), we meet a maverick inventor who is trying to promote the use of cryogenic gases to propel vehicles, while another use of cryogenic gases, grid-connected energy storage, is the focus of our Readers' Q&A feature (page 28).

"Langer's award is for his invention of sustained drug-delivery systems

We also look at one of the world's best-known engineering companies, Ferrari, and explain how it uses limited-edition vehicles to give its designers freedom to explore cutting-edge technologies that may trickle down to more conventional vehicles.

As always, we look forward to hearing your views and comments on all of the issues covered over the following pages.

Finally, we'd like to encourage you to register to attend our new event, The Engineer Design & Innovation show, which runs from 2–4 June at the NEC, Birmingham, alongside Subcon, The Advanced Manufacturing Show and The Engineer Conference. For more, visit ***www.theengineer-designinnovationshow.co.uk***.

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MATERIALS

Casting light on the future of graphene

Unique material could find use in flexible electronics

BY JULIA PIERCE

A new generation of semi-transparent, flexible and efficient electronics could be on the way, thanks to research carried out at the universities of Manchester and Sheffield.

Scientists have made use of graphene's unique properties to fashion new 2D designer materials that could be utilised to create light-emitting devices (LEDs) for the next-generation of mobile phones, tablets and televisions that are incredibly thin as well as flexible, durable and even semi-transparent.

The team was led by Sir Kostya Novoselov, joint winner of the 2010 Nobel Prize for Physics for ground-breaking experiments with graphene, and the breakthrough was made by creating LEDs that were engineered on an atomic level, constructing them by combining 2D crystals made from varying materials.

Being so thin, at only 10–40 atoms thick, the new components are capable of forming the basis for the first generation of semi-transparent smart devices, which emit light from across their whole surface. The components could be used to build heterostructures — stacked layers of various 2D materials — to create new possibilities for graphene-based optoelectronics, tailoring the devices' capabilities by varying the materials used to make them. They could also be used to introduce new types of quantum wells to control the movement of electrons.

Novoselov said: 'By preparing the heterostructures on elastic and transparent substrates, we show that they can provide the basis for flexible and semi-transparent electronics. The range of functionalities for the demonstrated heterostructures is expected to grow further on increasing the number of available 2D crystals and improving their electronic quality.

'The proof of principle has been demonstrated and the device worked nicely but there is still a long way to go. The LED comprises fewer than 10 atomic layers and is very flexible and bendable, and is semi-transparent as it is so thin. It could one day be used for any applications requiring flexible, semi-transparent lighting, whether this is a display or a regular light.

'The technology is so different from the LED technology used today; it allows the inclusion of other elements into the LED by adding extra layers, and you could also put a logic circuit in this. I expect that the first application will be something unusual; a multi-functional device rather than a mobile phone screen.'

According to the research team, the LED structures are robust and have shown no significant change in performance over many weeks of measurements, while the quantum efficiency — the number of photons emitted per electron injected — is already comparable to that of organic LEDs. The technology builds on the discovery of one-atom-thick graphene, which was first isolated and explored in 2004 at Manchester University.

'There are three different directions to take with our next step,' Novoselev said. 'We can combine more types of different materials to create more complex quantum wells, and we can explore the use of other materials so that the pool of materials used to make the heterostructures is bigger. The latter could possibly increase the efficiency of the devices or explore how we can change the colour they display. Finally, we will be looking at how to mass-produce the devices.'

At present, the researchers are not working with a commercial partner. However, they hope that — as with the case of previous developments around transistors and diodes in this field — industrial partners will soon show an interest in the work.

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Southampton scanning system will detect composite aircraft flaws

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MEDICAL

And the winner is...

Engineering 'nobel' for drug-delivery pioneer

BY STEPHEN HARRIS

The second Queen Elizabeth (QE) Prize for Engineering has been awarded to US chemical engineer and drug-delivery pioneer Prof Robert Langer.

The prize went to the Massachusetts Institute of Technology (MIT) professor for his work developing a range of medical innovations using material science.

Arguably his most notable achievement was the use of polymer capsules to deliver large-molecule drugs inside the body over a long period of time, but Langer has also developed artificial skin and, more recently, wirelessly controlled electronic drug implants.

Langer was selected for the extent to which his engineering has affected people's lives, said Lord Browne, former BP chief executive and chair of trustees for the QE Prize.

Langer's key innovation in drug delivery was to design polymer microspheres that would slowly release large molecules, which can be tailored to attack specific cells in order to treat conditions such as cancer, mental illness and diabetes, but which can be damaged by the body's internal environment making them unsuitable for administration through conventional means.

His polymer design created long, winding water-filled channels through which the large molecules gradually pass, meaning they are released slowly over as long as five years without being destroyed.

'There was originally great doubt that a polymer delivery system would be able to deliver the macromolecules required for various medical treatments, but he challenged that thinking and produced a methodology that is now the foundation of much of today's drug-delivery technology,' said QE Prize judge and Cambridge University's professor of chemical engineering Lynn Gladden.

Later work includes synthetic polymers that deliver cells to form specific tissue structures and form a kind of artificial skin. This technology has since been adapted to repair cartilage and spinal cord tissue.

More recently, he has developed a wirelessly controlled microchip-based implant capable of storing and releasing precise doses of medication, either on demand or over intervals for up to 16 years.

QE Prize judge and the Royal Society's professor for public engagement in science, Brian Cox, said Langer was the almost-obvious choice because of the nature of his work: 'What I found unique about this is it's something that has demonstrably already changed people's lives, and will change billions more lives in the future. There was a whole new area of research opened up by Bob Langer's work.'

The QE Prize was created in 2013 as a way to celebrate engineering, promote the profession to young people and highlight Britain's pre-eminence in the field. The first prize was jointly awarded to five pioneers of the internet including Sir Tim Berners Lee.

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SENSORS

Make sense of road hazards

System uses human reactions to warn drivers of bicycles

BY JULIA PIERCE

Jaguar Land Rover is developing new multisensory technologies to alert drivers to potential hazards, preventing accidents with bicycles and motorbikes.

The Bike Sense system includes car-mounted sensors that will detect when a bicycle or motorbike is approaching, then make the driver aware of the potential hazard before it is visible.

Rather than using a warning icon or sound, Bike Sense makes use of instinctive human reactions using lights and sounds associated with potential danger — for instance, the audio system will sound a bicycle bell or motorbike horn through the speaker nearest a vehicle to identify its direction.

If a bike or motorcycle is overtaking or coming past on the inside, the top of the car seat will extend to 'tap' the driver on the shoulder. As the cyclist gets closer, LED lights on the windowsills, dashboard and windscreen pillars will glow amber and then red. On a busy urban street, the system could intelligently prioritise the nearest hazard.

Bike Sense would also be able to identify an oncoming pedestrian or cyclist obscured by a stationary vehicle. If the driver ignores the warnings the system could make the accelerator pedal vibrate or feel stiff. Passengers opening doors could also be warned about approaching cyclists or cars.

'It could be ready within 5–10 years as a fully functional system and we are working with suppliers to identify and develop the technology to help make this a reality,' said Lee Skrypchuk, human machine interface technical specialist at JLR.

inbrief

More news daily at **theengineer.co.uk**

Skills and the state

The UK government is collaborating with automotive manufacturers to ensure that future skills needs are met across the sector. Business secretary Vince Cable has announced £11.3m of state funding alongside a £2.8m investment and £16.4m in-kind contributions from industry. The project has been developed through the Automotive Council's Business Environment and Skills Group.

Singapore ahoy

Singapore's Agency for Science, Technology and Research, Sembcorp Marine, Glasgow University and University of Glasgow Singapore are collaborating on new hull designs for large ships. Under the three-year agreement, the partners will use computational modelling and visualisation technologies to design vessels with improved hydrodynamics for better fuel efficiency.

Show stopper

The countdown has begun for The Engineer Design & Innovation Show 2015, which debuts at the NEC in Birmingham on 2–4 June. Running alongside The Engineer Conference and the Advanced Manufacturing and Subcon events, the new show will focus on everything an engineering designer needs to do their job: from high-end products and services to the components, materials and technologies used to create next-generation technologies and processes. Exhibitors at will include Tharsus, ML Electronics, Proto Labs, Infolytica Europe and Panasonic Electric Works, which will be showing its MIPTEC 3D injection-moulded circuit technology. For stand space and sponsorship enquiries contact Daniel Gray at daniel.gray@centaur.co.uk.

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AEROSPACE

Hybrid flier has an air of possibility

Aircraft is powered by a parallel hybrid-electric propulsion system

BY JULIA PIERCE

A hybrid-power aircraft has been successfully tested in the UK in an important step towards cleaner low-carbon air travel.

The aircraft, developed by researchers from Cambridge University with funding support from Boeing, is powered by a parallel hybrid-electric propulsion system where an electric motor and petrol engine work together to drive the propeller. It uses up to 30 per cent less fuel than a comparable aircraft with a petrol-only engine, and is also able to recharge its batteries in flight, the first time this has been achieved.

Until recently, the technology could not be transferred into the aviation sector as the batteries required were too heavy and had insufficient capacity. However, the development of improved lithium-polymer batteries has made hybrid aircraft a possibility.

The current hybrid demonstrator is a commercially available single-seat aircraft, which uses a combination of a four-stroke piston engine and an electric motor and generator coupled through the same drive pulley to spin the propeller.

The hybrid demonstrator is a commercially available single-seat aircraft

During take-off and climb, when maximum power is required, the engine and motor work together to power the aircraft. Once cruising height is reached, the electric motor can be switched into generator mode to recharge the batteries or used in motor-assist mode to minimise fuel consumption.

A power electronics module designed and built by the Cambridge team controls the electrical current to and from the batteries — a set of 16 large lithium-polymer cells located in special compartments built into the wings.

Although development of such a system for airliners is some way off, the technology has other uses.

'We are looking at downscaling the hybrid system for UAVs that, aside from any military uses, would be applicable to surveying and search-and-rescue applications where endurance is important,' said Dr Paul Robertson of Cambridge's Department of Engineering. 'Also, we are looking to upscale to larger aircraft in our simulation work to see what benefits the technology might offer — although airliner-scale systems are still some decades away yet.'

COMMUNICATIONS

Wireless at speed

Project spotlights rural blackspots

BY JULIA PIERCE

Rural blackspots and network congestion could end thanks to a new wireless high-speed data communications system from a European team led by engineers at Lancaster University.

The £2.8m EU-funded TWEETHER project aims to develop a W-band wireless broadband system to provide cost-effective, high-speed internet with a capacity up to 10Gbps and distribution of hundreds of Mbps to tens of terminals. This will allow current capacity and coverage challenges to be overcome.

The system will exploit unused portions of the spectrum utilising millimetre waves (extremely high-frequency waves found between microwaves and infrared waves) and will include a compact transmission hub, based on a novel travelling wave tube power amplifier and an advanced chipset in a compact terminal.

'The breakthrough of TWEETHER project is a novel wireless PmP (Point to multipoint) system that integrates a novel, compact, low-cost and high-yield Travelling Wave Tube (TWT) power amplifier at the transmission hub, to power an affordable high-performance transceiver,' said Claudio Paoloni, project co-ordinator and Lancaster University professor of electronics.

Specifications will be developed by operators including EE, Deutsche Telekom, Telecom Italia and Spain's Avertis. Then, the team (which includes Thales Electron Devices, and SMEs including Bluwan, OMMIC, HFSE and Fibernova, Goethe Frankfurt University and Politecnica de Valencia) will start the design of the different components. These include a W-band travelling wave tube, multi-GHz band MMIC (Monolithic Microwave Integrated Circuit) chipset and a synthesiser.

AEROSPACE

Solar cells take to the skies for world trip

Solar Impulse 2 will fly night and day, and will land in 12 locations across the planet

The round-the-world route for Solar Impulse 2, an aircraft powered entirely by 17,248 solar cells, has been announced. The first solar-powered aircraft able to fly day and night will land in 12 locations across the world and travel 35,000km in the first attempt to fly around the globe without using fuel derived from hydrocarbons.

Mission pilots and Solar Impulse founders Bertrand Piccard and André Borschberg will share flying duties during the flight, which they said aims 'to demonstrate how clean technologies and a pioneering spirit can change the world'.

Solar Impulse 2 (Si2) will take-off from Abu Dhabi in late February or early March and return by late July or early August 2015. The route includes stops in Muscat, Oman; Ahmedabad and Varanasi, India; Mandalay, Myanmar; and Chongqing and Nanjing, China.

After crossing the Pacific Ocean via Hawaii, the 72m-wingspan single-seater aircraft will fly across the US, stopping in Phoenix, Arizona, and New York City at JFK Airport. ***JF***

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"Traineeships drive talent into our sector"

Les Ratcliffe, Head of Community Relations at Jaguar Land Rover

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NUCLEAR

A future for safe reactors

Project emphasises data for reliability of nuclear power

A £1m project at Huddersfield University has been set up to provide the nuclear power industry with data to produce future reactors and radioactive waste storage facilities that remain safe and reliable.

The university is home to the MIAMI (Microscope and Ion Accelerator for Materials Investigations) electron microscope that utilises ion beams to simulate the effects of radiation damage on materials.

MIAMI was co-developed by Prof Stephen Donnelly, dean of the School of Computing and Engineering, who is leading a Huddersfield team.

Neutrons can weaken and alter the physical dimensions of materials and a build-up of helium can result in them becoming brittle and likely to fracture. Prof Donnelly and Senior Research Fellow Dr Jonathan Hinks — also a member of the team that developed MIAMI — will lead a group that will investigate these issues with the help of £889,839 funding from EPSRC.

'The project is about producing a base line of experimental evidence,' according to Dr Hinks. ***JF***

The piston accumulators will release energy that is stored within them

AUTOMOTIVE

Bloodhound gets energy boost

Piston accumulator will aid jet engine and rocket-powered vehicle

BY JULIA PIERCE

A composite piston accumulator designed by Parker Hannifin is set to form a vital part of Bloodhound SSC's attempt to break the world land speed record in 2016.

Parker's energy-storage system will provide fast access to a big energy boost if this is needed, for instance, during rapid braking after the attempt is complete.

The jet engine and rocket-powered vehicle will rely on air brakes to slow the vehicle from 800mph and below, but if a loss of hydraulic power occurs, Parker's two composite piston accumulators will release energy stored within them and deploy the air brakes at a controlled speed.

Compared to the steel bladder accumulators that might normally be used on such a vehicle, the composite accumulators are more compact and are 60 per cent lighter, while being stronger and less susceptible to fatigue.

Traditionally, composite accumulators have used metal liners with an outer composite reinforcing structure. However, Parker's engineers have been developing a high-performance hydraulic product that is almost entirely made of composites.

Their piston accumulator uses a novel plastic liner, integrated into the carbon-fibre-reinforced epoxy composite product. The barrel design consists of two parts — an inner liner and outer barrel. The fully composite inner liner carries the hoop loads of the internal pressure, while a fully composite outer barrel is responsible for supporting the axial loads, allowing it to perform under high stress.

The development phase has included fatigue testing approaching up to six million cycles, while the accumulator also features a safe failure mode where it can leak in the event of over-pressurisation. Although more expensive than a steel bladder accumulator, the technology has applications elsewhere.

'It's a fantastic product for Bloodhound,' said Mark Cattermole, product manager for industrial systems at Parker UK. 'It has to be positioned relatively high on the vehicle, so the low weight means it has less effect on the car's centre of gravity — the car must be very stable at such high speeds.'

SENSORS

Getting a sense of the networks

Lessening the impact of downtime

BY JULIA PIERCE

A new sensor system could allow energy and telecoms companies to quickly isolate network faults, reducing the length of service cuts.

