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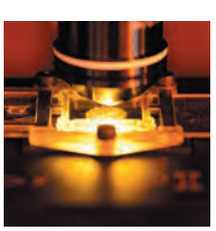

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inouropinion

Can you dig it?

There are some trends that always seem set to continue. General elections will keep getting more depressing than inspiring. Hollywood will keep making superhero movies. And populations will keep moving from the country into cities.

As the need to find room for urban working and living intensifies, it inevitably falls to engineers to think up solutions. In the 1920s, they built tall; and in some parts of the world they still do. Elsewhere, however, the pressures of city planning and sometimes unpleasant open-air environments are leading to an increasing interest in looking underground.

In this issue's cover feature (page 18), we take a look at some of the most innovative approaches to underground civil engineering in cities, from an inventive solution to an everyday problem in Tokyo; the remarkably practical approach to planning in Helsinki, where the local taste for an active lifestyle has to be balanced by the frostbite-inducing weather for much of the year; and an ambitious plan for an inverted skyscraper underneath the most important public square in Mexico City.

Our Q&A (page 30) stays with the subterranean theme, taking us into the tunnels and caverns of CERN in France and Switzerland for a rare insight into the engineering, rather than the physics, of the Large Hadron Collider (LHC). Senior engineers answer our readers' questions on how the LHC was upgraded to double its power, allowing it to hopefully shed light on the most puzzling theories about the universe.

We come back to the surface for our interview (page 28), where the senior engineer of automotive technology provider GKN talks about how hybridisation is improving the capabilities of road vehicles, including giving the performance of all-wheel drive without the increase in fuel consumption and emissions conventionally associated with them.

> **"The need to find room for urban working and living is intensifying**

Elsewhere, you can read about the shape of things to come at the cutting edge of 3D printing from one of the main centres for its development, Prof Richard Hague's labs at Nottingham University (page 23); the engineering consequences of the pharmaceutical sector's shift towards more personalised medicine (page 35); and moves towards the development of hybrid passenger aircraft (page 39). A preview of what visitors to some upcoming exhibitions can expect rounds off our May issue.

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NUCLEAR

US set to trial deep-hole waste disposal method

Technique is said to be cheaper than the proposed mined repository

BY HELEN KNIGHT

A method to safely bury the world's most highly radioactive nuclear waste in holes 5km deep will be tested in the US next year. The technique, developed in the UK by researchers at Sheffield University, involves drilling a borehole around 0.6m wide and 5km deep and lowering the waste into it.

Known as deep borehole disposal, or DBD, the technique is much cheaper than the mined repository proposed by the UK government for burying the country's nuclear waste, according to its pioneer Fergus Gibb, emeritus professor of petrology and geochemistry at Sheffield University.

Each borehole would cost a few tens of millions of dollars to drill, compared with hundreds of millions to tens of billions for a mined repository. Around six boreholes would be enough to store all of the UK's existing high-level waste, said Gibb, with each taking less than five years to drill, fill and seal.

Deep borehole disposal should also be safer than a mined repository, which at 500m deep would still be within the zone of circulating ground water, meaning any leakage caused by an earthquake, for example, could potentially return to the surface, he said.

"By going down several kilometres, it means the disposal zone at the bottom of the borehole is in a geology that is below, and isolated from, the normal ground water," he said. "So even if the waste eventually leaks out of the containers into the surrounding rock and water, it will never come back to the surface; instead it will leak into waters in the deep rocks that have been isolated from the surface waters for millions of years."

This should make it easier to gain public acceptance for a burial site, Gibb explained.

Although not a new idea, deep borehole disposal has only been made possible by recent advances in drilling by the oil and gas and geothermal energy industries, he said.

To ensure the waste is protected from leakage, corrosion or theft after it has been buried, the researchers have been developing two distinct sealing techniques, which they recently presented at a conference held by the American Nuclear Society in Charleston in the US.

Firstly, the waste would be slowly lowered down the hole in metal containers, and then a specially developed sealing and support matrix would be poured in with it.

For 'hot' radioactive waste – that which gives off heat of more than 190°C as it decays – metal alloy shots that melt into a solder to seal the waste in the casing would be used, said Gibb.

But for waste that does not give off as much heat, Gibb's colleague, Dr Nick Collier, is developing a special type of cement that can be poured down the hole, which will not set until it reaches the bottom, up to five hours later.

Once the waste has been sealed in position, the hole is then filled above the disposal zone with crushed granite, said Gibb. An electric heater is used to melt the granite, which is then cooled slowly to allow it to re-crystalise, in a process known as rock welding. "So we create a weld that is both continuous with, and identical to, the host rock around the borehole," he said. "This completely seals the hole, just as if you've never drilled through it."

The US trial, which is being run by Sandia National Laboratories for the Department of Energy (DoE), will take place at a yet-to-be-determined site in late 2016.

If it proves successful, the DoE plans to build a much smaller, 22cm-wide hole to dispose of small capsules of highly radioactive cesium and strontium being held at the Hanford nuclear facility in Washington State.

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ISS laser plan to clear space debris

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Eye-inspired camera can work outdoors

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SPACE TECHNOLOGY

Surging forward

ESA selects Skeleton Technologies' ultracapacitor for space mission

BY JULIA PIERCE

The European Space Agency (ESA) has chosen a new ultracapacitor energy storage technology that increases safety while reducing weight and costs for a possible mission in 2018.

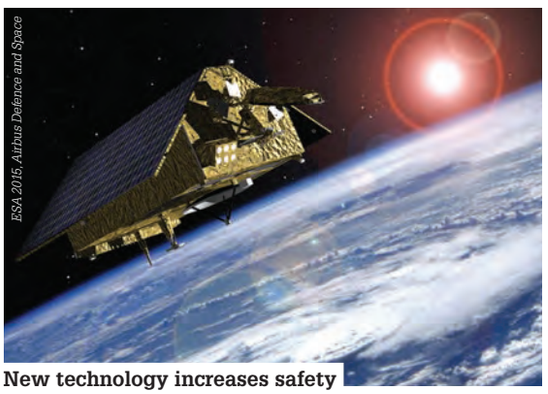
Originally developed by Estonian start-up Skeleton Technologies for use in the motor industry, the technology is 60 times lighter and 30 times more efficient than the lithium-ion batteries it will replace, considerably reducing the amount of weight and room required for energy storage on a space vehicle. While batteries can store more energy than ultra-capacitors, they are slow to charge and discharge and lose 30 per cent of their energy through heat alone. They also require frequent replacement.

Such an energy storage system is required by spacecraft and satellites to provide surges of power when required. Energy from the Sun is harvested using solar cells and is stored for when the vehicle moves to the dark side of a planetary object, away from the Sun, where the power is used for tasks such as adjusting antennas and moving solar arrays.

Skeleton Technologies' system uses patented nanoporous carbide-derived carbon (CDC), also known as curved graphene. They have also developed a proprietary method for preparing the ultracapacitors.

"We took a technology that was widely used in the motorsport and tier-one automotive market and deconstructed and reconstructed this for use in space in, for instance, a high-radiation environment," explained Oliver Ahlberg, Skeleton Technologies' general manager.

"Normally, our products have twice the energy and four times the power of our competitors' systems, but the performance of this is even better. However, in space, safety is a major concern. We are currently undertaking further testing of the devices in space-like conditions, with high radiation and in a vacuum. The advantage of our ultracapacitor is that no chemical reaction takes place when charging it, unlike with a lithium-ion battery, which can combust if it is faulty. With the Skeleton system, the ions are changing places in the electrodes, making it a physical, not chemical reaction. This means we have no issues at all with, possible explosions."



New technology increases safety

As the ultracapacitors store energy in an electric field rather than in a chemical reaction, they are highly efficient at delivering sudden surges of energy and can charge and discharge more than a million times, delivering significantly more power for weight than batteries. With every pound of payload put into space currently costing around €9,000 (£6,500), adopting this technology is expected to achieve significant efficiency savings.

As well as the motor industry, the technology is also making inroads into use in the development of smart power grids.

ELECTRONICS

Star of the screen

Team of UK researchers develops new class of ultra-thin displays

BY JULIA PIERCE

A team from Oxford University has created an entirely new class of ultra-thin, ultra-high-resolution displays with nanosecond access speed and no power consumption in static mode.

The technology has a range of applications in the rapidly growing microdisplay market, and can be used in compact, projection-based displays such as those of emerging near-eye applications.

Headed by Dr Peiman Hosseini of Oxford University's Department of Physics, the researchers' nano-display device utilises optical and electronic property modulation in phase-change materials – materials that are also used to create CDs and Blu-ray discs.

Dr Hosseini said: "The ultimate, most difficult yet most exciting application of this is the building of a high-resolution nano-display.

"In, for instance, a Google Glass device, you need to display a picture or video on a very small screen in front of you. This display must have a very high resolution when magnifying the image."

Hosseini continued: "On Apple's latest retina display system, one pixel equals 66 micrometres. With our technology, the whole picture must be only 79 micrometres in size.

"Our device is also three times the speed of existing technologies, which is essential as, if the image is too slow in refreshing, it will cause the user nausea. Importantly, it also does not consume power when resting, conserving battery life."

The first prototype displays are currently under development, with a small working device set to be completed within the next 12 months.

One of the first applications of the display is likely to be in smart jewellery that can change colour with a very pure brightness, and Hosseini and his colleagues are currently speaking with a major brand to develop this. Other applications include security-tagging systems.

inbrief

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Powertrain partners

Mira and Samsung Techwin are to work on battery and powertrain systems for automotive and off-road hybrid and electric vehicles. Samsung Techwin is a Samsung subsidiary that develops energy and security systems. During a three-year collaboration, they will develop optimised systems for commercial, defence and niche vehicles, using Mira's expertise in battery and powertrain design, validation and testing, and Samsung's manufacturing facilities.

Winging it

NASA and partners have completed initial flight tests of a new morphing wing technology that could reduce fuel costs, airframe weight and aircraft noise during takeoffs and landings. NASA's Armstrong Flight Research Center in California flew 22 research flights with experimental Adaptive Compliant Trailing Edge flight control surfaces, which offer improvements over conventional flaps used on existing aircraft.

Explosive new research

Research illustrating what happens when Lithium-ion batteries explode could help engineers improve their design and make them safer for transport and use. The study carried out by UCL, ESRF, Imperial College London and the National Physical Laboratory shows for the first time how internal structural damage to batteries evolves in real-time and how this can spread to neighbouring batteries.

Colour scheme

New research reveals the potential for graphene to help bring 3D colour holograms closer to fruition. Led by Swinburne University of Technology, Melbourne, scientists have capitalised on graphene's properties and are confident of applications in fields such as optical data storage and imaging.

IMAGINE DESIGNING

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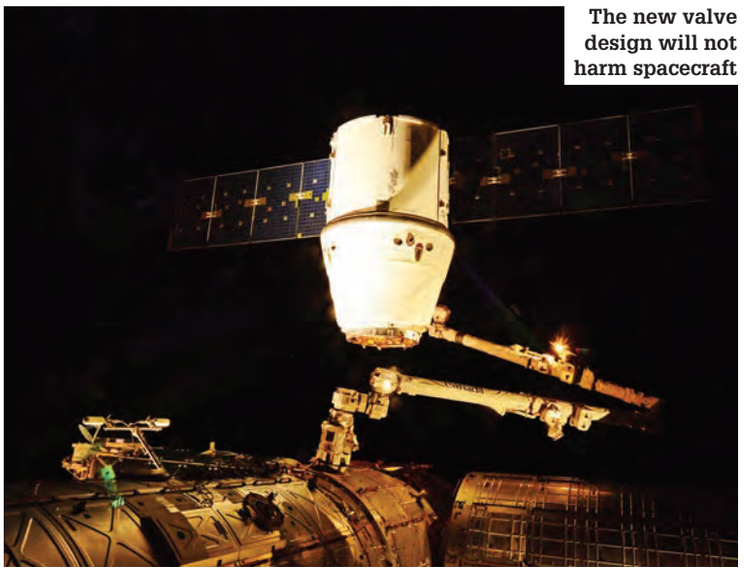


The new valve design will not harm spacecraft

SPACE TECHNOLOGY

Cosmic event for AMRC design duo

Explosive-free valve design receives Space Propulsion Innovation Award

BY JULIA PIERCE

A safer, pyrotechnic-free design for space valves from the Advanced Manufacturing Research Centre's (ARMC's) Design and Prototyping Group has won the UK Space Agency's UK Space Propulsion Innovation Award.

Sam Hyde and Valdis Krumins beat 14 finalists from leading space science companies, design agencies and university research centres with their new design for permanent valves – valves on a spacecraft that operate only once during a mission, after which they remain open or closed.

Currently, standard valves use a pyrotechnic activator consisting of a small explosive charge to open or close valves permanently. However, firing creates gases, particles, shocks and vibrations, which can break welds and cause the satellite or rocket to be damaged.

The pair replaced the moving cylinder of the old valve with a tapered cone and replaced the explosives with a simple spring, which is compressed and secured by a piezoelectric trigger.

When a current flows through the trigger, it releases the spring, which pushes the valve into its new, permanent position.

The trigger returns to its original position when the current is switched off and then prevents the valve from moving back.

Krumins, project engineer (design) at AMRC's Design and Prototyping Group said: "The shape of the piston in a pyro valve is usually cylindrical and it has O-rings on it to create a better seal.

"While designing the permanent valve, we realised that there is a mature solution in medical sector, which does a somewhat similar task – a Luer slip connector that is used to secure a needle on a syringe," Krumins explained.

He continued: "Luer slip creates a good seal between two tapered surfaces and does not require O-rings. It is a simpler solution and has a larger contact surface area, which potentially creates a better seal.

"Our concept is simpler and safer to assemble when compared with existing pyro valves, which house a small charge of explosives. It is scalable and can be used in almost any application in which there is a need for a valve that has to open or close permanently."

The pair plan to use their £10,000 prize money to conduct a desktop study and to build a partial technical demonstrator for testing the critical parts of the concept.

Hyde added that he hopes the project marks the start start of wider engagement between AMRC and Britain's space industry.

LASERS

Message in a bottle

Plasma implants could help protect against potentially dangerous counterfeit goods

BY HELEN KNIGHT

An ultra-fast laser system that creates unique images within glass bottles could protect consumers from potentially dangerous counterfeit goods.

The manufacturing platform, dubbed ULPI (Ultrafast Laser Plasma Implantation), is designed to create plasma that is implanted into the glass to generate individual patterns on the surface of the bottle.

These could be used to identify individual bottles or batches of alcoholic beverages, pharmaceuticals or perfumes, according to its developer Dr Matthew Murray, a research fellow at Leeds University.

"Our aim is to create a security measure that is in place right from the moment that the glass comes out of the furnace, up to the point that it goes into a customer's home," explained Murray, who was recently awarded the Royal Academy of Engineering ERA Foundation Entrepreneurs' Award for the technology, known as Alpin.

To create the patterns, the system uses a femtosecond laser, which creates a series of very short light pulses.

When these pulses, which contain large amounts of energy, are focused onto a target material, the material converts it into plasma in an ablative process, said Murray.

"Because of the tremendous amounts of energy involved, it causes [this plasma] to explode off the surface at high velocity, in what looks like an aerosol spray," he explained.

This plasma is then captured in the glass bottle to become implanted within the material, said Murray.

"We are mixing up the target and substrate material during this implantation process, and when we do that we create a unique environment that can't be replicated through any other kind of process," he added.

In this way, the system is able to create unique optical signatures that can describe where or when a product was manufactured, and by whom.

A spin-out company, Ultramatis, has been created to commercialise the technology.