The technology — which measures voltage, current, temperature, pressure and vibrations in fibre-optic cables — has been designed by Synaptec in partnership with Strathclyde University. It uses fibre-optic Bragg grating sensors written into the core of the optical fibre used in Britain's energy and telecoms transmission networks to measure strain and temperature. These sensors are connected to piezoelectric actuators that measure voltage and current.

Taken together, the measurements provide a complete picture of the line. Should a fault occur, the network operator can make fast, low-cost measurements to find the fault, even if the location is in a remote area, allowing them to fix it quickly and lessen the impact of fines imposed for network downtime.

Britain's electricity transmission network has fibre-optic cabling installed on around 75 per cent of all lines, although this will grow to 100 per cent at transmission level. Synaptec's sensors can couple into this fibre, which runs in parallel with the lines. The sensors make use of a different part of the spectrum of light to the sensing system, avoiding interference with the core functionality of the line. The technology can also track the amount of generation and demand on the grid.

'The system can be retrofitted or used in new builds,' said Philip Orr, managing director of Synaptec. 'It would be used as an extra layer of back-up and functionality, saving companies money. Our system allows companies to see the location of the fault quickly, identifying whether it is underground or not.'

A prototype will be tested on UK electricity networks once it has been fully developed.

Making an escape plan

Jane Burston argues that the risk of methane leaks through fracking in the UK is an issue that needs to be addressed

I was one of the witnesses called to give evidence to the Environmental Audit Committee inquiry on the potential environmental risks of fracking. The National Physical Laboratory (NPL) had provided written evidence to the committee and I was asked to provide more details on some aspects of this, particularly the risk of fugitive methane emissions, or leaks.

In the committee's final report, published at the end of January 2015, any intentional 'leaking' (i.e. venting) of methane emissions was deemed to be unacceptable. It looks likely that, for production sites at least, that recommendation will be taken up, avoiding one source of emissions to the atmosphere.

There were also calls for full containment of methane to be mandated in all permits, independent monitoring, regular unannounced audits of fracking sites and public disclosure of monitoring data. Containing all leaks is impossible on any industrial site, but operators ought to do their best to detect leaks — and then fix them — as soon as possible.

Monitoring methane leaks is an issue that has been much debated over recent years. Dr Robert Howarth and his team at Cornell University in the US raised it in their 2011 paper, *Methane and the greenhouse-gas footprint of natural gas from shale formations*. In this they claimed that shale gas is ultimately as polluting as coal due to the amount of methane leaked from both the fracking process and the transportation of the gas.

Dr Howarth and his team stated that the main reason behind this was down to the high global warming potential (GWP) of methane. Its climate-change impact is at least 25 times that of carbon dioxide over a period of 100 years.

These are not disputed figures, far from it. If Dr Howarth were to run his numbers again using up-to-date figures, the results would be even more alarming. The latest report from the Intergovernmental Panel on Climate Change increased the estimate of the impact of methane from 25 times that of carbon dioxide to 28 times. The report also stated that when the 'climate-carbon feedback' impact of the gas is incorporated, the impact increases to 34 times that of carbon dioxide.

A mobile monitoring station will measure UK emissions

The leak rate from the fracking process has been the primary source of debate and hence the subject of a large number of scientific studies. Some studies calculate leaks based on gas-flow rates; these tend to place the rate of leaks at anywhere between one to eight per cent of the gas produced over the lifetime of the well. Others have attempted to measure leaks using various methods. Examples include data collected from aircraft flying over shale basins, which suggested emissions of around four per cent and data collected from monitoring equipment on tall towers in a different region, which suggested emissions of six to 12 per cent. Further research studies in the US have taken place and the results will be published throughout 2015.

> **"Hydraulic fracturing is likely to be different in the UK to the US, so it is difficult to apply US-led research findings here** Jane Burston

The hydraulic fracturing processes are likely to be different in the UK to the US, so it is difficult to apply US-led research findings here. For example, some practices, such as allowing fracking flowback water to sit in evaporation pools, have contributed to methane emissions in the US but will not be allowed in the UK.

The second part of Howarth's calculation looked at leak rates in transporting the gas. There is less research available in this area and it is even harder to transfer knowledge from one country to another due to variations in the state of the grid and how it is monitored.

We need to remember that at present all of our gas comes from conventional sources, which can also leak. The leak rate of conventional oil and gas extraction is conventionally thought of as between 0.5 to two per cent of the gas produced over the lifetime of the well but, in reality, this is likely to vary hugely from facility to facility.

At NPL we are working on two shale gas projects. Both will use our Differential Absorption Lidar (DIAL), a bespoke mobile monitoring station that will be used to measure emissions from UK-based operations.

At present, we have not completed any measurements (due to the lack of operational sites in the UK). Cuadrilla has agreed to provide access to operational sites once the licences have been obtained and work commences.

The Report from the Environmental Audit Committee brings new arguments to the debate about fracking. From a measurement perspective there are three key elements that need to be addressed. First, the baseline status of the environment is critical. For example, measuring the background levels of methane in the atmosphere around a site would allow regulators to compare measurements taken during and after fracking with those taken before. Alongside this should be guidelines for industry outlining a best-practice approach to monitoring sites. Finally, we need to better understand leak rates and how leaks can be fixed or avoided, to enable us to work towards agreeing mandatory standards for maximum leak rates.

Jane Burston is head of the Centre for Carbon Measurement at the NPL

Join the debate at **theengineer.co.uk**

thehottopic

Making space for autism in engineering

Ivan Zytynski's online viewpoint article, which argued that industry is missing out on the skills of people on the autistic spectrum and can do much to make workplaces comfortable for them, sparked a lively debate.

I have Asperger's; I have been in engineering more than 25 years and in that time have met many people on the autistic spectrum, within engineering. They, like me, tend to do the jobs that require a great amount of concentration in a particular field such as development or forensics. These people tend to be very good at what they do, although due to the autism may not interact well with others. This, I dare say, may put off employers. However, not every employee needs to be a team player, as being on the outside looking in can strengthen a company.
Anonymous

I have an autistic daughter, and both my wife and I are probably also on the spectrum. When she was first diagnosed, we were told that a survey of the occupations of parents and grandparents of autistic people showed a significant bias to the engineering professions. Like Ivan, I worry about what the future holds for her, knowing that she is extremely bright, but determining what she knows is difficult. Hopefully, with increasing awareness and appropriate support she will be a contributor to society.
Father of two daughters

As the parent of a child with typical autism, who is accessing mainstream high school with support, I welcome any initiative and proposal that improves the life chances of any person with the life-limiting problems of autism spectrum disorder (ASD). However, this article again raises the 'they've got autism; they must be really good at music, maths, drawing, remembering, logic...' canard. This is just a stereotype and is as true as the miserly Scotsman. Most people with ASD do not have a special power; they cannot work out what day of the week the 15 November 2150 will occur on; they cannot draw flawless detailed townscapes from memory. Most people (diagnosed today) with ASD struggle to deal with everyday life and interactions; they struggle against huge learning difficulties; in fact, getting on for half will never tie shoelaces. The fictional 'Rainman' did not live independently, even though he was based on a high-functioning Asperger's sufferer. Temple Grandin, Stephen Wiltshire and (possibly) Isaac Newton are exceptional people; if they had not suffered from ASD they would probably have excelled at what they did anyway; they have overcome the handicap of the ASD in their lives in a way that it works for them, and that is fantastic. Autism produces the most wonderful diversity among children, and some of the most beautiful personalities. Please don't perpetuate the special-abilities myth.
Anon

Great article highlighting a critically under-tapped talent market. More companies need to create workplace environments that leverage autistic talents and provide targeted accommodations to help these professionals be successful.
Lauren

I agree entirely that the strengths I highlighted are not universal. If there is one thing I have learned about autism in the last three years it is that there is nothing universal about it. The problem I had when writing this is that I didn't have the space to write an entire book about all the various manifestations of autism. Believe me: I could quite easily write 20,000 words on the topic and still not have covered much. I simply wished

inyouropinion

Futurefocus

Last issue's interview with the head of Imperial's Energy Futures Lab sparked a discussion on the UK's future energy mix.

■ I wish I knew why he was optimistic because he lists a whole lot of reasons why we shouldn't be: the difficulties of carbon capture and storage (CCS); the coal and nuclear decommissioning by 2023; the increasing percentage of wind energy, which as of now needs fossil fuel back-up or battery storage; the interconnectors and smart grids that have to be paid for by consumers; the stagnation of the nuclear industry; and the nimbyism we face with shale gas. What's to be optimistic about? Oh yes — we have a lot of wind. Trouble is it's an intermittent and expensive option that Hoovers up public money that may be better spent elsewhere, doesn't replace base load capacity and possibly doesn't even reduce emissions. So is there something else he knows but isn't telling us or is it just blind faith in British ingenuity?
James G

■ Prof Green's claim that 'Norway has a surplus of pumped storage capacity' perpetuates a myth. It would be a matter of grave concern, if this were to 'inform' policy. Norway has less installed PHS than the UK and one cable, such as NorthConnect (£1.7bn), could probably use all their capacity with a couple of Scottish wind farms running at full tilt.
David Smart

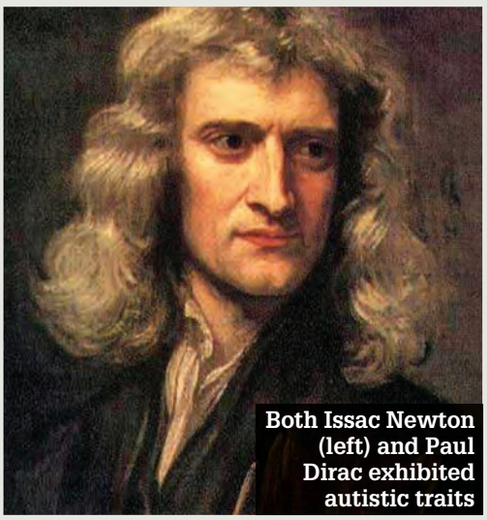
■ The question not asked or answered here is crucially important. It's not which forms of energy production are viable (economic, low enough in carbon, etc); it's this: do we seriously believe renewables and nuclear can run unchanged in our fast-paced and high-powered economy/society? Our way of living has become the norm but it only arisen because of our fortunate legacy of easily extracted, energy-dense fossil and nuclear fuels. Our growth-based consumer economy is inherently unsustainable for a variety of reasons (the most obvious one being that we live on a small planet with finite resources). We're wrong to strive to maintain it at all costs and to imagine it powered by renewables. The engineering profession is failing humanity if it persists in supporting the idea that technology alone can provide the answers.
Robert Palgrave

Identitycrisis?

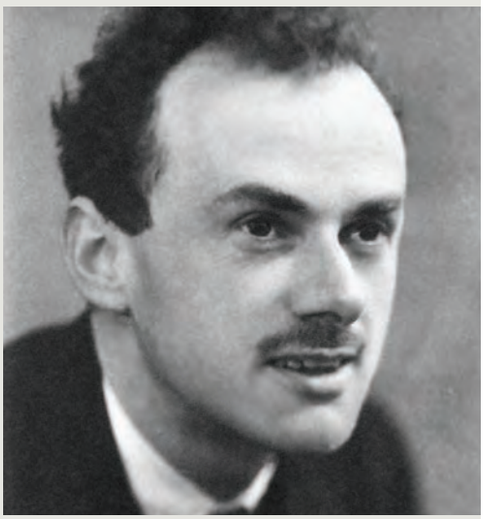
Our online article about potential human applications of RFID technology provoked a lively debate.

■ Very disquieting. Arguably if used in a positive manner it could provide for increased safety in hazardous areas, for example, by enabling automatic logging of persons on site allowing real-time personnel lists to be available in the event of an emergency. However, like a lot of technology, the positive benefits are soon outnumbered by the negative effects of unscrupulous exploitation of the technology. Tag prisoners and those out on licence by all means as they pose a potential threat to society, but for the rest of us it is a serious infringement of what few rights we have left.
Robert Jones

■ This is nothing new. I was a member of a privacy interest group whose focus was RFID. I learned that this group and others stopped things from happening in Walmart. There are instances of RFID chips being permanently embedded into clothing, shoes and other items. So after purchase, when you walk over an RFID



Both Issac Newton (left) and Paul Dirac exhibited autistic traits



to highlight three potential strengths that autistic people have a propensity towards. This does not mean that all autistic people will have these strengths, but it does mean that they are more likely to be strong in these areas than a random sample of Joe Public. As such, they are worth considering for engineering jobs and it is well worth a hiring company's time to make some reasonable adjustments in interviewing process and working environment so those strengths can be utilised.
Ivan Zytynski

A wonderful article and one that confirms my experiences in the workplace. I find people on the autistic scale really do have an extraordinary power of focus if engaged correctly and can produce fantastic results. The trick is to put round pegs in round holes (but then that applies to the so-called 'mass populus' as well — right?)
Nick Pattie

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scanner, it will recognise you and create targeted marketing to you. If you remember the movie *Minority Report*, this is what the target is. So there is a plan in place folks. Let's try to keep big brother out of our lives.
Ron

Carepackage

Many readers had a view on how technology could help the NHS survive.

■ You mention 'the significant cuts of the last few years'. Do you have figures for the extent of these cuts? A lot of the NHS debate is blighted by politicians and journalists bandying vague terms about without any numbers. I would hope engineers would adopt a more measured and less emotive approach so the problem can be quantified so solutions can be judged objectively.
Anonymous

■ Immediate solutions are available, in certain critical sectors of healthcare, provided horizons are widened and we do not fear to adopt tangible solutions from innovative communities such as New Zealand and several others: UK medical technology is excellent, but let's not pretend we have a monopoly of all the right answers.
Dick Wallis

■ If I recall, there was value and interest reported some years ago that the refuelling of civilian aircraft and the triage applied to emergency patients admitted to A&E both benefited from analysis of the skills exhibited by Formula 1 pitstop teams — surely a classic example of using the best, most efficient system on Earth as an example to assist a different activity.
Mike blamey

I meet IT people trying to help the NHS — it can't even absorb what they have to offer because it's so difficult to get decisions made and because so many systems and functions inter-relate that they can't change one thing without changing many others — which comes back to nobody being able to make decisions. For example, one pal of mine described a sort of decision circle — you ask somoene to decide, they refer you on and the next person refers you on and finally you arrive back at the first. It needs to be engineered socially.
Tim Murphy

Deep impact

Engineering has been shown to have a significant, positive effect not only on the economy but also on individuals' lives

Since the publication of our annual State of Engineering report in January, the Centre for Economic and Business Research (CEBR) has completed the research we commissioned into the contribution of engineering to the UK economy. What that research tells us is not only that engineering sectors contribute £456bn (27 per cent) of UK GDP, but also that the impact of the sector is felt more widely than you might think.

"It is crucial to remember the difference that engineering makes to people

The direct impact is reflected in the £1.17tn turnover, but in addition (and considered as part of this latest piece of research) is the impact that level of activity has on others within the supply chain and then more widely in the economy as a whole.

For every £1 in gross value added (GVA) generated in engineering, a further £1.45 is generated elsewhere in the economy, putting engineering's total GVA impact for 2104 at £996bn. This is equivalent of 66 per cent of UK GVA and represents a GDP contribution of approximately £1,117bn.

The knock-on effect is equally apparent in terms of employment as engineering is estimated to have supported an aggregate 14.5 million jobs last year and for every new engineering role an additional two jobs are created in the economy.

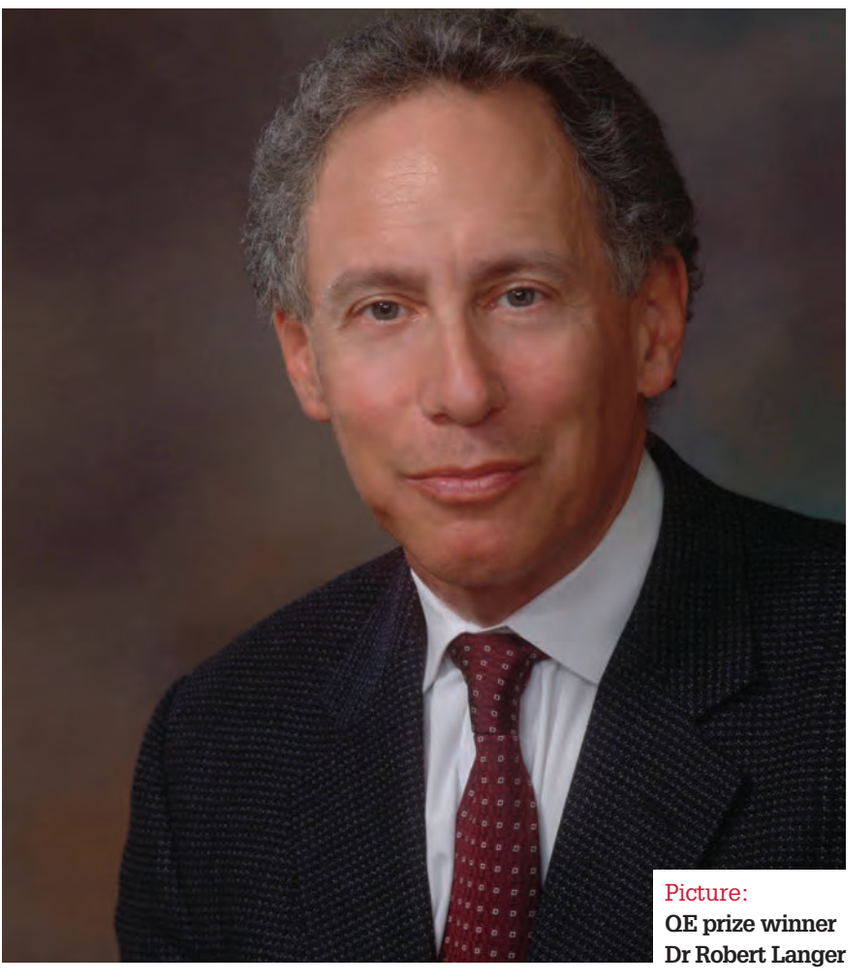
As we talk about economic growth and potential for the sector, what we are really talking about is the growth and potential of engineers, those already in the sector and those who they will inspire to become the engineers of the future.

The economic contribution of engineering is a significant and important one but it's also crucial to look beyond the pound signs and employment figures and to remember the difference engineering makes to people's lives.

Take pioneering chemical engineer Dr Robert Langer (pictured), who has just won the Queen Elizabeth prize for engineering. Langer was the first person to engineer polymers so they could control the delivery of large-molecular-weight drugs when treating diseases such as cancer and mental illness.

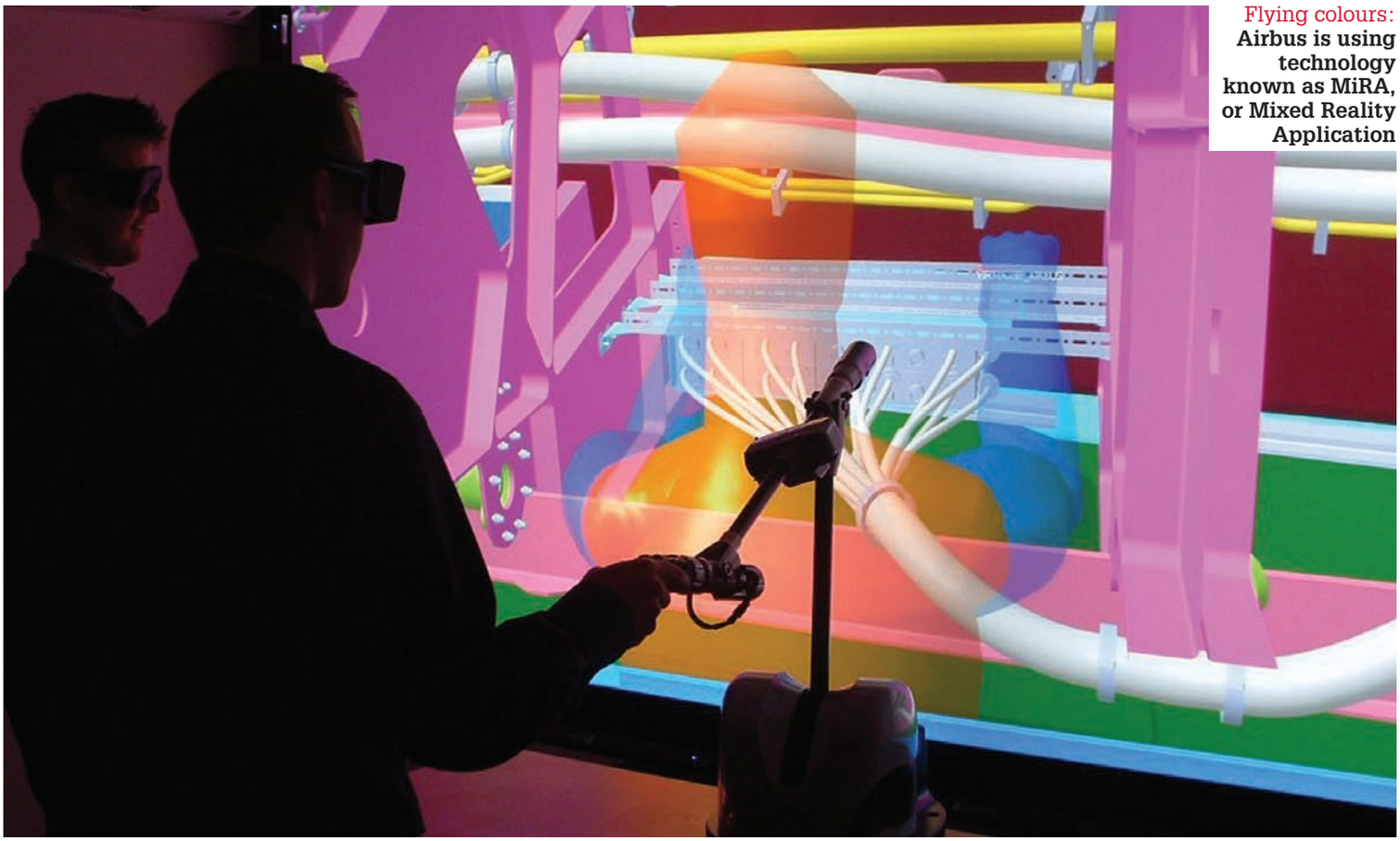
Everyone understands doctors' roles in saving lives and supporting wellbeing; here it's the man in the background who is recognised for his vital contribution. His work has been the basis for long-lasting treatments for a range of conditions, including brain and prostate cancer, diabetes and schizophrenia that have benefited 10 million patients. Worldwide more than two billion lives have been improved by the technologies created in Langer's lab. Now that's an engineering legacy to be proud of.

Very recently I have been thinking about what shape a year of the engineer might take — you may remember that secretary of state for transport Patrick McLoughlin first mentioned the idea at last year's Conservative Party Conference. It's clear to me that any celebration of engineers has to include recognition of the wide-ranging, global impact of the engineering innovations we so often take for granted.



Picture: QE prize winner Dr Robert Langer

Paul Jackson is chief executive of EngineeringUK



Flying colours: **Airbus is using technology known as MiRA, or Mixed Reality Application**

In touch with reality

New design processes and tools are revolutionising the manufacturing industry. Stuart Nathan reports

Manufacturing is changing. The advent of new ways to design things and build them is having an effect not only on the products that factories make but also on the factories themselves, and engineers are increasingly using tools such as virtual reality (VR) to put themselves in the middle of manufacturing processes to work out how humans and machines can work together to make new generations of products.

This is combining with the increasing use of technologies such as additive systems to bring new machinery and tools into the manufacturing sector to create a 'factory of the future' that will bear little resemblance even to the highly automated production plants of today.

At the forefront of this change is Lockheed Martin, which is employing a strategy it calls 'Digital Tapestry' to incorporate new digital design and manufacture technologies.

Dennis Little, Lockheed Martin's vice-president for production, explains how the company uses a system it refers to as 'virtual pathfinding' to streamline its manufacturing processes to cut the time it takes to build products — notably in its space systems business — and thereby cut costs. This is used as part of a framework called model-based engineering (MBE), which maintains digital data throughout the design and production process, from CAD files through to production. Virtual pathfinding is carried out at the Collaborative Human Immersive

Laboratory (CHIL), in Colorado. CHIL uses technology directly inspired by video gaming and special-effects work, notably motion capture, to enable engineers to build components or carry out maintenance tasks in the virtual world to identify and eliminate the bottlenecks in the process; for example, bolts can be tightened without other parts of the assembly blocking the path of the wrench. Initially used to design GPS satellites for the US Air Force, CHIL is also lined up to help Lockheed Martin design the manufacturing facilities for the Orion crewed space capsule for NASA and for other projects. The goal, Little said, is for all products to be built virtually before the physical factories are built, to prevent having to go back and redesign systems that didn't work the first time around.

Lockheed Martin is also looking at new ways of deploying additive manufacturing technologies. Installing extrusion heads onto six-axis robot arms and connecting them to mixers and blenders allows the company to use a technique called pointwise composition control to change the properties of the printed material 'on the fly' within the structure of the part as it is printed; this, for example, might allow the rigid spars, flexible skin and solvent-resistant fuel tanks of the wing structure of a small unmanned aerial vehicle (UAV) to be printed in a single shot, rather than made as individual components and assembled, saving time and producing a stronger structure.

In the more commercial aerospace world, Airbus is using a technology known as MiRA, or Mixed Reality Application, where engineers installing equipment inside aircraft fuselages use a tablet computer and a sensor pack, which tracks their position and relates it to a Realistic Human Ergonomics Analysis (RHEA) tool, a full-scale 3D digital model of the aircraft they are working on. This enables them to, for example, call up an image of a bracket installation in the area where they are working to ensure that they have fixed it correctly. Geolocation devices attached to the aircraft interact with the sensor pack to allow them to view their work location from any angle. The RHEA is updated as each component is installed. This technique has helped reduce the time to inspect the 80,000 brackets inside an A380 fuselage, which hold systems such as hydraulics pipes, from three weeks to three days.

> **"The tools for high-end VR are pretty much common across all the sectors that use them**
> Brian Waterfield

Another example of this is used in wiring systems from Airbus helicopters. Wiring harnesses are assembled flat on a system called a jigboard, which holds cabling in place so that the necessary components for the electrical systems can be assembled and connected in the right place and in the right order; the entire harness can then be removed from the jigboard and installed in the aircraft. This is a complicated procedure that used to be achieved by printing out a prototype arrangement and following that. But now, a digital version of the jigboard is projected onto a screen and engineers use a tablet computer to help them navigate the route that wiring has to take.

Another projection system is reducing the time it takes to paint camouflage patterns onto Tiger and NH90 helicopters. This uses lasers to project the outlines of the pattern's colour blocks directly on the fuselage, so that painters can fill in the colours; this speeds up the process, compared with the traditional technique of hand painting the outlines then filling them in.

Among Airbus's digital manufacturing tools is a VR suite from Manchester-based Virtalis at its site in Broughton, which is connected to a haptics system to help engineers navigate potential tool clashes. This system was used to design the manufacturing process for the A350 wing, which is built in a horizontal configuration rather than the more common vertical configuration.

Meanwhile, in the automotive sector, Jaguar Land Rover (JLR) is joining the aerospace sector in using VR technology to design its production processes.

The use of VR is becoming more common in the automotive sector, with several companies — particularly at the high end of the industry — using the technology to give prospective customers a taste of the vehicle layout and look. But with its Ergonomics Lab at its facility in Gaydon, JLR is taking this to another level, using VR in a similar way to the aerospace sector, with a VR suite incorporating Sony 4K high-resolution screens. Almost half of the time on the VR suite

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indepth

3D printing is helping to reduce the time and costs associated with production operations

In the last three or four years, 3D printing has developed in certain areas in particular. While the best-known use of the technology is to produce the products themselves, perhaps the most useful facet of the technology for many manufacturers is to use it as a part of its manufacturing processes.

'One key area in which 3D printing is making — and will continue to make — an even bigger impact in the future is too often left in the shadows,' said John Cobb of 3D printing specialist Statasys. 'Known as "augmented manufacturing", this is an area in which the technology is making a truly significant and genuinely tangible difference in terms of cost and time reduction within production operations.'

Augmented manufacturing refers to printing the manufacturing tools rather than products: the jigs, fixtures and other devices that position, hold, protect and organise components and subassemblies during the manufacturing process. 'These components maintain quality and production efficiency while also being used to manufacture other parts and products,' said Cobb. 'These tools are virtually invisible when production is running smoothly, but their importance becomes evident when problems arise.'

When this happens, Cobb said, new jigs and fixtures must be rapidly designed, manufactured and deployed to avoid production halts or product defects. They are typically made from metal, wood or plastic in small quantities using manual or semi-automated processes, and each tool can take one to four weeks to design and build. 'Elaborate or intricate tools can sometimes require several cycles of design prototyping and evaluation to attain the required performance, so it's easy to see that this area of manufacturing can be costly in both a money and time,' he said. This is an area where 3D printing is rapidly making inroads, providing a fast and accurate method of producing these tools. Using fused deposition modelling (FDM), the traditional fabrication process is substantially simplified.

From a commercial standpoint, this is where 3D printing is truly revolutionising manufacturing, not only for individual businesses but for the industry sector itself. 'It creates a positive knock-on effect so huge that it offers the potential to affect whole economies,' Cobb said. For manufacturers, there are instant pay-offs in productivity, efficiency and quality. Companies using these techniques are not simply replacing machinery; they are redesigning their entire product lines to make the work more efficient, accurate, fast, simple and profitable.

Some of our Stratasys customers have reported leadtime reductions of between 70 and 95 per cent and cost savings of between 40 and 90 per cent. A good example is the German supplier of parts for household appliances and commercial vehicles, Seuffer. Since incorporating 3D printing in its manufacturing process, Seuffer has significantly reduced the time and cost of producing injection-moulded sample parts.

Seuffer can design first drafts of the injection mould within a few days and print them in less than 24 hours for part evaluation. Traditionally, it would have taken eight weeks to manufacture the tool in metal using the conventional CNC process. Not only that, the company would have previously paid €40,000 (£30,000) for a conventional tool — as opposed to less than €1,000 for a 3D-printed tool.

Big impact: **3D printing enables 'augmented manufacturing'**

Design driven: **VR technology is helping Jaguar engineers design an engine bay**

is used for vehicle package engineering, such as fine-tuning the cabin ergonomics, improving vision from the driving seat of the instruments and ensuring that the vehicle frame doesn't obscure the driver's vision in dangerous ways. Other areas where it is used include crash simulation and aerodynamics and in designing the assembly process.

'The tools for high-end VR are pretty much common across all the sectors that use them,' said VR manager Brian Waterfield. 'You aren't going to find much difference between our kit and the type of setup used in aerospace.' The design of Range Rover Evoque depended heavily on VR, he added. 'It was a real challenge. Being a much more constrained design than we had done previously, we had to work out how everything fitted together very carefully.'