AEROSPACE

Making light work

A UK-based 'airship' company has received a €2.5m funding boost

UK company Hybrid Air Vehicles has been awarded €2.5m (£1.8m) of European funding to refine the development of its 'lighter-than-air' hybrid aircraft technology.

Based at Cardington in Bedfordshire, the company has been refining its technology for a number of years and, following an abandoned project to develop a high-altitude reconnaissance aircraft for the US military, is now working on a civil variant of its technology.

According to the company, the funding – which has come through the EU's Smart, Green and Integrated Transport Societal Challenge programme (part of the Horizon 2020 seven year research programme) – will be used to continue work on refining the civil variant, as well as to help develop a regulatory framework for the vehicles.

The company, which has also received £2.5m from Innovate UK, a grant from the Regional Growth Fund and money from a number private investors including Bruce Dickinson, front man of rock band Iron Maiden, is also looking to raise funds on crowdfunding platform Crowdcube. ***JE***

ENERGY

All walks of life

Pavegen set to provide London's Canary Wharf with a sustainable energy boost

BY JULIA PIERCE

A pilot project that is designed to create electricity from the footfall of commuters is set to be installed at London's Canary Wharf this summer, helping the district to be more sustainable while enabling vital data to be gathered on visitors' habits.

Pavegen's flooring technology consists of slabs that are constructed from recycled rubber and polymer concrete that convert the weight of a footstep into renewable electricity.

When a slab is stepped on, it deflects the top sheet by 5mm, and the movement is converted to electricity, which is delivered into a regulated 12V feed.

Unlike other energy-harvesting systems, Pavegen's technology does not rely on piezoelectricity, where energy spikes make it hard to give a constant flow of energy.

Each step on a Pavegen slab contains enough energy to power an LED streetlamp for 30 seconds. The energy conserved can also be stored in lithium polymer batteries underneath the floor to be used at a later date.

The technology was a finalist in the Cognicity Challenge award, a scheme run by the Canary Wharf Group to help small businesses set up pilot projects and grow.

With 100,000 commuters passing through Canary Wharf each day, the public spaces are an ideal place to place the tiles in order to gather footfall data as well as generating renewable energy.

"As well as generating energy, we can look at real-time analytics of footfall and where people go," said Laurence Kemball-Cook, an industrial design engineer and a graduate of Loughborough University, who created Pavegen while researching kinetic off-grid energy solutions in areas where low-carbon technologies such as solar and wind are not practical.

"We can then do things such as targeting advertising," he said. "We can see how the high street is performing in real time."

In a related development, a recent collaboration with Samsung saw shoppers in Sandton City mall in Johannesburg using a 68-tile walkway to power an interactive screen, displaying real-time footfall data and providing a visual payback of the energy harvested from its monthly footfall rate of two million footsteps. This power was then channelled to deprived communities in South Africa.

SENSORS

Gate to success

Rapid single-electron sensor developed in the UK holds promise for quantum devices

A European team in Cambridge has designed a sensor that can detect the charge on a single electron in the fastest time ever recorded.

Researchers at the laboratory where the electron was discovered in the 19th century have designed a sensor that can detect the charge of a single electron in less than a microsecond. The sensor, which was designed at Cambridge University's Cavendish Laboratory, could be used in quantum computing to detect information stored in a single electron's charge or spin, the team claims.

Known as a gate sensor, the device gets its sensitivity through coupling to a silicon nanotransistor that forces electrons to flow effectively in single file, the team explained in *Nature Communications*.

The new device is more compact and accurate than previous gate sensors and the detection speed of around a nanosecond is the fastest obtained so far for this type of system.

Devices such as ultra-precise biosensors are all predicted to work by using the properties of individual electrons. ***SN***

The VCCO is part of Dstl's Cyber Situational Awareness project

DEFENCE AND SECURITY

Operations centre set to protect key assets

Airbus takes charge of a system designed to shield the military against cyber attacks

BY JASON FORD

A system designed to verify and mitigate cyber attacks on military assets is being developed by Airbus Group Innovations.

Airbus Group Innovations will lead a 16-month study following the award of £1.4m from the Defence Science and Technology Laboratory (Dstl) to develop the Virtual Cyber Centre of Operations (VCCO), which is part of Dstl's Cyber Situational Awareness research project.

"Cyber situational awareness is a very difficult problem because, in the modern era, we have very complex digital systems that are interconnected," said Dr Kevin Jones, research team leader – Cyber Operations, Airbus Group Innovations. "I'm not just talking about information; I'm taking about assets – UAVs [unmanned aerial vehicles] and ISTAR [intelligence, surveillance, target acquisition, and reconnaissance] assets.

"As they are interconnected and highly complex, we have to be able to understand the whole domain, all of those assets within that domain and the types of attack that people are going to put against those types of assets."

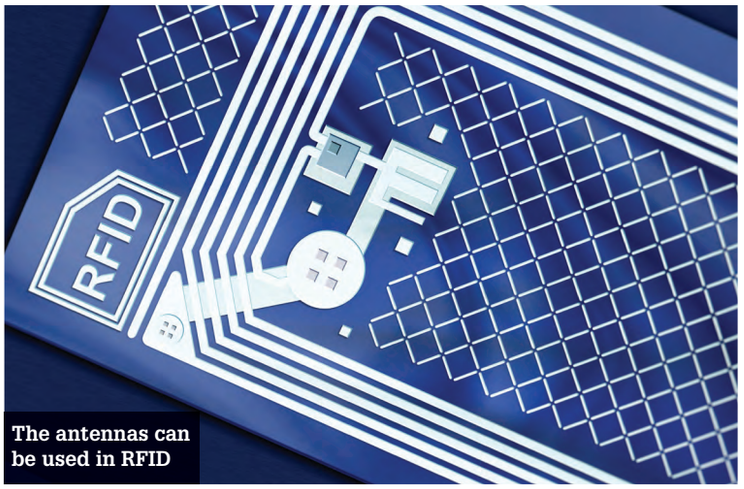
During the project, Airbus Group Innovations will work with MooD International and Xuvasi to develop a 3D virtual world to enable collaboration and shared situational awareness.

The VCCO project will show how virtual collaboration might give commanders a better understanding of how they are being targeted by cyber enemies on the battlefield.

Jones said: "If we think about a distributed network… I'm likely to have many cyber-security operation centres or many pieces of the jigsaw. How do I bring them all together? That's what VCCO will do. It will sit in the middle, [and] provide you with all the tools, all of the information you'd expect to see in a physical [cyber] security operations centre but in a virtual world," he said.

"In this environment, I could also have experts ready wherever they are in the world to help me solve my problems in real time," Jones added. "The advantage here of a virtual environment is that these people can come in to a live situation to a live cyber event and understand exactly what is going on as if they are physically present in that room."

The collaboration between Airbus Group Innovations, MooD International and Xuvasi follows initial research by each supplier, previously funded through cyber-themed competitions run via Dstl's Centre for Defence Enterprise.



The antennas can be used in RFID

COMMUNICATIONS

Antennas shrink to fit in computer chips

Researchers utilise thin-film materials

BY HELEN KNIGHT

Wireless antennas small enough to squeeze onto computer chips could be built thanks to research at Cambridge University.

The antennas – 10 to 100 micrometres in size – could be used in mobile phones, radio frequency identification (RFID) tags and the so-called Internet of Things. The research is published in *Physical Review Letters*.

Antennas are designed to work by converting electrical energy into electromagnetic, or radio, waves. These radio waves are then picked up and converted back into electrical energy by an antenna on the receiving device.

But while the electronics used in mobile devices are constantly shrinking, the antennas have remained bulky in comparison, said Gehan Amaratunga, professor of engineering at Cambridge University, who led the research team. "At the moment, there is no prospect of integrating the antenna onto a chip because it's just too big," he explained. "A typical antenna used in a mobile phone occupies around one quarter of the device's cover."