VR gives engineers a much more intuitive view of simulation, Waterfield said. 'As we're moving towards more and more simulation, it becomes more important to us.' Using the VR system to plan out changes to the manufacturing track allows potential safety, productivity and maintenance problems to be detected, visualised and solved before equipment is installed and even, in some cases, before it is ordered. For example, some manufacturing jigs have protusions on their upper surfaces that can cause problems when installing car roofs and have, in the past, required repositioning or changing tools — this is not the case any more.

The package also allows such things as the effect of the position of lighting on work spaces to be evaluated. 'Normally we start a project with ergonomics specialists working in the VR rig, but as we progress we will have engineers off the track come in and try it out,' Waterfield said.

The next stage of development for JLR's VR system is likely to be increasing the incorporation of haptics, Waterfield said. 'We can do quite a lot with haptics now, but we aren't quite there with all the things we'd like to be able to do to fully simulate the manufacturing environment,' he said. Research in this area is ongoing.

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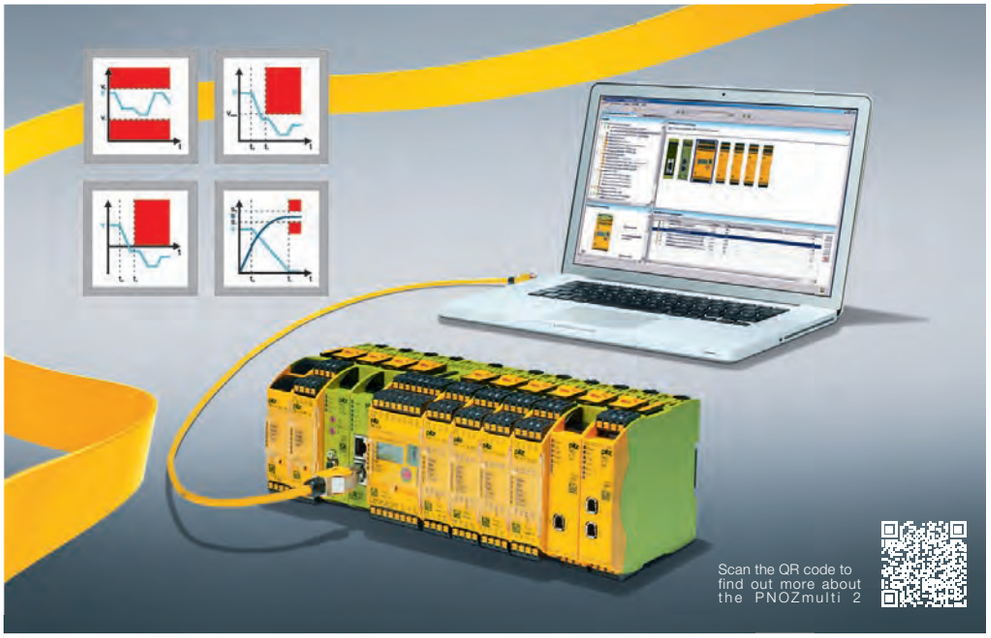

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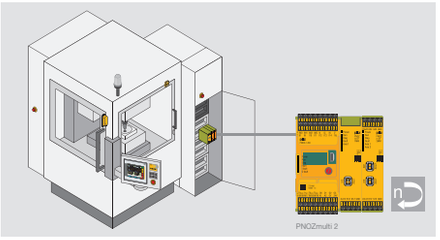

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Quick off the marque

Ferrari design chief Flavio Manzoni talks to Jason Ford about the firm's latest 'hypercar': the FXX-K

In 2005, Ferrari used the Bologna Motor Show to debut the FXX, a limited-edition vehicle that would add considerable exclusivity and mystique to the brand.

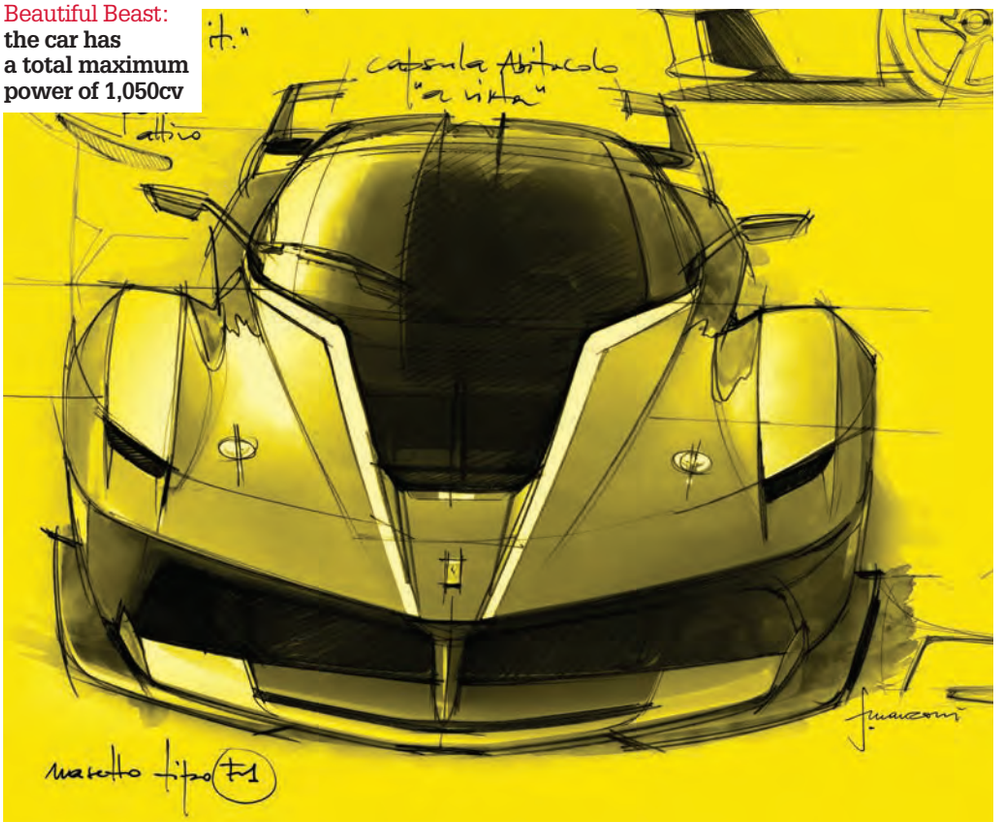
Only 29 FXXs were produced and ownership was decided by a committee that evaluated applications from those with a proven devotion to the marque and €1.5m (£1.1m) to spend on a vehicle that couldn't be driven on the road and wouldn't compete in any race series.

Instead, the select batch of inaugural FXX owners — aka client test drivers — signed up to a programme where they would be able to take part in track events at prestigious circuits around the world with a support package that included technical teams and personalised driver development.

Ferrari has a tradition of building limited-edition sports cars and it was envisaged that the FXX research and development programme would provide the framework on which specific future vehicles would be developed.

The FXX programme did not concern itself with homologation (i.e. the normal rules of the road) and its first vehicle brought with it Formula One (F1) gearbox technology that allowed drivers to change gear in less than 100msec, an aerodynamic design that provided a 40 per cent increase in down force compared with the Enzo, and a 6,262cm^3 V12 engine capable of delivering 800hp at 8,500rpm.

Driver feedback, telemetry and data gathered during 16,500km of tests carried out in 2006 and 18,500km in 2007 fed into a so-called evolution package that saw a modified engine deliver 860hp at 9,500rpm, gearshifts of 60msec and a 25 per cent increase in aerodynamic performance.



Beautiful Beast: **the car has a total maximum power of 1,050cv**

The evolution kit saw the FXX programme extended for a further two years to 2009, with the entirely new 599-XX debuting in 2010 and the FXX-K in December 2014, a point when Flavio Manzoni, Ferrari's head of design, contacted *The Engineer* to ask: 'Did you see the "Beast"?'

Manzoni's Beast — the FXX-K — is a hybrid based on the LaFerrari (a hybrid road car unveiled by Ferrari in 2013) that employs a KERS system with total maximum power of 1,050cv, total maximum torque greater than 900Nm, maximum revs of 9,250rpm, and 140kW (190cv) in electric motor output. According to Manzoni, the FXX-K marks the ideal confluence between style, engineering and aerodynamics and, in the purest tradition of the Maranello marque, betters any GT that preceded it.

'LaFerrari offered an ideal basis to push limits even further, the result of close collaboration between the GT division and Gestione Sportiva, Ferrari's racing arm,' he said.

'The FXX-K expresses the full potential of the design, thanks specifically to the development work carried out with the aerodynamicists. Its forms express

> **"The FXX-K's forms express an irresistible force, underlying the promise of unbridled driving excitement**
> Flavio Manzoni, Ferrari

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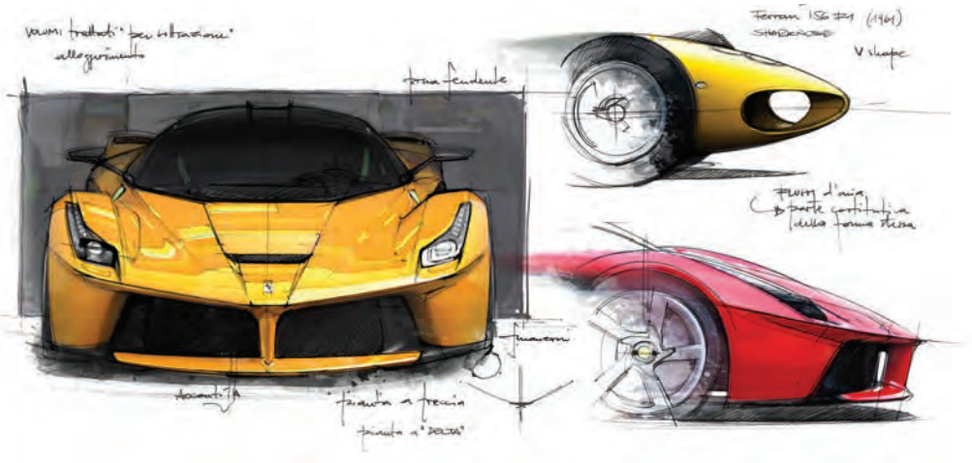


an irresistible force, visually conveying the car's outstanding power and underlying the promise of unbridled driving excitement.'

Hypercars are not designed with subtlety in mind and Ferrari's latest design announces itself long before it is seen, thanks largely to the removal of silencers from the exhaust. Such vehicles will also outrun their predecessor, as witnessed at Ferrari's private Fiorano racetrack where the FXX-K completed a lap five seconds faster than the LaFerrari.

Hypercars are built for speed and seemingly possess very little finesse, but Manzoni stressed that the latest XX moves away from kit format to a complete redesign that keeps faith with the stylistic principles of the car's base.

'This is the pinnacle of Ferrari production and the most extreme Ferrari,' he said. 'It was necessary to have a very original design, not obvious, not too… inspired by the past, and this was a key problem: how to get a very original shape and at the same time how to be absolutely recognisable as a Ferrari, even without the prancing horse.'

This was achieved in part by maintaining continuity with the designers, aerodynamicists and engineers that had worked on the LaFerrari, thereby creating the strong synergy needed to take the FXX-K forward in the way Manzoni envisaged.

'In Italian we say *assimilari*; it means to deeply understand each single need of every part of the car,' said Manzoni. 'If you understand it then you can form a shape that is absolutely consistent with that.'

Carrying the group synergy forward, the Ferrari team developed an aerodynamic shape with a 50 per cent improvement in down force in the low-drag configuration and 30 per cent improvement in the down-force configuration.

Manzoni explained: 'The most obvious aerodynamic features are the flap profiles at the front and the rear winglets perched high on jet fighter-like tail deflectors. The latter are… integrated into the design of the rear wings as opposed to being simply tacked on, and contribute both to longitudinal stability as well as to channelling the air efficiently to maximise the efficiency of the rear spoiler. The front headlights have been removed to save weight, replaced by high-efficiency LEDs… inserted in small recesses. Their horizontal disposition underlines the concept of a light bonnet spanning the dynamic side-pods housing the wheels. Likewise, the round tail lights have given way to an outlet duct — extracting air from the wheel arches — which integrates LEDs in their perimeter, forming a distinctive C shape not unlike early design proposals for the LaFerrari itself. The rear view is clearly without compromise: each element of its design is borne out of a functional approach, starting with the prominent lower diffuser, which projects forcefully out [the] rear.'

> **"The good thing about these extreme cars is that they set the scene; they say 'this is the art of the possible'**
> Mike Dickison

Would, however, such high-end modifications be acceptable to the buyers of regular road cars? And are the hybrid drivetrain technologies taken from F1 ever likely to make it into the design inventory of the volume automotive OEM?

Mike Dickison, director of niche vehicle programmes at Coventry University has worked on a project with Jaguar Land Rover, plus consultancies and OEMs, to consider what had to be done to make existing vehicles more aerodynamically efficient.

'We were able to do that and the result that we came up with did look a bit strange, especially at the back of the vehicles,' he said. 'What a mainstream company wouldn't do is immediately just put on the ultimate in terms of aerodynamic kit because the customers just wouldn't be able to take it on board quick enough. The good thing about these extreme cars is that they set the scene; they say "this is the art of the possible" and the challenge is for mainstream OEMs to turn it onto something they can actually sell in a car that people will buy [because it] won't be hugely expensive.

'On that basis, we have a team of our researchers working with GKN on their gyro drive system that basically came from F1 technology. We're working on it terms of the manufacturing process, in terms of the materials, in terms of looking at the durability so that we can get something that we know works — but is extremely expensive — to something that not only works but is also cost effective to produce.'

Dickison added that a significant amount of work needs to be done before technologies employed on the XX make their way into the sorts of vehicles that appear regularly on the Society of Motor Manufacturers & Traders' monthly new registration lists, but that isn't to say that the programme lacks virtue.

He said: 'They [Ferrari] have been quite honest about it in so far that it isn't just a styling exercise to make it extreme. I think its radical in as far as it does actually work and I think this is the difference between where we are now and where we were maybe 10–15 years ago, where extreme things were being done in terms of styling and shapes but there wasn't particularly wonderful understanding of how it works. Now, the computing power has moved on so much that these shapes and concepts can be pretty well evaluated.'

For more on this story visit **www.theengineer.co.uk**

Going to extremes: **the latest XX moves away from kit format to a complete redesign**

Liquid logic

peter dearman
Co-founder, Dearman Engine Company

- Left school at 15 and took his first engineering job with a metalworking company, spending his spare time taking things apart in his shed.
- His first idea for an invention was an engine driven by the rapid expansion of nitrogen as it converted from liquid gas, but his blueprints were shelved.
- Design engineer and consultant for various engineering companies in the 1980s.
- In 1990 he invented the microvent resuscitator, later manufactured and sold by BNOS Electronics.
- Later in the 1990s he returned to his cryogenic engine idea and by the early 2000s had a working prototype that could power a car.
- In 2005 he co-founded Highview Power Storage after a Leeds University study identified energy storage as the most marketable application for the technology.
- In 2011 he co-founded the Dearman Engine Company to put the technology to use in automotive applications.