> **"Typical mobile phone antennas occupy a quarter of the device's cover**

To overcome this, the researchers investigated the use of piezoelectric thin-film materials such as gallium nitride and gallium arsenide. These films, which vibrate when a voltage is applied to them, are a type of dielectric, or insulating, material. Piezoelectric thin films are much more efficient at storing energy within a certain volume than the dielectric materials conventionally used for mobile phone antennas, according to Amaratunga.

But the researchers found that at a certain frequency, the materials also become efficient emitters of electromagnetic radiation, thereby becoming effective antennas.

They attribute this to a process known as 'symmetry breaking' of the device's electric field.

"This simply means that the energy of the electric field is changed in time or space," said Amaratunga.

By connecting only one end of the material to an electric signal and leaving the other end free, the researchers were able to break the symmetry of the field, generating electromagnetic radiation.

"If you excite the material from one end and leave the other end floating, then – as the energy builds and cannot be returned to a supply through another contact – it is released as electromagnetic waves," he said.

The work was carried out alongside researchers from the National Physical Laboratory (NPL) and Cambridge-based company Antenova.

MEDICAL

Shoulder injuries hang by a thread

Nanofibre trials are set for later this year

BY HELEN KNIGHT

A nanofibre thread designed for use in medical sutures could enter clinical trials later this year in surgery to repair injured shoulders.

The thread, dubbed Bioyarn, has been developed with a novel manufacturing technique by researchers at Oxford University.

They hope to begin testing it in surgery to repair torn tendons in the rotator cuff. Around 40 per cent of surgeries on this painful condition fail and the researchers hope that the thread will improve the success rate.

Nanoscale fibres are extremely porous and have a very high surface area by volume, making them excellent candidates for use in surgical sutures, tissue scaffolds and wound dressings, according to Nikolaos Chalkias, senior technology transfer manager at Isis Innovation, Oxford University's technology commercialisation company.

Until now, there has been no way to reliably produce very long filaments of the material, which would allow it to be woven into different types of fabric or medical devices.

Now the researchers have developed a technique to spin the fibres onto a moving wire, allowing them to stretch out very long strands. "We can effectively make a ball of electrospun yarn," said Chalkias.

The technology is based on conventional electrospinning, in which a solution is drawn through an electrically charged hollow needle onto a grounded target, in this case the wire.

As the solution is drawn towards the wire, it stretches out into a very fine fibre. Then, as the wire moves past the needle, the material attaches to it and is drawn along with it.

"Since the fibre does not stick fast to the wire, it can simply be peeled off using an automated machine," explained Chalkias. "We can then weave that thread into fabrics or into medical device materials like patches."

Thanks to their nanoscale dimensions, these patches can mimic the extracellular environment within human tissue, meaning that they should help support cell growth, according to Chalkias.

AWARDS

African innovation

Engineers gain recognition in new event

Technologies developed by African engineers have been named as finalists in the Royal Academy of Engineering's newly launched Africa Prize for Engineering Innovation.

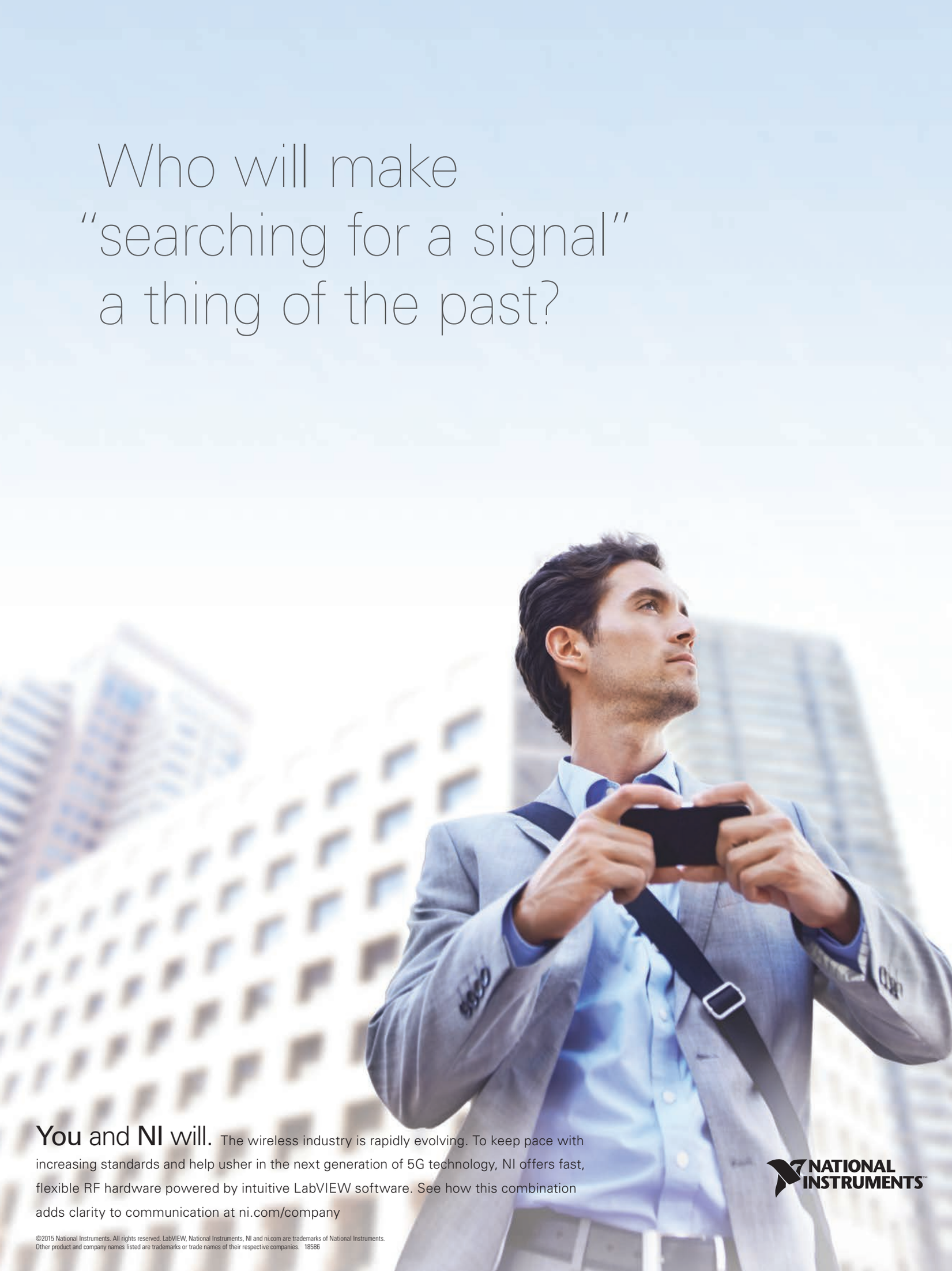
The prize – which is claimed to be Africa's biggest award for engineering innovation – was established to stimulate innovation in Sub-Saharan Africa and covers all disciplines from mechanical, civil and computing to biomedical, oil and gas, mining and electronic engineering.

The four finalists include South African engineer Ernst Pretorius, who has developed a fence-mounted security that warns owners of fires or intruders, and Tanzanian engineer Dr Askwar Hilonga, whose sand-based nanofilter is able to remove a range of contaminants from water, rendering it safe to drink.

Another finalist is Zambian innovator Musenga Silwawa, whose fertiliser applicator offers an alternative to manual fertiliser application for small-scale farmers.

The overall winner – to be awarded £25,000 – will be chosen after the finalists present their engineering innovations and business plans to the judges at a ceremony in Cape Town later this year. ***JE***

Who will make "searching for a signal" a thing of the past?



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NATIONAL INSTRUMENTS™

Follow the leader

Targeting specific leadership programmes at undergraduate level is necessary, says engineering professor Neil Hopkinson

We don't just need more engineers in the UK – we need more engineering leaders. And where better to find them than among our undergraduates? There are now plenty of excellent initiatives to get schoolchildren interested in science and engineering, and these are feeding through to increasing applications at degree level. Targeting more specific leadership programmes at undergraduate level is now needed. Those that walk through the doors of our universities signed up to a four-year master's in engineering, are all high-quality candidates, destined for a great career. But also among them are some exceptional individuals who have what it takes to play a leadership role in the sector.

To be honest, these individuals might rise to the top anyway – eventually. But as we know, the need for leadership is there; it makes sense to help them on their way as much as we can. When being interviewed for the new Sheffield Engineering Leadership Academy (SELA), one of our students described it perfectly. He said that being part of SELA would get him on the motorway to a leadership role; without it, he'd have to get there on the A-roads.

SELA is the first extra-curricular leadership programme in a UK university to cover all the engineering disciplines – unashamedly modelled on US initiatives such as the Gordon Engineering Leadership Program at MIT. The RAEng leadership awards also target undergraduates across the UK. This is an excellent scheme but, necessarily, has a limited reach. Running leadership programmes on campuses is a sensible solution to reach a critical mass and to enable time-pressured engineering students to engage more easily.

It is also in our interest to do it – and by 'our', I mean both UK plc and Sheffield University. We do believe the benefits to industry will be enormous – helping it to identify exceptional candidates and starting its leadership education early. But there's a benefit to Sheffield's Faculty of Engineering as well. We want to be able to identify potential future leaders in engineering research and enable them to assess if studying with us for a PhD is a worthwhile step for their career. Our undergraduates are taught by academics who are active in research, but they don't get experience of actually doing research until their final-year dissertation project. The SELA programme includes two summer work placements; these can be in research or industry.

Some individuals have what it takes to play a leadership role

> **"Running leadership programmes is a sensible solution to help students to engage more easily**

The needs of industry and academic engineering research are closely aligned. A 2011 EPSRC/Cambridge University review of international approaches to manufacturing research concluded that to compete globally the UK needs more engineering research leaders. The report looked at approaches to manufacturing research in the US, Germany, Japan, Sweden, China and Singapore that were significantly different to the UK and that could offer competitive advantage. It found the UK lagged behind these nations in aspects including the importance placed on the role of doctoral engineers in underpinning the manufacturing research base. The report stated that without close interaction between the research base and real-world manufacturing, the UK would not be able to compete in the new science- and technology-based industries of the future and that key to this interaction was having leaders with experience in both industry and research.

So what extra skills do we need to provide within a leadership programme and how do we identify the students who will benefit? At Sheffield, we define the attributes we want the SELA cohort to display now, the extra skills we believe they will need and how those will be taught. For example, we believe our future leaders need to be enterprising. For this, they need creativity, proactivity and the ability to problem-solve.

We look for evidence of this in a student's application to join SELA and in the interview. Once selected, SELA provides training in these areas through the initial boot camp that students attend and two group projects they undertake over the two years of the programme.

We've identified other leadership qualities in a similar way: good judgement; technical and academic ability; the ability to inspire others, to create and communicate a compelling and purposeful vision of the future; flexibility; self-awareness of your strengths and weaknesses and a willingness to learn; and finally personal vision, ambition and courage. SELA seeks to enhance these attributes through work placements, skills workshops, group projects, guest speakers and mentors.

Sheffield University may be the first in the UK to set up this kind of engineering leadership academy, but given the advantages these schemes bring for all involved, don't be surprised to see other institutions follow suit.

Neil Hopkinson is professor of manufacturing engineering at Sheffield University and director of the Sheffield Engineering Leadership Academy

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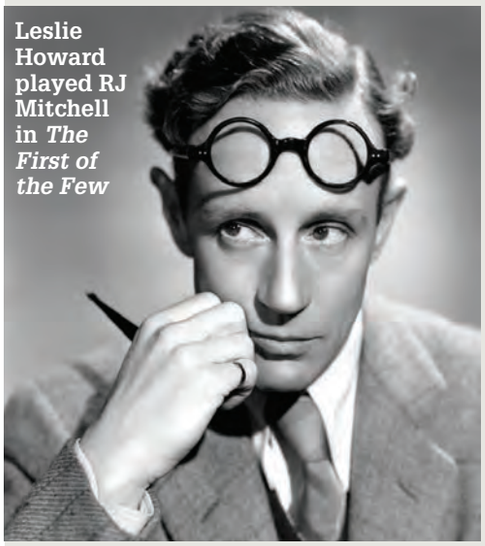
What makes an engineering hero?



Leslie Howard played RJ Mitchell in *The First of the Few*

Our piece on recent depictions of engineers on stage and screen generated lively debate and some suggestions

What about Alan Turing in *The Imitation Game*: again portrayed as a lone genius responsible for creating the Bombe, when in fact he worked on a team developing an original Polish invention. And there was *Castles in the Sky*, depicting Watson-Watt's role in the invention of radar. Free thinking, but a team player, the drama showed him as far warmer than Turing and so a far better role model. Pity someone couldn't commission a drama on the role of Tommy Flowers and his Post Office team in the development of the first computer, to counter the image of engineering conjured up by *The Imitation Game*.
Anonymous

Victims of your own success once again, as it's the engineer's accomplishments that are celebrated rather than their characters. What you need is XGineers or *Strictly Come Engineering* to promote your image as team people, not loners. And I am serious here, the technology engineers are promoted as characters and quirky individuals with cult followings – the late Steve Jobs being the best technology 'engineer' at the PR craft.

Although, to be fair, mechanical engineering always had the guy who presented *Traction Engine and Industrial Chimney Weekly* on the BBC for years, and most of you gathered round the telly agreeing that "them were the days".

No wonder the youth of today aren't interested in engineering, while there are glamorous and interesting things such as abseiling or base jumping off the biggest bridge in the world you have just constructed; engineers would rather discuss rivets or welds or something equally tedious.

Even architects are outstripping you with *Restoration Man* etc, showing people how to make something modern instead of seemingly wallowing in the past.

The boring presentation of engineers in film and media is because that's the way you seem to the rest of the world. And little wonder when the best some engineers can do is tediously slag off the higher-education system and art students, who do a damn site better job of selling their profession than engineers do engineering.
David Redfern

Two brilliant depictions include: *The Challenger Disaster*, following Richard Feynman's quest to get to the truth, and *The Wind Rises*. The latter is a Japanese animation depicting the life of a talented aeronautical engineer, Jiro Horikoshi, who was the key driver behind the design of what became the Mitsubishi Zero in WWII. It shows hours of thought and draughting required at the expense of a personal life. It includes a gritty depiction of how he had to navigate his way through internal and world politics to achieve his personal goal of perfect flight. There is memorable scene where he convinces his team of the possibility, even with the restricted resources available at war time. A film quite unlike any most mentioned in these pages.
Andrew Codd

inyouropinion

Divestmentdiscussion

Our poll on the *Guardian*'s campaign to persuade charities to divest from petrochemical interests promoted some strong feelings.

■ It is not really investing. The only money that reaches the company is during an IPO. After that, the 'invested' money goes to another gambler (i.e. an investor). In my humble opinion, better investments would be in cost savings – insulation of buildings, for example. If surplus money needs to be parked somewhere to prevent it being taken by government, there are probably better places than engaging in the snowball system called the stock exchange.
Ralf Muller

■ The only effect of divesting is to give people a warm feeling that they've done something. Maybe then they won't have to worry about the damage they cause to the environment when they burn the oil. It's not going to affect the oil majors, and if it did Gazprom and Aramco etc would be more than happy to boost supply. At best, it achieves nothing. At worst, its a distraction from the efforts we all need to make to reduce CO_2 emissions.
Alex

■ I was reading recently (assuming it is correct) that our government is still spending billions each year, searching for oil. This would perhaps be better spent on renewables. With oil being a large and integral part of the economies of so many countries, I would have thought a slow gradual natural decline in usage and share prices, as renewables take over, would be the safest scenario – rather than trying to change things too quickly by making oil a dirty word.
David Hogan

Nuclearsafety

A recent news story about a method of disposing of nuclear waste in 5km-deep holes attracted a few suggestions.