Peter Dearman has spent almost his entire adult life considering the possibilities of an engine that runs on liquid nitrogen. Stephen Harris reports

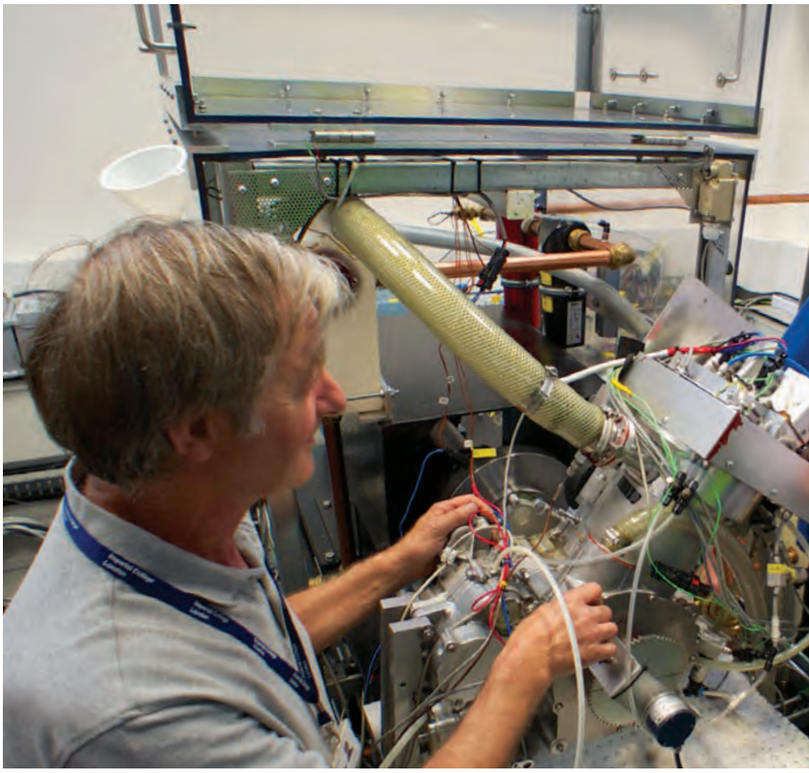
Racing cars, self-driving vehicles and even military trucks are all relatively common sights at the Mira proving ground. But since the end of last year, the test facility in Warwickshire has seen a vehicle that's far more ordinary and yet virtually unique: a refrigeration truck in which diesel fuel is replaced by liquid nitrogen. If road trials due to start in March are successful, the model could pave the way for a new form of zero-emission automotive propulsion.

The man behind the concept is Peter Dearman. A self-taught engineer in the grand British tradition of the garden-shed inventor, he is overseeing a new kind of engine that he has spent almost his entire adult life thinking about: one that runs on liquid nitrogen and, he thinks, could be an alternative to batteries and hydrogen fuel cells in low-emission vehicles.

'Even with modern electric vehicles you can't actually fast-charge them because it shortens your battery life and the realities of pumping that much power in is not really practical, but putting a liquid fuel in is a much better idea,' he explained, when *The Engineer* met him last year at the Dearman Engine Company's test lab in a rented facility at Imperial College London.

'Then you've got hydrogen-handling problems that I don't believe are solved... It's always going to be expensive because transporting hydrogen is not an easy thing because of the very high pressures. Whereas this is a much more simple technology; it's very easy to transport.' On top of this, the large amount of available liquid nitrogen produced as a by-product of liquid oxygen means the fuel itself could be very cheap.

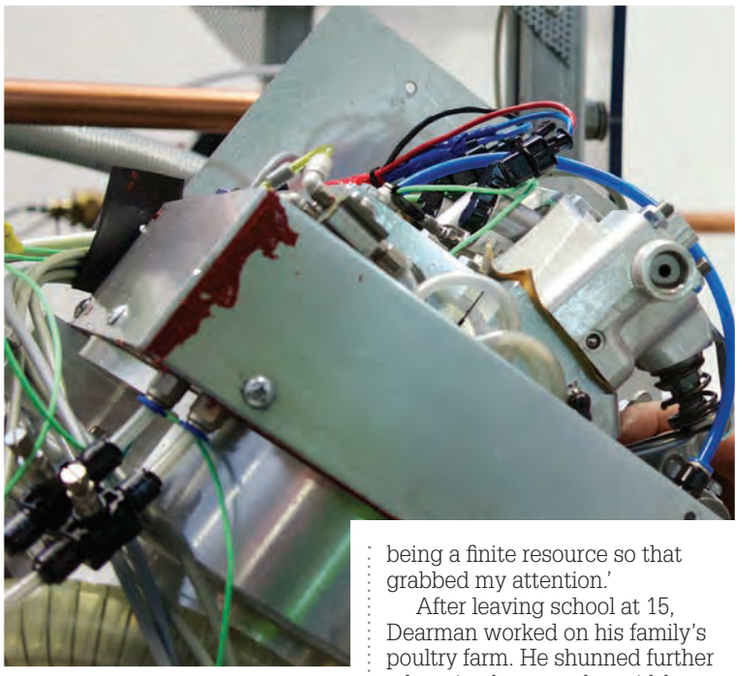
However, a mass-market cryogenic car is still a long way off and may not be a viable product at all. Instead, Dearman is initially concentrating on how his technology could replace diesel engines in commercial vehicles, starting with the secondary motor that drives refrigeration in food-delivery trucks.

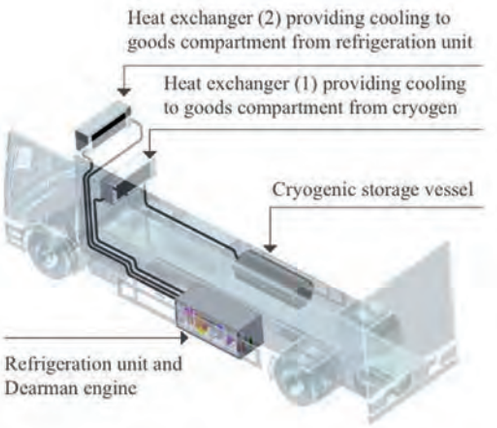


"Even with modern electric vehicles you can't actually fast-charge them because it shortens your battery life
Peter Dearman

The idea behind a cryogenic engine is that allowing liquid nitrogen to boil produces compressed gas that can be used to generate mechanical and/or electrical power. Its only emission is a blast of harmless but potentially useful cold nitrogen gas. Dearman's innovation is to circulate heat-exchange fluid inside the engine in a way that doesn't flood it but keeps the gas relatively warm as it expands in order to maintain the engine's efficiency.

Using this technology to replace the diesel generators on board refrigeration trucks has the potential to eliminate a significant but often-overlooked source of carbon and nitrogen oxides (NOx) emissions, at a time when governments are increasingly cracking down on vehicle pollution in cities. 'It's the easiest one to do





The prototype Dearman engine provides both a cooling effect and additional shaft power of 5kW–6kW to drive a small refrigerator compressor

because there's a ready market for it,' said Dearman. 'If you try and develop something that's not got a market it's very much harder because you've got to create your own market. But [tighter] pollution laws are coming in just at the right time for us as we're developing this.'

Dearman's original idea, however, stretches back several decades to a time when the world was first seriously considering how it might move away from fossil fuels. In fact, a liquid nitrogen engine was the first idea he had as an inventor. 'Of course you get that moment when you decide to be an inventor and then you get a total blank and cannot think of anything,' he said. 'So what you have to do is look at things there's a need for. There was quite a lot of talk about oil being a finite resource so that grabbed my attention.'

After leaving school at 15, Dearman worked on his family's poultry farm. He shunned further education because, he said, he didn't want to overshadow the memory of his clever older brother who had died in a car accident aged 16. Before long, however, his desire to become an inventor led him to take a job with a local metalworking company.

'I wanted to get into engineering so I could make things,' he said, adding that he realised being able to bring his ideas to life would be key to persuading people they would work. 'I think if you just try to put ideas forward, nine out of 10 of them are going to be bad. It's much better to make something that works and then people can make their own minds up. That's a bit like what we're doing now. We've gone into niche markets that don't need a lot of persuading.'

But Dearman's cryogenic engine idea remained parked for many years while he worked as what he describes as a freelance inventor for a variety of companies, at one point developing a more portable handheld microvent resuscitator that is widely used in ambulances. This experience also taught him a lesson about protecting intellectual property.

'I end up in court quite often with these things,' he said. 'Big companies know they can take you to court. [One company] said I still worked for them and they owned all my ideas. The judge said: "How much do you pay him?" [The company said:] "Oh we don't pay him." It's a ridiculous thing because it bankrupts you. But that's the way it goes so you have to be a bit careful.'

When pressed for more details about this story, Dearman said he couldn't remember them, not for the first time in our conversation. A difficult man to read, he would sometimes answer questions with one-word answers in a way that was impossible to tell whether he didn't want to hide something away or just thought the topic unimportant. But he would also volunteer snippets of information with a knowing smile, leaving you equally confused as to his seriousness.

How did he finally build the first Dearman engine, for example? In the 1990s he saw a liquid-nitrogen-powered vehicle built by the University of Washington on an episode of technology television show *Tomorrow's World*, he explained, prompting him to study the available research and build his own breakthrough engine. But how did he do it? Did he manufacture a prototype? 'No I just put things together to show it could power a car.'

"There's no strategic materials involved... It's all pretty cheap stuff
Peter Dearman

This reluctance to talk about his achievements was in line with his tendency for self-deprecation. 'I'm what's known as a broken-clock inventor: you have to think of hundreds of things and eventually one of them's going to work,' he said. 'It's best to get into niche areas because I'm not very clever. I just think about things all the time that other people don't. I don't think it takes anything special, it's just a lot of people don't want to think about things, or you get nutty ideas, which of course I get all the time.'

What he would talk about enthusiastically, however, was the potential he saw for his technology. It's already found relative success in a grid-scale energy-storage system produced by sister company Highview, which has run a pilot plant since 2011. And, as well producing the refrigeration truck demonstrator, the Dearman Engine Company is working on a hybrid powertrain for large vehicles, which uses a cryogenic motor alongside a conventional internal combustion engine (ICE) to provide mechanical power to the wheels.

In this model, heat from the ICE will drive the boiling operation in the Dearman engine more efficiently, which in turn reduces the necessary size and fuel consumption of the main engine. The firm claims the technology could reduce diesel use by up to 25 per cent in commercial vehicles while costing significantly less than electric-hybrid systems.

Did he always have a particular vision that the engine would power passenger vehicles? 'Not really,' he said. 'You just have to do it and hope that something happens. I always thought that fuel would become so expensive that people would want to look for alternatives… The thing about this system is there's no strategic materials involved. Everything's abundant and it's all pretty cheap stuff. We're using aluminium and plastic in the engine, nothing that's horrendously expensive. There's no limit to it.'

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Energy savers

An expert panel answers your questions on the emerging field of grid-connected storage. Stuart Nathan reports

Grid-connected energy storage is sometimes called the 'missing piece in the puzzle' of a modern energy distribution system. Seen as necessary to help store the energy generated by renewables at times of low demand so that it can be supplied to the grid during peak periods and when the renewables are not available, it is also useful for smoothing out the supply, for example while coal-fired power stations come on stream and shut down. There are an increasing variety of technologies available for energy storage, and to answer readers' questions we invited an expert panel including:

- **Anthony Price (AP), director of the Energy Storage Network and founder of energy storage consultant Swanbarton;**
- **David Blood (DB), market manager for energy grid tie-in in Europe, Middle East and Africa for Parker Hannifin; and**
- **Fernando Morales (FM), business analyst at Highview Power.**

■ What do you think about the necessity for local energy generation and storage? Should local non-grid-connected energy be the future?

AP: Local generation is, in general terms, a good thing — providing it is sustainable and economical. All power systems need storage, and smaller systems tend to need relatively more storage, because the averaging effect of multiple sources and multiple demands tends to be less. Rather than considering just grid- and non-grid-connected systems, it may be better to consider interconnected systems based on self-sustaining or self-healing microgrids and these should all have storage.

DB: In countries where there are already established power grids, that's unlikely as large-scale power plants tend to be highly efficient. But even in places such as the UK, there are remote locations where grid-based connections are not feasible.

Local energy storage works particularly well off-grid (say, as micro-grids on physical islands, or remote non-grid-connected locations in undeveloped countries). Take the isle of Eigg in the Inner Hebrides, for example, which is powered with a mix of solar PV, wind and hydro-generation systems as well as energy storage.

Micro grids consisting of diesel generators and variable renewable generators (such as solar PV or wind) need storage to form a stable power grid when the level of renewable generation becomes high. As demand is clearly intermittent, supply has to change to meet it; but with a renewable generator, you're at the mercy of the elements, so it becomes harder to balance a system with higher levels of generation. While achieving 100 per

The Dinorwig pumped hydro plant in Wales

cent renewables generation may be the ultimate goal, it is immensely difficult to do, requiring not only electricity storage but sophisticated energy management systems too.

FM: The economic performance of fossil fuel baseload power generation plants benefits from economies of scale. For this reason, large-scale baseload generation plants were installed. Most of these plants are located far from demand centres so a complex and large-scale transmission grid taking large amounts of energy to distribution networks is needed. But with the increase in renewable generation and embedded generation, the power sector structure and *modus operandi* are changing.

Last year, a number of banks released equity and commodity reports that highlighted the impact that battery-backed-up renewables will have on large utilities, and most of these reports concluded that if big utilities don't innovate to deliver a set of services compatible with the new power sector structure, these would be negatively affected — especially in countries such as Germany where the share of renewables in the energy mix is one of the highest.

Local non-grid-connected energy will continue to play a more relevant role in countries where the grid hasn't been able to deliver an adequate level of security of supply and in countries with a focus on further exploiting renewable resources as a means to reduce carbon emissions. A number of factors such as energy efficiency improvements might also contribute to reduce demand and help the case for local non-grid-connected energy.

An alternative to delivering security of supply while keeping CO_2 emissions at an acceptable level is through the deployment of expensive large-scale nuclear plants that would definitely favour a business-as-usual model in which local non-grid-connected energy doesn't play a significant role.

The realisation of the potential of local non-grid-connected energy will depend on the energy policies adopted by each country.

■ **A significant debate in energy storage research circles is small, localised, non-connected versus large, grid-connected storage. There is actually a third possibility that is rarely, if ever, discussed. This is storage based on local requirements but connected by a grid sized for purpose.**

FM: The apparent (as I have only simulated this) advantage here is that sizing for local needs will result in all storage nodes on a network charging and discharging at differing times and rates — sometimes not differing by much but, as simulation demonstrates, they do not need to. This would result in some areas being out of stored energy on occasion and the network then allows energy to be bussed to depleted areas from those in surplus. This allows integration of distributed renewables, as surplus generation is then parked in storage wherever it is available and most cost efficient to use. The network, on average, can be configured to operate at near-constant load for most of the time with minimum I^2R losses, and large storage facilities will also integrate with the same network allowing large and small storage and generation to co-exist efficiently. A final benefit is that defining storage by local requirements will result in some surplus over an entire network. This then gives a longer-term store distributed across the network that can deal with, for example, a couple of days of no wind, a large power station going offline, etc. I have performed some modelling of such a system and the benefits seem fairly obvious: a surprising amount of longer-term buffering accruing fairly easily and, while the melting pot of differing storage technologies inevitably shakes down to a few worthy survivors, allows this shakedown to occur while still keeping early-stage choices viable over their respective service lives.

Since this philosophy does not appear to be common, I would like to hear the panel's views.

The reason for looking at small, localised, non-connected versus large, grid-connected storage might be related to the lack of mechanisms to monetise the value of storage across the electricity value chain. At the moment, security of supply in remote locations and frequency response, an application especially well suited to small energy storage systems, are underpinning the deployment of energy storage systems. On the other hand, large-scale systems benefit from economies of scale and are economically viable (e.g. pumped hydro, CAES). However, demonstration projects such as the UK Power Network Smarter Network Storage that was designed based on local requirements will definitely help demonstrate the case of grid-connected storage and at the same time it should highlight market barriers and other relevant issues related to the deployment of this kind of system to optimise the operation of local networks.