■ This sounds like a really cost-effective way to dispose of nuclear waste. (Hopefully, though, valuable spent fuel won't be disposed of, but will be recycled). Existing disposal concepts are always opposed by locals, even if proven to be safe. This could also be done in very remote locations where there are no locals; somewhere like St Kilda, or even using an oil platform.
Alex

■ The problem with remote locations is the inherent risk in getting the waste to them.
Editor

■ Such final disposal of these materials may well be considered a mistake in the future when they can be used as fuel in new reactor designs. The total quantities are quite small; as was said, above six 60cm boreholes is enough for Britain's stockpile of these materials.
Roger

■ And yet when I tried to bury all that old asbestos off my garage roof in a ditch behind Sainsbury's, I got a £400 fine and was bound over by the magistrate. As usual, it's one rule for Sandia National Laboratories and one rule for the rest of us.
Prof John Fortescue

■ Why dispose of it at all when the new generation of molten salt reactors where this 'waste' is actually the fuel is just around the corner. Sounds silly to go to this much trouble to throw away a valuable fuel resource, and the new reactors are so safe, I would not hesitate to move in down the road from one.
James Stewart

thesecretengineer

Engineering didn't have much of a mention in the run-up to the election – perhaps because it's one thing the parties agree on

I suspect that, no matter wherever in the world it is you're reading this, you will know that in the UK Her Majesty's Parliament has been formally (although sadly not literally) dissolved and the bun fight for power has run its course.

I thought I would take a look at what the major parties are offering for us engineers. A quick search of "[political party] policy engineering" revealed that they are all concerned about the number of young people entering our profession and each has their own idea regarding how to combat it.

Interestingly, none of the solutions are actually driven by pure political ideology. I had hoped to find that the Tories would be snatching children's dinner money, Labour confiscating the gold of the nobility and the Liberals doing whatever it is that Liberals are supposed to do – but no. It all actually seems sensible if universally lacklustre and devoid of a grand vision. Of course, it could be that they are all spending their time on lesser matters such as the economy and employment?

The first thing that springs to mind is that as engineers there is no one party offering us anything substantial. They all make the right noises but we are obviously not the section of the electorate being targeted. In fact, the impression is that they see what we bring to our country and economy as being of no interest to any of the electorate whatsoever.

Looking back, the politicos are fond of having their photo taken in engineering environments but they then usually talk about non-engineering issues. Generally this is the latest embarrassment to befall their own party; be it a senior member going off message, some newly discovered hole in their policies or, in the case of UKIP, a candidate being expelled for unsavoury views…again.

So our choice of party comes down to either our in-built leanings or matters outside of our profession, but this need not be an entirely bad thing. If the parties are generally in agreement, then why not try to get them working together to implement all of their ideas to help us out? We could lobby our institutes to lobby whichever shower actually ends up in power and then, even if we don't get much, at least we will get something.

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

Jobsalaries

We received several opinions on an article about reports showing the number of engineering jobs in the UK rising, but salaries stalling

■ I think we need to be careful of opinions or 'analyses' such as those that Lucy Care offers regarding the supposed fragility of our 'interdependent world'. The example given of the 2008 financial crash (which she admits was only partly triggered by 'interdependence') and the perception that we have a fragile society may sound modern. Also 'systems' types of analysis are obviously attractive to engineers (who then naturally offer themselves as experts to solve these problems) because few others supposedly can. This still forgets that other moral cultural and political issues are not so susceptible to these kinds of analysis. I don't totally reject some of the above analysis, but I think that by highlighting the assumed 'fragility' of society as a 'system' we can quickly end up with a fatalistic approach to the future, close to the greens, whereby things are best largely left alone – or only changed in small incremental ways. Bold, ambitious experimentation then goes out of the window and we end up with a conservative take on the future where any significant engineering-related impact on the planet is curtailed. Another approach to the concern with 'fragility' may be to consider that it is a reflection of our leaders' inability to 'boldy go' anywhere over the past 25 years since the break-up of the Soviet Union, which was seen as giving them the freedom to do so.
Paul Reeves

■ It doesn't pay if you tell anyone how things work. People will still believe in double-dip curves of the stock market as the cause of everything. If you see something coming, prepare yourself. Keep some cash in the house for when this bank or that bank has a computer glitch and no ATM works. Keep your money in different banks. In volatile times, anything can and will happen. You need to have a buffer or storage to cover shortages, just like a good circuit has capacitors and coils to remove the volatility and provide a stable power supply. It's called risk management.
Anonymous

Have your say, visit us at **theengineer.co.uk**

A real transformation

A few examples of modern engineering paint a very promising picture of the future of our health service

For the past month or so we've heard seemingly endless discussions about the NHS, from what's devolved and what isn't to current challenges and promises for the future. While talk continues around top-down reorganisation and the funding crisis, a quiet engineering revolution is going on. A number of things have struck me recently as showing the way in which our health service will actually be transformed.

At University College Hospital not far from the EngineeringUK offices, an apparently small change to the doors to wards highlights the potential impact of innovative approaches to significant problems. The 'hygiene handle', as I believe it's called, automatically dispenses alcohol gel when you hold it to open the door. A small change that can stop the spread of disease and really save lives. Then there's the toothbrush that can analyse DNA to detect the onset of cancer or diagnose Alzheimer's disease. That's the type of innovation that has the potential to transform how health professionals monitor and screen patients.

"I was most interested to learn about the new members of the workforce operating in underground tunnels, not least because they're not human

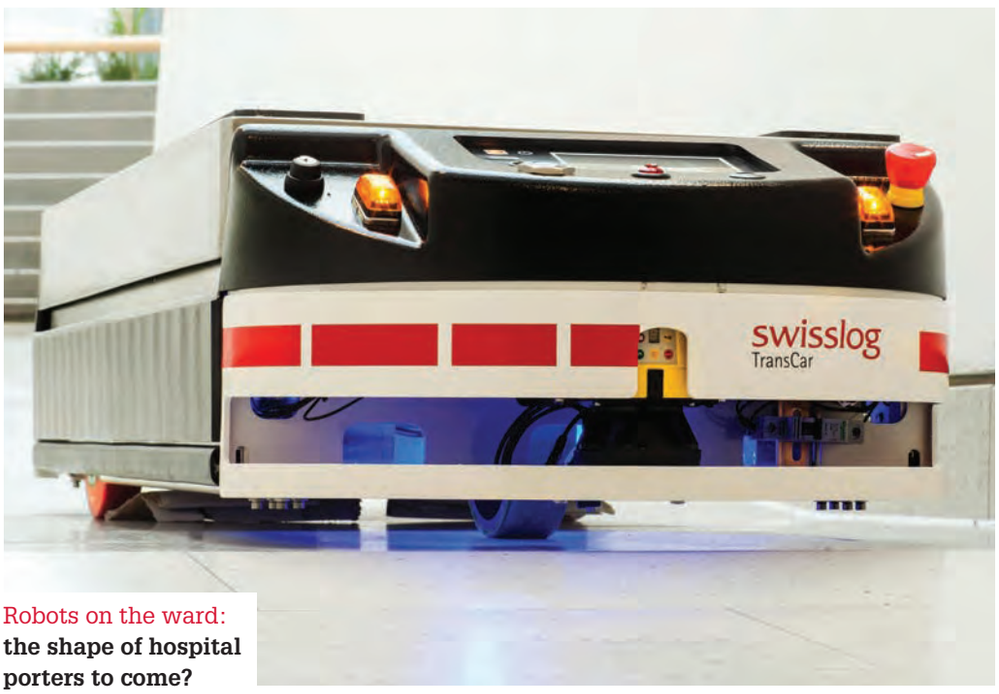
That transformation is also being seen in terms of what is available over the counter. Now on sale in the UK is a DIY HIV test that is reportedly easy to use and gives results in 15 minutes. Latest research estimates that around 26,000 people in the UK are unaware they have HIV, so again you can suppose that ultimately this too will save lives.

The new, state-of-the-art South Glasgow University Hospital boasts some of the latest innovations in patient care. I was most interested, however, to learn about the new members of the workforce operating in underground tunnels, not least because they're not human. The hospital has a fleet of more than 20 'robot porters' transporting linen, food, medical supplies and waste around the hospital.

These autonomous vehicles are not the driverless cars that we might generally associate with the term, but they are working in our hospitals right now and in spite of the current price tag they are no doubt destined to become much more commonplace.

This is not only what modern medicine looks like; it is a reflection of the possibilities offered by modern engineering. These examples effectively paint a picture of the future, where our health service is viewed in terms of modernisation and real life applications, investment and transformation, rather than the rhetoric we've all been hearing.

These are all great, but I wonder whether smarter procurement is the missing tool that could transform extraordinary innovations in one or two places into a globally relevant powerhouse for growth.



Robots on the ward: **the shape of hospital porters to come?**

Paul Jackson is chief executive of EngineeringUK

POWER FROM ABOVE

Britain's biggest overhead crane and hoist manufacturer, Street Crane Company, now has ten cranes installed across different sites supporting the Crossrail project. The 40 tonne double-girder Goliath crane shown here is used to remove spoil during excavation of the shaft and lower tunnel segments at the Western Ticket Hall site adjacent to Oxford Street.

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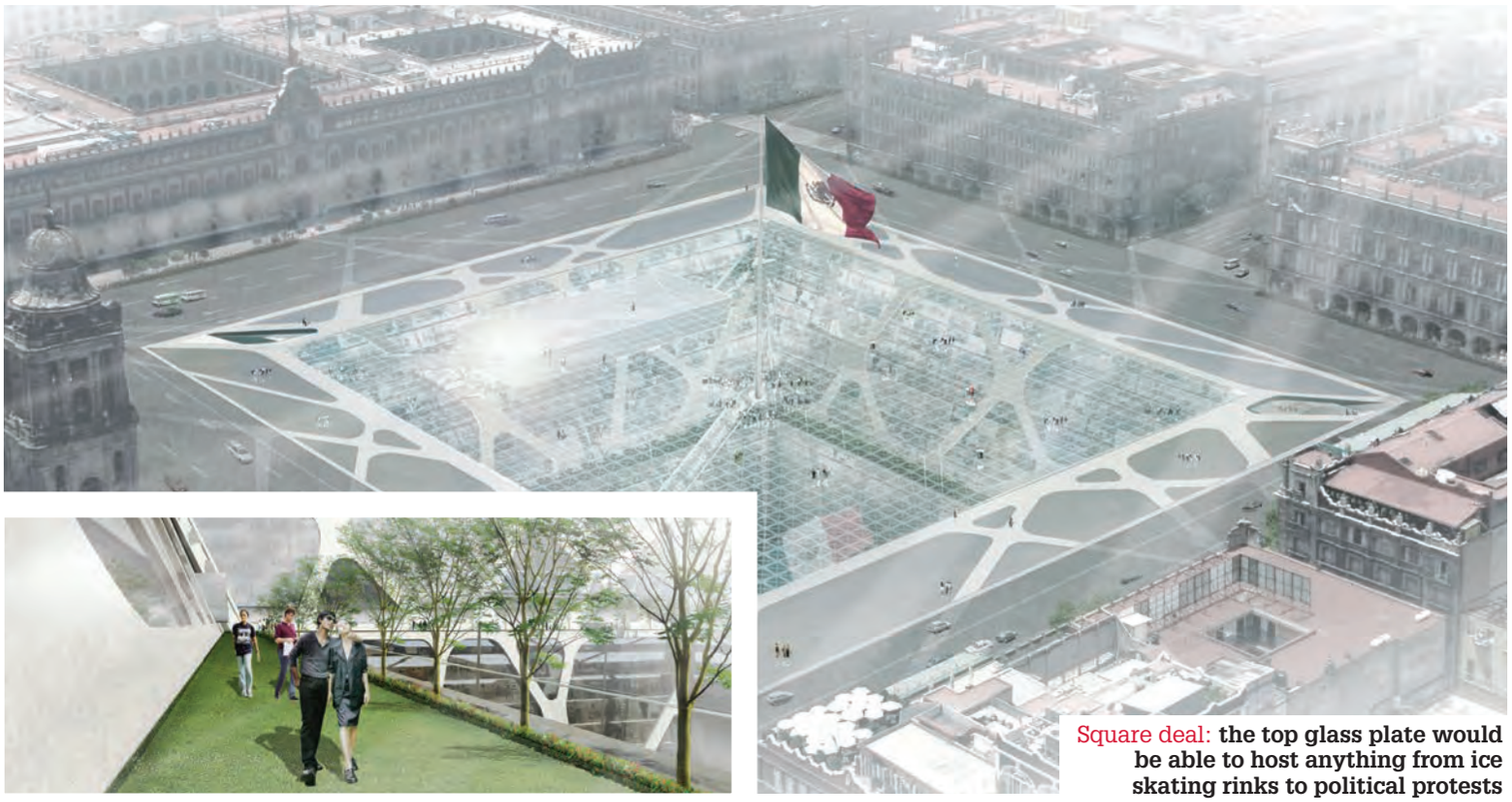
The only way is down

Could underground engineering help solve cities' overcrowding problems? Stuart Nathan reports

Culture is replete with the concept of civilisations living underground. It crops up in everything from HG Wells to Elizabeth Beresford. Of course, Wells' underground dwellers were mutated cannibals and Beresford's were pointy-nosed mammals with an excellent grasp of English and an ecological bent, but the exploration and exploitation of the realm below the surface has been a trope for decades.

Now, the lure of subterranean space is growing, especially in cities where land is at a premium and building becomes ever-more difficult. And while travelling underground is



Square deal: **the top glass plate would be able to host anything from ice skating rinks to political protests**

part of everyday life for millions in cities around the world, other uses for underground space are becoming ever-more innovative; and more may well be to come. The challenge for engineers will be how to construct these underground spaces, make them suitable for the uses earmarked for them and maintain the conditions inside them to keep their contents and users safe and comfortable.

There are many reasons you might want to go underground. Space is an obvious example. In crowded established cityscapes such as London or New York, or the chaotic, fast-growing cities of India and East Asia, there just isn't much space on the surface. Taking a small ground footprint and building upwards into a skyscraper, the choice for maximising space since the 1920s, has its limitations. In many cities, the planning regimes are increasingly frowning on ever-higher skyscrapers, and even in the Middle East and East Asia, where it seems easier to get permission to build high, there's a practical limit to how high you can go. Hollowing out the space under the ground could be a way to get around these problems, as it gives more scope to expand laterally, rather than linearly. Go wide, not deep.

Another factor might be an inhospitable outdoor environment. In Canada, the northern states of the US, Scandinavia and Eastern Europe, the winters are so bitterly cold that building underground, where the environment is stable and insulated by the surrounding soil and rock, is an attractive prospect. Similarly, nearer the Equator, subterranean spaces could offer an escape from steamy humidity; and in heavily industrialised cities with air quality problems, it could be easier to guarantee a healthy, breathable environment underground.

But sometimes it's just a matter of space. In Tokyo, for example, bicycle parking has been taken underground using a system devised by engineering firm Giken Seisakusho, which can store 144 bikes in a space just 7m wide. Bikes are becoming more popular in urban Japan, where air quality from traffic is a serious issue. But parking them is a perennial problem. Giken's solution, an anti-seismic parking system, takes the bikes underground and out of the way, with only a deposit system at the surface.