The results from the cited model are in line with requirements published by EPRI and Sandia for a number of high-value energy storage applications such as renewables integration, in which long-duration energy storage systems are required.

Highview's technology is especially well suited for long-duration applications. The capacity of each of the main components (i.e. charging device, energy store and discharging device) can be sized independently. This flexibility allows for bespoke tailoring around precise application requirements. The technology has no geographical constraints and has a much better energy density compared with pumped hydro and CAES.

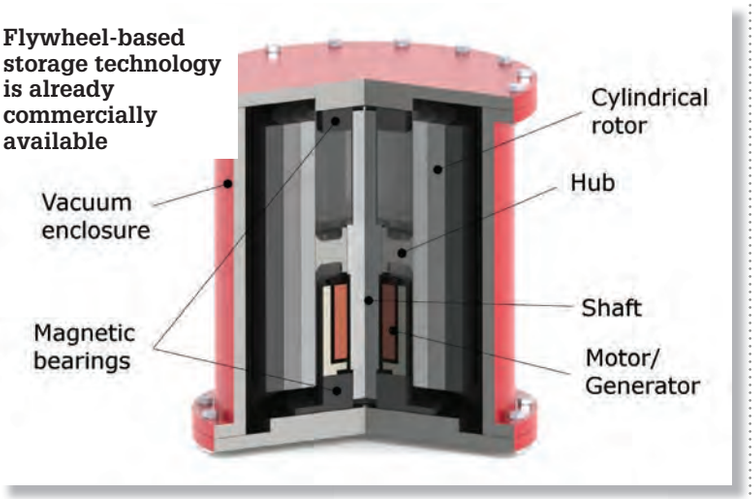
■ **What is the type of energy storage currently in most use commercially or most popular? And which technologies do you see as most promising?**

AP: The most prevalent form of grid-connected electricity storage is pumped hydro. But for grid-connected applications, batteries are very versatile, scalable and adaptable. You may argue that batteries are already dominant because of their role in UPSs and non-grid-connected applications. We heard last week at the annual Electricity Storage Network Symposium about other new types of storage that are commercially available now, such as those based on cryogenics and flywheels. Storage technologies are ready for deployment now — they are being held back not by technology, but by regulatory, commercial and investment issues.

DB: The type of energy storage that is in most use commercially today is probably conventional pumped hydro, such as Dinorwig in Wales. Such systems are capable of storing very large amounts of energy, but require suitable geology (mountains and lakes), which is not always available. They also require a great deal of money and time to build.

Most of the newer energy storage projects going onto the grid use batteries, mainly lithium-ion technology. This has certainly been Parker's experience over the last few years, although we've also been involved with projects using flywheel energy storage and redox-flow batteries.

Lithium-ion battery technology is suitable for storage capacity of between 15 minutes and a few hours. That's sufficient to provide grid services such as frequency regulation ->



Flywheel-based storage technology is already commercially available

and power transmission peak limiting, and most of the projects we've worked on fall into this category. Battery storage technology coupled with modern power inverters allows for very rapid responses to events such as grid frequency excursions. Typical response times from such assets to a step-change in demanded power is within 100msec. In modern grid systems with reducing levels of 'inertia', the ability to respond rapidly to such events will become increasingly valuable to provide stability.

For longer-duration storage, redox-flow batteries are a great solution. I also like the concept of liquid air energy storage (LAES) as this offers the potential to store very large amounts of energy, but without the need for mountains and lakes.

FM: Currently the technologies in most use are lead-acid and lithium-ion. However, as demonstration projects help reduce technology and market risks, a number of technologies will offer a better option. The levelised cost of energy (LCOE) of lead-acid and lithium-ion is among the highest in long-duration, frequently cycled applications. The energy capacity of energy storage systems based on these technologies needs to be oversized to account for limitations on depth of discharge. In addition, these technologies degrade with every cycle and need expensive replacements.

Depending on the scale and application, the most promising technologies are:

- Fast response, short power burst: lithium-ion
- Small scale, long-duration commercial and industrial Applications: NaS batteries
- Medium scale, long-duration commercial and industrial applications: flow batteries and LAES
- Grid-scale applications, long duration: LAES, pumped hydro and CAES

■ Is there a particular barrier to storing energy collected by solar panels or other renewable energy technologies?

Grid-connected electric vehicles offer storage potential

AP: A storage device does not really care where its charging electron comes from or where it goes. The only consideration is whether a particular technology requires an even rate of charge or can accommodate variable, and quite possibly highly rapid, variability in its charging profile.

DB: In principle no, as the technologies to do this are now well established and available. For grid-scale energy storage of solar PV, the main area that distribution network operators (DNOs) may question is commercial viability; comparing the costs of installing energy storage versus that of infrastructure upgrades, due to transmission capacity constraints, for example.

Lithium-ion battery technologies are now commonly used for energy storage applications. Battery suppliers have shown roadmaps for the cost of lithium-ion battery modules to fall to less than $500 per kWh by 2020, mainly driven by the expected volumes of hybrid and electric vehicles. This price reduction will make grid energy storage more viable, but the real boost for storage will come from legislative changes — either as a new payment mechanism specifically for storage assets, or maybe a storage requirement alongside variable renewable generation. California's mandate to add 1.3GW of 'new' energy storage to its power grid by 2020 (to better integrate solar PV production) is a great example of how legislation can kick-start a new industry.

FM: the extra cost of including an energy storage system and the lack of mechanisms to get a return on the extra investment might be the main barrier.

■ What storage capacity is being looked at as a percentage of generating capacity? And, with the technology available near term, what is the minimum power demand required to make the installation of a storage system viable?

AP: Many years ago, EPRI considered that a power system should have a minimum of six per cent of its capacity as storage. At that stage, GB had just about three per cent and so was under the threshold. Matters have not improved since.

With more renewable energy, system studies show that up to 20 per cent storage would be valuable. Many people have already installed units of 1kWh or less for domestic applications and found them to be quite viable. We think that storage, at all scales, and representing all applications, is an essential part of the power system. Amber Rudd, minister at the Department of Energy & Climate Change, said last week that 'energy storage innovation could save the UK energy system more than £4bn by 2050'.

■ Why are nearly all these grid-scale technologies storing electricity? That's the worst option.

The 'low-hanging fruit' lies in before-generator accumulators. I would argue that this is only a practical option within marine renewables, because water enables the transportation of the very large-pressure vessels you'd need, in the form of cylindrical caissons and/or floating steel shells. And this principle would (quickly) build the Bristol Channel Barrage that we'd need.

So don't put generators in any marine devices. Use variable-displacement water pumps instead. Redesign offshore wind from the 'ground' up. But first you'll have to change political ideology in respect of the ownership of intellectual property rights (patents).

The generator of intermittent electricity must be required to install a level of energy storage commensurate with the capacity they deploy.

■ In the UK, we have a so-called free market of generators, DNOs and electricity retailers, with National Grid providing the high-voltage long-distance transmission. Centrally generated power is sold into a pool and treated much as a commodity. How do storage operators fit into this? They are not generators or retailers. Should National Grid pay a 'balancing fee' for every MWh they store and for every MWh they release? Does the operator have the freedom to buy electricity when it is cheap, e.g. overnight nuclear/wind, and sell it at a higher price at peak times?

AP: Moreover, how does a storage operator 'buy' electricity generated by small-scale renewables like solar PV farms and small wind turbines and connected via the distribution network?

Number of points. In Great Britain, there is no longer an electricity pool, but trades based on bilateral contracts and ->

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a balancing mechanism. Existing storage operators work within the current market arrangements, offering energy services to generators and supply companies, as well as offering ancillary services to National Grid.

There is a question as to whether National Grid should use storage on a tolling basis; this would be a good solution, but is not necessarily preferred by that company. A storage operator can either buy electricity from a generator, either directly or through a broker, or if he is directly connected can consider this to be part of self consumption. Unfortunately, the current wholesale market does not make this easy for small storage operators and the questioner has highlighted an important obstacle to the free development of a market for storage. This is one of many detailed points that the Electricity Storage Network has highlighted and is working to be resolved.

DB: Today there is no specific mechanism available to pay for storage capacity. We have generation, distribution and consumption with nothing aimed at storage. The new 'capacity market' is interesting, and will help bring online much needed new generating capacity to replace older plant that needs to be decommissioned. However, storage is not generating capacity; storage is storage, with a finite ability to sink or source energy to the grid.

The lack of a specific storage payment mechanism makes it harder for DNOs to create a business case and invest in the technology. This is borne out by the pilot schemes springing up around Europe (mainly supported with government grants), with the aim of investigating various grid services to make the scheme pay — frequency regulation, peak power limiting, infrastructure deferral and so on.

As levels of variable renewable generation on our power grid inevitably rise, storage will be required to stabilise the grid and help keep the lights on. So the sooner we start to build more new storage the better. And a new payment mechanism to make the technology a more compelling investment can only be a good thing.

FM: Energy storage can be deployed across the entire electricity value chain offering a number of services at each level. For example, deployed at generation level, an energy storage device can be used to provide flexibility, ramping it up and down and avoiding the need to cycle a thermal plant. This allows for maximum fuel efficiency as the thermal plant is operated at its optimum level and for reduced maintenance costs as the plant is less exposed to thermal shocks. At transmission and distribution level, energy storage can be used to provide security of supply and can provide reactive making infrastructure reinforcement investment deferral possible. In the case of suppliers (i.e. electricity retail level), energy storage can help them balancing their positions and reducing imbalance charges. If deployed down stream, the electricity value chain energy storage can capture more value — for example, at distribution level a system can offer services to the system operator by providing ancillary services during times at which the system is not required to provide security of supply in the distribution network.

Energy storage operators can offer a number of services in already established markets such as the ancillary services one (e.g. frequency regulation, reserve). In this case, storage operators receive a payment for availability based on the rated capacity of their assets and for utilisation based on the actual energy delivered to the grid, whenever they are called to do so. Other revenue streams come from, for example, TRIAD management. Transmission Network Use of Systems (TNUoS) charges in England tend to be very high and avoiding TNUoS payments through the use of a storage device is definitely one of the most significant sources of value for these devices, especially because the escalation rate of these charges has been well above inflation for the past 20 years and the need to reinforce the grid to integrate an increasing amount of renewables will require further investment in the transmission network. In terms of arbitrage revenue, it is possible to see that in the SNS project developed by UKPN smartest energy, an electricity supplier, will be in charge of monetising these opportunities.

Inside the Dinorwig hydro plant

■ In developing countries, could independent power plants use energy storage to minimise penalties due to backing down generation due to serious problems in its planned generation? What is the best way to do this?

AP: Anyone can do this, irrespective of whether the country is classified as developing or developed. Large generating companies often own storage (usually pumped hydro) in order to provide security of supply through portfolio management. This is one strong reason why we need to include storage in the overall industry structure.

DB: Energy storage can certainly be coupled with conventional plants to provide grid support during events such as frequency deviations, and Parker has been involved with such schemes.

The key issue will be the level and duration of expected grid support. Battery technologies such as lithium-ion are possible for storage duration for up to a few hours (and redox-flow for longer durations).

However, providing a significant proportion of a power station's output for longer periods would need storage technologies on a much larger scale — such as compressed air, liquid air or pumped hydro.

Perhaps the most interesting application for developing countries is the rise of off-grid micro-grids. These combine conventional diesel generator sets, variable renewable generation (from solar PV and wind turbines) and storage. In these applications, the aim is to allow the maximum possible penetration of renewable generation to the point of diesel shutdown, reducing fuel costs, CO_2 emissions and maintenance, repair and operation (MRO) generator costs. Storage and sophisticated energy management systems are key to making such schemes work in practice.

FM: Sizing an energy storage system requires a good understanding on demand requirements (e.g. hourly profile and growth rate) these parameters would determine output power capacity and energy capacity (duration). In addition, it would be necessary to understand available sources to recharge the system and hourly generation profiles and levels of renewable energy curtailment.

Energy storage systems are very costly as most technologies still face first-of-a-kind costs. In addition, off-peak to peak price differentials in developing countries where regulators keep prices down might not offer an appropriate level of return. It would be necessary to invest in feasibility studies to assess this option with greater certainty.

"Storage is storage — with a finite ability to sink or source energy to the grid
David Blood

Winning formula

The Mercedes F1 team hit the heights last season with a hybrid engine that used less fuel. Helen Knight reports

When Formula One (F1) teammates Lewis Hamilton and Nico Rosberg first unveiled the car they will be driving for the 2015 season in Spain earlier this year, expectations for the new vehicle were understandably high.

Not only did the Mercedes team win both the drivers' and constructors' titles last season, but its car, the Mercedes F1 W05, won 16 races, including 11 in which it took both first and second place. It also racked up 18 pole positions and 12 fastest laps, making it one of the most dominant cars in the history of F1 racing.

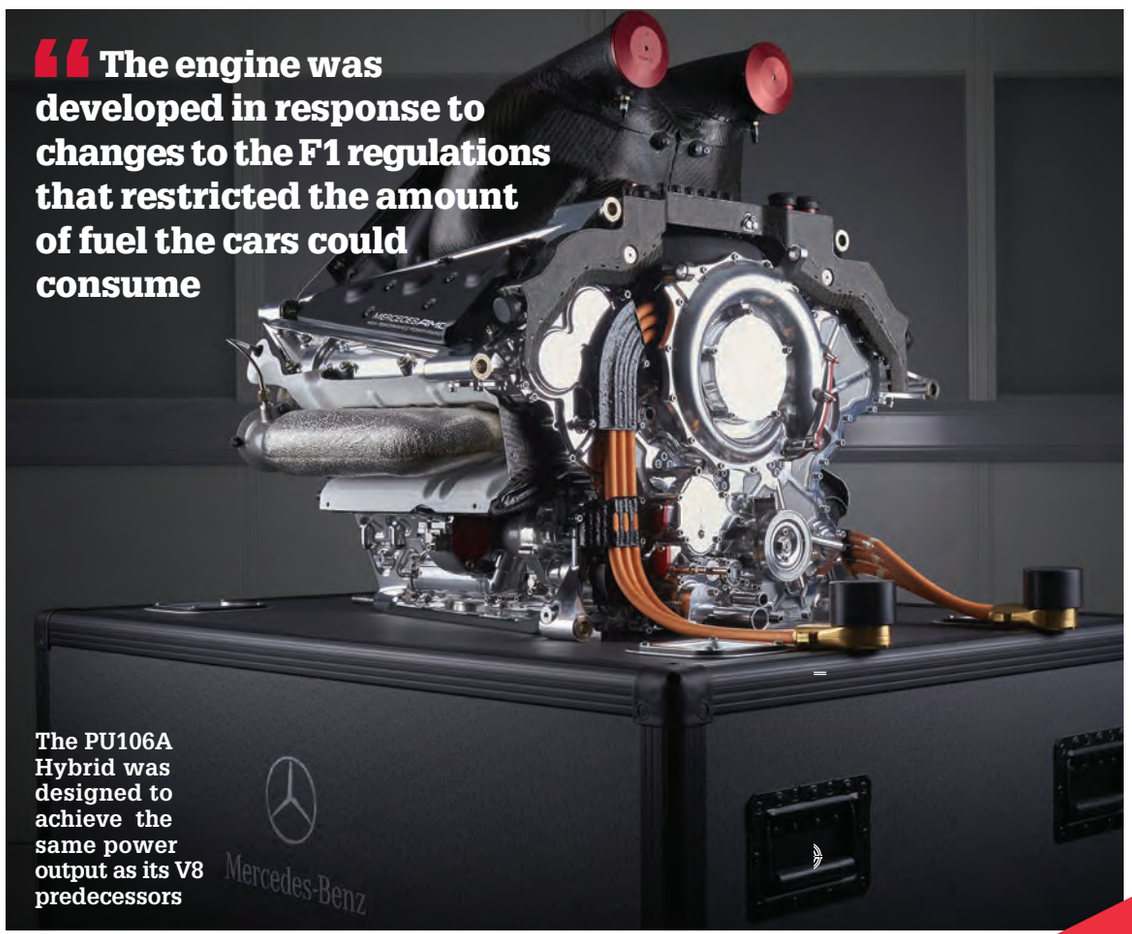
Perhaps most remarkable of all, however, is that it achieved this success without the noisy gas-guzzling 2.4-litre V8 engines used in previous F1 seasons, but with a 1.6-litre V6 hybrid.

Developed by Mercedes AMG High Performance Powertrains in Brixworth, Northamptonshire, the PU106A Hybrid was designed to achieve the same power output as its V8 predecessors — around 750 horsepower — while using one-third less fuel.

With a thermal efficiency of more than 40 per cent (compared to the 29 per cent previous F1 engines typically achieved), the PU106A has been hailed by some as the most efficient gasoline powertrain ever built. In October, it was awarded the Royal Automobile Club's Dewar Trophy for outstanding British technical achievement.

The engine was developed in response to changes to the F1 regulations, which came into force at the beginning of the 2014 season. Rather than limiting engine capacity, the new rules for the first time restricted the amount of fuel that the cars could consume. Teams that had previously used around 150kg of fuel each race were now limited to 100kg.

"The engine was developed in response to changes to the F1 regulations that restricted the amount of fuel the cars could consume



The PU106A Hybrid was designed to achieve the same power output as its V8 predecessors

This was a huge culture change for F1, said Andy Cowell, managing director of Mercedes AMG High Performance Powertrains. It shifted the focus away from developing engines that could reach astonishingly high revolutions per minute but had little relevance to modern road cars, to squeezing every last drop of power from each kilogram of fuel.

The regulations also opened up development of new technologies within F1, by introducing turbochargers and systems to recover waste energy.

So, for example, the PU106A includes a turbocharger in which a turbine wheel recovers waste energy in the exhaust and uses it to power a compressor. This then

"The powertrain also contains a system to recover some of the energy that would normally be lost during braking

The Mercedes team won both the drivers' and constructors' titles last season

increases the pressure of the air going into the combustion chamber in order to boost power.

Connected to this is a further device, the Motor Generator Unit — Heat, which recovers any excess waste energy harvested by the turbine in the exhaust and not needed to power the compressor. The energy can then be stored in the battery, or used to increase the speed of the turbocharger to prevent what is known as 'turbo lag'. This is when low pressure in the exhaust slows the turbine, creating a delay between the driver pressing their foot down on the accelerator and receiving the desired power boost.

'The beauty of the MGU-H is that the motor provides speed control for the turbocharger, which means you don't need many of the tuning features that you see on a more conventional turbocharger,' said Cowell. 'So it's a very neat feature.'

Harnessing the waste energy in the exhaust in this way was a significant challenge, said John Wood, chairman of the RAC's Dewar Trophy technical committee. 'This was a big step forward,' he added.

The powertrain also contains a system to recover some of the energy that would normally be lost during braking and convert it into electricity, known as the Motor Generator Unit — Kinetic. Unlike the previous F1 kinetic energy-recovery system, known as KERS, which was able to provide up to 60kW of power for short bursts of a few seconds per lap, the new unit can provide up to 120kW for more than 30 seconds per lap.

'For some circuits it can be on for 100 per cent of the time that the driver wants it,' said Cowell.

The engineers at Brixworth worked closely with their colleagues at the Mercedes AMG Petronas F1 team in Brackley to ensure the power unit and car were developed together. Their first engine, which was designed to develop the new hybrid technologies, was 50kg overweight and far too bulky to fit inside an F1 car, said Cowell. 'But because we had the right discussions early on, we could do a careful calculation of what was good for the race car in mass, centre of gravity and aerodynamics, and what would help the power unit to push the car down the straight, and we could balance all of that out.'

For example, using very efficient motors in the hybrid system helped to limit the energy lost through waste heat, increasing the amount of power available. But it also reduced the size of the radiators needed to reject excess heat, improving the overall aerodynamics of the car, according to Cowell.

The new regulations, with their emphasis on fuel efficiency, have also made F1 technology far more relevant to road car research and development, said Cowell. 'It is much more analogous to what is going on in the road car world, where regulations are progressively reducing the amount of carbon dioxide that can be emitted per kilometer.'

Work carried out for the previous KERS system has already trickled down into road vehicles such as Mercedes' S500 Plug-in Hybrid and SLS AMG Electric Drive cars. Now several R&D projects are under way to incorporate the new hybrid technologies into future road cars, said Cowell.

'In the road car world development will continue to go in the direction of reducing the capacity of the engine while increasing the amount of boost, so an electric turbocharger will help there,' he said. 'And a high voltage MGU-H built in to the turbocharger is a lovely marriage between a hybrid system and an internal combustion engine.'

Whether the Mercedes AMG Petronas F1 team can repeat the success of last year in the 2015 season is yet to be seen. But the PU106A Hybrid remains a significant achievement, said Wood.

'This was a brilliantly executed approach,' he said. 'They have done something quite remarkable with what is a very complex system.'

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Tuning in the factory

Radio frequency identification is helping to pave the way for a new era in creating bespoke products on the assembly line. Evelyn Adams reports

Photos: General Motors

> **"Automotive production is one of the most challenging applications for RFID**
> Jarkko Miettinen, Confidex

Henry Ford once said of his Model T car: 'You can get in it any colour, as long as it is black.' He was speaking at the turn of the 20th century when making a profit meant making products fit the mould. It was an era when customisation was out and standardisation was most definitely in.

Today, things have taken a U-turn. Factory robots and advanced software have made process lines far more flexible. As a result, customers are demanding bespoke products, and manufacturers are racing to find the best way to produce them at a low cost. Now, from aerospace to pharmaceuticals, one technology has emerged that could help do just that.

Radio frequency identification, or RFID, has been in use for decades in tasks such as inventory monitoring and the recording of maintenance histories. But as RFID increases in reliability, it could have the potential for much more. For instance, it can store information about each component to tell the rest of the factory what work has already been done, and plan for the work that still needs to be completed.

Ultimately, engineers are hoping that RFID could help create automated bespoke manufacturing operations where products are personalised on an assembly line. The technology uses radio waves to automatically track products. There are a number of ways to do this but, most commonly, data is stored in a tag. A reader then converts the radio waves reflected back from the tag into digital information that can then be passed onto computers.

Its capabilities are well known in the automotive industry, which was one of the first to make use of the technology. 'A typical application would be on the car-body jigs that circulate through the paint shop,' explained Mark Higham, general manager process automation at Siemens. 'As the jig with the tag attached passes a reader, this verifies the unique ID for the body and the control system instructs the automatic spray booth to paint the car in the correct colour.'

General Motors has used RFID tags in its factories for more than a decade to identify assembled engines. Last year, the company began attaching them directly to the cylinder heads and engine blocks at its plant in Tonawanda, New York, using something called 'databolts'. These look like ordinary bolts, but their heads are hollow. The empty heads are filled with RFID tags and coiled metal filaments that work like an antenna.

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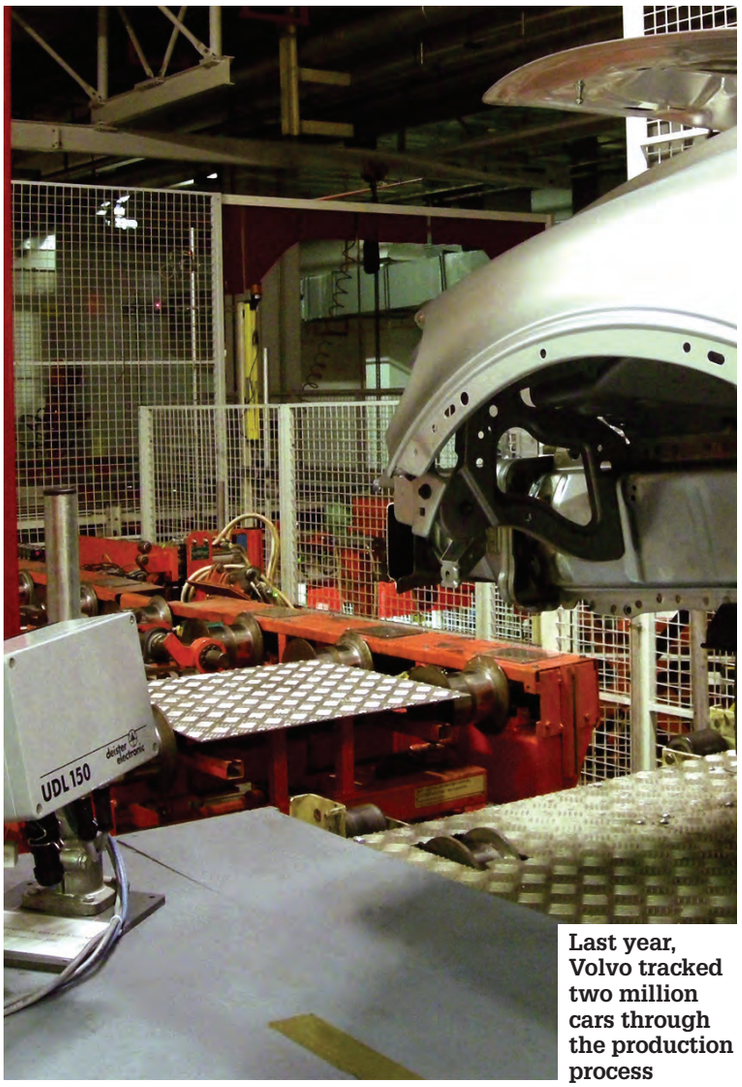

Last year, Volvo tracked two million cars through the production process

Each databolt holds 2KB of data, relatively little by general computer standards but more than enough to track detailed information of each process. It can record every single manufacturing process involved in creating and testing the engine block and cylinder head. Overall, General Motors said there are around 50 different points through the production line where data is moved to and from the bolts. If an error occurs, the automated machine responsible for the mistake goes offline and is inspected by a worker.

'Automotive production is one of the most challenging applications for RFID not just because of its complexity, but also due to its uncompromising, high-reliability requirements', said Jarkko Miettinen, vice-president of sales at Confidex, who supplies RFID tags to Volvo. Last year, the car manufacturer rolled out passive RFID technology to track two million cars as they move through the production process at its manufacturing facilities in Belgium and China.

'Other markets such as aerospace and pharmaceutical have adopted the technology more recently for tracking and traceability; in the case of pharmaceutical to, say, meet legislative requirements,' said Higham. 'The companies are obligated to trace batches through the manufacturing process and store detailed records of that "birth history". In the case of a recall this history is used to identify all process steps and process equipment used.'

"Barriers to the widespread adoption of the technology have historically been cost and customer nervousness
Mark Higham, Siemens

For instance, last year, Airbus adopted something it called 'RFID Integrated Nameplates' to improve the traceability of aircraft parts within the company. They work in the same way as a conventional nameplate with printed text but also include an RFID tag creating what the group describes as a single 'compact, durable and lightweight hybrid device'. Technology such as this, it said, will help monitor parts both during manufacturing and in the supply chain.

An RFID system essentially consists of three elements: tags, readers and a control system. 'Tags range from low-cost, disposable paper tags through to high-specification ruggedised tags that can withstand heat and chemical attack,' said Higham. 'The tag is a data-storage medium that can hold a few bytes through to kilobytes of data. They are generally attached to jigs, products, packaging within the production environment.'

The readers, meanwhile, can be static and attached to machines, conveyors and doorways. They can also be handheld. The readers 'energise' the tags by emitting a short-range radio frequency signal. The data held on the tag is then exchanged with the reader or written to the tag to store status data. This is then passed to the control system, which acts upon the data received.

'Barriers to the widespread adoption of the technology have historically been tag cost and customer nervousness in adopting this 'new' technology as there can be issues with reader consistency,' said Higham. 'Like any technology using wireless transmission it is susceptible to interference. However, a lot of effort goes into the design of the technology in order to minimise interference and make it as robust as possible. A correctly designed and implemented system will be very reliable and robust.'

Industrial processes have traditionally been conservative when implementing innovation, but experts believe the cost benefits of technologies such as RFID will help introduce a 'fourth industrial revolution' in as little as 10 to 20 years. With smart factories becoming increasingly interconnected, bespoke products created on large production lines could soon become commonplace.

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Main event

This year's Maintec show will feature a range of returning and first-time exhibitors as well as a selection of seminar sessions

Running from 24–26 March at the NEC in Birmingham, Maintec is one of the leading UK events for the maintenance, plant and asset management industry.

Exhibitors include major names and show regulars including Hörmann UK, Pruftechnik, Thermaflue, KeyTracker and AV Technology, many of whom will be using the show to launch new products to the market or to unveil their latest upgrades.

Products on display will include eMaint's new MX Mobile, a wireless version of its computerised maintenance management software, and the latest CMMS systems from Ashcom Technology.

Other companies with a major presence at the event include RMS Reliability, which will be presenting a new web-based learning tool designed to help industrial plants to establish sustainable reliability improvement programmes, and Lobo Systems, which will be showcasing its platform scaffold products. These combine the flexibility and strength of traditional scaffolding with the simplicity and mobility of tower systems, but they are much more versatile.

Meanwhile, first-time exhibitor IndySoft will also be using the show to promote its IndySoft Software and its Motion Tablet Computer. The Motion F5v has an integrated 1D and 2D barcode scanner built into the carry handle as well as an option for RFID tracking.

Crimson Industrial Vision will be using Maintec 2015 to highlight its range of remote visual inspection systems and thermal-imaging cameras. On show will be its VISIO PRIME Inspector — a portable 6mm robust industrial endoscope system with full four-way articulation and light output, capable of taking both video (mpeg) and still (jpeg) images. Crimson Industrial Vision will also present its INVIZ VUMAN Ra-Y, a premium video endoscope system with the unique Remote Focus capability, enabling the user to adjust the focus for optimum image quality while the probe is deployed.

Exhibition area: **show regulars will include Hörmann UK, Pruftechnik and KeyTracker**

"Visitors will have plenty of learning opportunities at the event courtesy of a packed seminar programme

Visitors will also have plenty of learning opportunities at this year's event courtesy of a packed seminar programme touching on the latest research, new innovations and case studies exploring the hottest topics, challenges and trends.

There will also be a return for The Business Strategy Forum, which will include sessions from expert speakers and major industry names.

There will be additional show-floor entertainment in the form of show favourite Lions' Lair, which will once again be returning to Maintec with brave exhibitors presenting their new technologies, innovations and concepts to a panel of experts, in front of a live audience, in a bid to be voted best of show.

Building on last year's event, which saw Maintec's floor plan and visitor base expand massively, the organisers have confirmed that it will again run alongside Facilities Management — the UK's only event for the facilities industry outside London.

Playing the field

Low oil prices have hit recruitment in the sector, but there are still good opportunities if you know where to look. Stephen Harris reports

Going deep: **Gunashli offshore platform in Azerbaijan**
Source: BP

A nasty shock has hit the oil and gas industry over the last six months. The price of oil has plummeted from more than $110 (£66) a barrel to around $45 due to a glut of fossil fuels from US shale operations and weakened demand from China and the struggling eurozone economies. In the UK, the result has been dramatic for an industry that was already undertaking much soul searching in the wake of the declining production and rising costs of the North Sea.

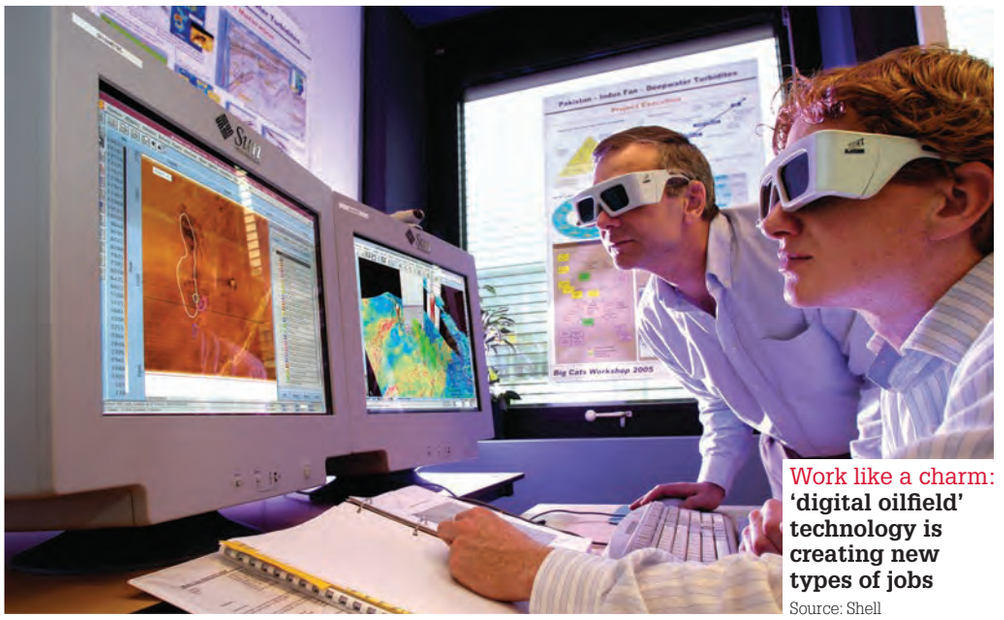
The major oil producers including BP, Shell and Chevron have announced a total of nearly 1,500 job cuts in the UK and are slashing their spending worldwide. In the supply chain, manufacturers such as Baker Hughes and Weir Group are also making cuts (so far mostly in other countries), as are service companies such as Schlumberger, which is reducing its fleet of support vessels by more than a third, and Wood Group, which has lowered its contractor pay levels by 10 per cent.

In some ways, the collapse in oil prices couldn't have come at a worse time for the North Sea. After more than a decade overseeing falling production and unhelpful tax changes after the last election, the UK's oil and gas industry was finally hoping that its decline might be stemmed, at least in the short term.

The last few years have seen a record amount of investment in new oil fields and new technology to get at the North Sea's remaining but increasingly difficult-to-reach reserves, and production was expected to stabilise and perhaps even grow. Last year's government-commissioned Wood Review set out a path for the industry to rejuvenate itself through greater exploration and use of technology.

All that has now been called into question by an oil price so low that much of the remaining North Sea reserves may not be worth the expense of recovering them. Energy consultancy Wood MacKenzie estimates that around £2bn of investment in new projects could be at risk of cancellation. And existing operations are looking for possible ways to reduce their costs. Much of this will come at the expense of back-office roles, but it could also have an impact on new engineering jobs.

'People have been sharpening their pencils,' said Andrew Speers, managing director of specialist recruitment agency Petroplan. 'Projects not at the production phase or not fully funded or well established are being put on hold. That's having a very real impact on the marketplace with regards the opportunities today.'



Work like a charm: **'digital oilfield' technology is creating new types of jobs**
Source: Shell

The North Sea has been dealing with the reality of its long-term decline since production peaked in 2000. A report produced for Oil & Gas UK by consultancy EY in December 2014 found that the number of jobs directly supported by the industry was set to decline by roughly nine per cent from 281,000 to 255,000 by 2019. 'Cost reduction was already under discussion,' said Steve Couch, human resource services partner at PwC's Aberdeen office. 'We're trying to make the work in the North Sea last as long as possible.'

In addition, the much reported skills shortage is now thought to be lower than previously claimed. The Oil & Gas UK/EY report found that the oil and gas workforce was ageing less rapidly than the national average and the industry has a high proportion of mid-career professionals, with half the workforce aged 25–45. However, the oil price has potentially acted as a catalyst.

'We have been seeing a change in recruitment over the last 18 months and the drop in the oil price has really accelerated many changes that have been happening,' said James Mildon, oil and gas manager at recruitment firm Matchtech. 'What we have seen to date is companies reviewing their manning levels; reviewing all of their supply chains as well. And that has… had a knock-on effect on recruitment plans. We've seen many companies put in recruitment freezes.'

Perhaps the biggest impact has been felt in the amount of exploration and drilling work: the industry expects to drill around 10 exploratory wells and bring 12 new fields on stream this year — much lower than the 10-year average. As such, related jobs in reservoir/petroleum engineering, commissioning and well appraisal and construction are the least in demand in the industry, according to the Oil & Gas UK/EY report.

Despite all of this bad news, however, the UK oil and gas industry is still a major component of the economy, directly employing well more than a quarter of million people. Oil & Gas UK estimates that, even taking into account industry decline, 12,000 new recruits will be needed over the next five years as existing workers leave or retire. There's also an expectation that, in order to cut costs, companies may well hire permanent staff where they may previously have used contractors.

More than a third of companies contacted for the EY report said they were recruiting operations staff and almost as many needed new maintenance teams. 'Projects that have been well funded and are well under way and at a production stage are continuing to hire, develop and do business as usual,' said Petroplan's Speers. In particular, there are some key areas where companies still find it hard to recruit the necessary staff: approximately 70 per cent of respondents to the EY report said they had difficulty filling senior positions in technical safety, drilling, geosciences and business support.

"You cannot look at the UK oil and gas industry as just being the North Sea. We're seeing quite a lot of activity in Azerbaijan
Andrew Speers, Petroplan

The changing nature of the industry is also creating new kinds of jobs as different technologies come into play. More technically challenging operations are starting to rely on enhanced oil recovery (EOR) technologies such as low-salinity water injection and miscible gas injection. More than 20 per cent of respondents to the EY report cited a growing demand for skills in this area. In addition, there's a desire for much greater use of software and electronic systems, whether for remote control of vehicles or increased data analysis, in order to improve efficiency and initiate an era of 'digital oil fields'.

Outside of the North Sea, the demand from international markets for UK expertise remains strong and total global investment is expected to rise despite the oil price fall, especially in locations where oil is much easier to recover. The proportion of the UK-based workforce supporting overseas projects is expected to grow from 26 per cent to 35 per cent by 2019. In some key markets such as West Africa, support from the UK is expected to double.

'You cannot look at the UK oil and gas industry as just being the North Sea,' said Speers. 'We're seeing quite a lot of activity in subsea. One of our clients is in Azerbaijan; their hiring campaign for people with experience in subsea engineering is significant over the next 12 months. In the Middle East, we still see a lot of demand for skills generally because the cost of production is typically much lower than offshore UK.'

The greatest international demand increase is expected in drilling and marine expertise while the UK is set to hold a competitive advantage in subsea, geosciences and petroleum engineering. But international investment also means increased export work for UK-based supply chain firms. The EY report noted that the export market for oil and gas supply chain companies is now worth £14.8bn, up from £10.3bn in 2008.

Finally, it's worth bearing in mind that the speed with which the oil price has come down illustrates just how volatile it can be. The OPEC cartel of oil-producing nations could decide to cut production in order to reduce supply and force the price back up. Meanwhile, some of the US shale operations that helped produce the current glut of oil are already closing because of the low price.

As such, companies may well be wary of losing valuable engineers who will be vital in maintaining momentum if the industry rebounds. 'In the past, organisations may have overreacted in terms of cutting specialist employees, so I think there's some caution around not wanting to cause shortages in due course,' said PwC's Couch. Ultimately, the world's appetite for oil isn't going to disappear any time soon.

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- Experience with onshore processing facilities
- Experience of offshore engineering (FPSO, platforms, FLNG etc. wouldbe beneficial)
- Strong engineering background, comprising discipline engineer experience and Lead Engineer responsibility.

Required Knowledge, Technical or Professional Skills:
- Process Engineering: Process, Utilities and Offsite Design
- Plant Design and Engineering
- Basic knowledge of economic modelling and evaluation; technical input for CAPEX development; technical input to OPEX development
- Development of Contract Strategy; technical review of variations and claims; contract negotiations; review and approval
- Preparation of technical scope of work for ITT documentation
- Quality: e.g. preparation of Basic Engineering Design Data; preparation of project quality plans; preparation and development of technical standards
- HSEQ
- Organisational Work Processes: e.g. work procedures; project management processes; Technical audit and design review; project team management; co-ordination with clients
- Documentation management: document work flows and issue cycles; technical queries
- Site Engineering
- Compliance: e.g. local/national and international standards and codes
- Construction and Installation
- Willingness to travel and be mobile

february1946

The Engineer reported on the Lincoln — the last of the Royal Air Force's piston-engined bombers

The world and technology changed rapidly after the end of the Second World War, perhaps nowhere more noticeably than in aerospace. The Royal Air Force's (RAF's) iconic heavy bomber, the Lancaster, had served the country well, but by the mid-1940s it was ageing and needed replacement.

Jet engines had already started to make their presence felt in military aircraft, but only in single-seat fighters, and the replacement for the Lancaster was the AVRO Lincoln, which *The Engineer* covered in 1946. Classed as a Superbomber, it bore a strong resemblance to the Lancaster despite being larger, and indeed used many of the same components: it was another four-engined aircraft, using Rolls-Royce Merlin engines (although a more powerful variant than the Lancaster), with a wingspan of 120ft and a 78ft-long fuselage carrying 4.5 tons of equipment and housing a crew of seven.

"The Lincoln was able to operate at a maximum altitude of 35,000ft and fly for 1,350 miles while carrying a 10-ton bomb

A notable use of new technology was radar, including a complete unit just for the rear gunner, allowing him to aim his weaponry even if he didn't have a direct line of sight to the target. The forward guns were aimed and fired by the air bomber (formerly called the bomb aimer).

The Lincoln could reach a speed of 314mph at an altitude of 18,000ft, although it was capable of operating at a maximum altitude of 35,000ft (6.5 miles) and could fly for 1,350 miles while carrying a 10-ton bomb. Its maximum range was 4,450 miles. It carried more fuel than the Lancaster and flew higher and further.

It was to be the RAF's last piston-engined bomber. The need to carry nuclear weapons led to the development of the jet-engined V-bombers — the Vickers Valliant, the Avro Vulcan and the Handley-Page Victor — which could fly faster, higher and further. These were already in development in 1945 — the same year that the Lincoln became operational.

Although the Lincolns remained in service until 1963 — seeing action in Kenya and Malaya — they were mostly phased out during the 1950s, and the old, characteristic RAF bomber silhouette, with its straight wings and H-shaped tailplane, was gone forever. ***SN***

For more on this story visit **www.theengineer.co.uk**

prizecrossword

When completed rearrange the highlighted squares to spell out a subdivision of engineering. The first correct answer received will win a £20 Amazon voucher.
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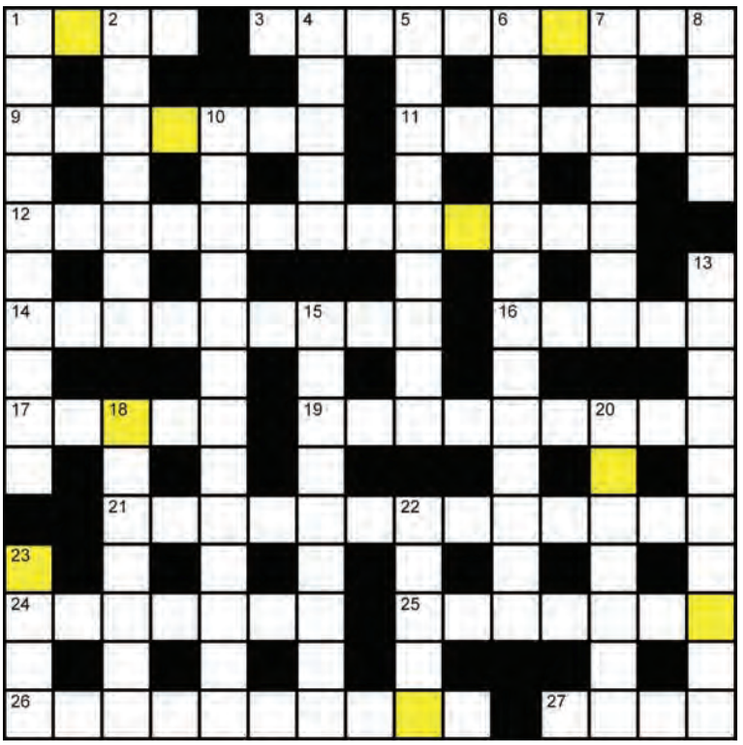

ACROSS

1 Enclosure made of wire (4)

3 Heavy motionless load (4,6)

9 Separate a metal from an ore (7)

11 Small dynamo with a secondary winding (7)

12 From or between other countries (13)

14 French mathematician and philosopher (9)

16 Projection to fit into a mortise (5)

17 Adjust back to zero (5)

19 Preliminary paint applied to a surface (9)

21 Lacking cleverness (13)

24 Male partner of a ballerina (7)

26 Divides into pieces (5,5)

27 Inquires about (4)

DOWN

1 Piece of plastic used for payments (6,4)

2 Manage to get a machine operational (3,2,2)

4 More than is needed (5)

5 Lacking mental capacity and subtlety (3,6)

6 Making metal parts on an old machine (6,7)

7 Unidentified problem in a machine (7)

8 Implement used for a specific job (4)

10 Fitness to fly (13)

13 Associations organised to promote science (10)

15 Fill a space in a disorderly way (7,2)

18 Russian artificial satellite (7)

20 Hand tools used for unfastening sealed containers (7)

22 Intense beam of coherent light (5)

23 Horizontal passage from the surface into a mine (4)

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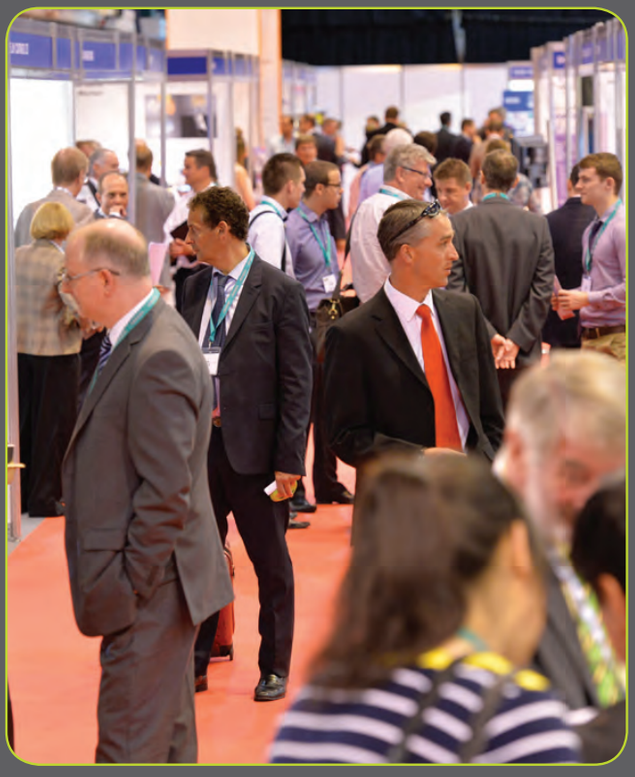

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