Under the ground is a cylindrical silo some 11m deep and 8m across that holds a racking system, arranged radially around a central mechanism that incorporates a lift system and a robotic placing machine that whisks bikes from the street-level kiosk (it's this that is 7m wide; the kiosk doesn't cover the whole area of the shaft throat).

Each user's bike is equipped with an ID tag attached to its front forks, with owners holding a matching smartcard. To use the system, the bike's front wheel is pushed into a slot on the surface kiosk; the placing mechanism grabs onto it, whisks it down into the silo and files it into one of the radial slots. To retrieve the bike, the owner holds the card up to a panel on the kiosk; the mechanism then works in reverse, locating the filed bike and bringing it back to street level; this takes an average of 13 seconds. The store can hold mountain bikes, electric bikes and bikes with front baskets or rear child seats.

"It's a formidable space-saving technique – imagine how much area would be needed on the surface for a bike park to hold 144 bicycles," said Haan Admiraal, chair of the underground space committee (ITACUS) of international tunnelling and underground space association ITA-AITES at a recent seminar on underground engineering at the Institution of Civil Engineers in London. It is built with a proprietary system developed by Giken that uses interlinking piles, pressed into the ground hydraulically to form the walls of the silo; the void is then excavated up to this wall. This is a low-noise, vibration-free, seismically safe system that causes minimal disruption to neighbours when installed, developed for the crowded, earthquake-prone region, and is also used for other types of construction.

For some applications, underground may just be the best environment. ITACUS vice-chair Antonia Comaro gave the examples of museums and art galleries. "Architects and engineers spend an inordinate amount of effort, time and money to design iconic, beautiful buildings, and quite rightly," she said. "But then they have to spend even more effort and money to devise ways to protect the priceless artworks they are to hold from sunlight and changes in the environment. The Paris Louvre had the idea to put its lobby underground, with the famous glass pyramid as its entrance; but it might well be that below ground would be the best place for the entire institution, and other galleries where light- and moisture-sensitive objects are going to be on display. You are starting from a default position of no light – the effort is spent on bringing it in and controlling it, not keeping it out – and the insulating effects of soil and rock help keep the environment very stable."

This is one of the rationales behind one of the world's most intriguing plans for a large building: the Earthscraper, which has been designed for a specific location in Mexico City by architecture practice BNKER Arquitectura (pleasingly, the company name in English is said as 'Bunker Architecture'). Best described as an underground skyscraper, the Earthscraper has museum space as an integral part of its concept. This is partly owing to its location.

Originally devised as an entry for an architecture competition, Earthscaper is designed for the city's largest public square – and, indeed, one of the world's largest – the Plaza de la Constitucion, known as Zocalo. Bordered by the city's cathedral, the National Palace and the city government buildings, Zocalo is a square 240m on each side, giving it a total area of 57,600m^2. It is a ceremonial space with a flagpole at its ->

centre that is raised every morning and lowered every night, and is a significant area in Mexico City's public life.

Which makes it slightly incongruous that the plan for the Earthscraper involves digging it up; especially as Mexico City has a long history, being the site of Tenochtitlan, the capital of the Mexica and Aztec civilisations, and a correspondingly rich archaeological record, parts of which would be showed off in the structure's museum space. However, the land pressure on the city is extreme. "New infrastructure, office, retail and living space is required but no empty plots are available," said BNKR founder and chief executive officer Esteban Suarez. "Federal and local laws prohibit demolishing historic buildings and, even if this was so, height regulations limit new structures to eight stories. So we have a massive programme of hundreds of thousands of square meters and nowhere to put it. This means the only way to go is down."

"In creating a pleasant environment underground, we hope to convince the sceptics of our scheme's viability
Esteban Suarez, BNKR

Earthscraper is designed to be "the antagonist of the skyscraper". It is an inverted pyramid 300m deep – as deep as the Shard in London is high – whose base would occupy almost the entire area of Zolcalo apart from the roads around the edge. The base would be covered with a thick glass sheet to allow Zocalo to still be utilised for its current uses, while still allowing light to penetrate into the void at the centre of the structure, which will act like an enormous lightwell for the structures arranged around the walls of the pyramid.

The pyramidal form is not coincidental. If it were housed in a simple vertical shaft, the walls would tend to cave in and would need enormous supporting structures to prevent a catastrophic collapse. Sloping the walls inwards on all sides means they are more self-supporting, Suarez explained. It's also a matter of concern that Mexico City is in an active earthquake zone, but again the pyramid is a logical choice. "Because its structure must already resist the lateral forces of the surrounding earth, it would be especially strong against the lateral forces of an earthquake," Suarez said.

With the 'buildings' sections of the Earthscraper lining the walls of the pit, natural light can penetrate down into its depths, although the plans include a fibre-optic system to illuminate the deepest levels; vents in the top sheet would also allow natural ventilation. "We hope that in creating a pleasant environment underground we would convince sceptics of the viability of our scheme," Suarez said.

The floors nearest the surface would be museum space, with retail developments below that, then residential, and office space at the bottom. The top glass plate – which we hope will be frosted in some way or only the boldest would walk across it – would be able to host anything from Christmas skating rinks to major artistic performances, religious gatherings and political protests. "It preserves the iconic presence of the city square and the existing hierarchy of the buildings that surround it," said Suarez.

In engineering terms, one of the biggest challenges would be water. The lowest 165m of the pit would be below Mexico City's water table, and therefore effectively floating on mud. This would necessitate a "greater investment in structure" than a skyscraper, making it about 30 per cent more expensive. The cost would require government intervention, with tax breaks for developers similar to those that helped finance the new buildings on London's Isle of Dogs.

For the moment, however, the Earthscraper remains an intriguing and ingenious concept, a potential space to be watched. For real underground activity, a city much further north shows a way forward.

One of the biggest stumbling blocks with building underground is what's already there. Whether it's the basements of buildings, sewerage systems, electrical infrastructure or existing tunnels for roads, subways and underground railways, cities without an underground hinterland of some sort are rare. "You need to have accurate and reliable surveys of the existing situation," said Martin Knights, senior vice-president for earth engineering at contractor CH2MHill, "and some sort of overarching plan of what else you want to fit in and how it's supposed to be used."

Leading the way in this respect is the Finnish capital of Helsinki, where the local population love outdoor life but, for most of the year, can't indulge in it without risking frostbite. The city has an underground masterplan that governs all of its subterranean activities, which are extensive: underneath its central park can be found a 100-yard-long lake that can hold nine million gallons (41 million litres) of icy Baltic water, which is used to cool the city in the summer (when temperatures can reach 30°C). Conversely, the city also has a huge underground heat pump system, which recovers thermal energy from wastewater and diverts it into domestic district heating.

Elsewhere under the city is a running circuit, an ice-hockey hall, the Itäkeskus swimming pool, the Temppeliaukio Church and a shopping centre. A series of light wells dotted around the surface light up the subterranean spaces, whose volume adds up to some nine million cubic metres, with 400 separate facilities linked by tunnels, and the master plan has another 100 locations earmarked for future resources. There are also plans for an 80km undersea tunnel linking Oulo in northern Finland with Helsinki, to create an economic 'twin town'.

But in many cities, the main reason to go underground is the same as it has been for more than a century: to get roads off the surface, relieve congestion and open up surface ground for new uses. One example is Boston, Massachusetts, where a project known as Central Artery Tunnel or the 'Big Dig' took an elevated highway that was considered a blight to the city below ground and constructed a new tunnel under the harbour. Further west, Seattle, Washington, is attempting to bury an the Alaskan Way overpass, which is old and decaying. This is not going well, with the tunnel boring machine stuck 10 per cent of the way through a 1.7-mile dig for more than a year.

In the UK, meanwhile, two major tunnelling projects could transform west and south London beyond recognition. CH2MHill is involved with feasibility studies to turn the Hammersmith Flyover into a tunnel. Another study is looking at the possibility of burying the South Circular Road. In a £30bn project that includes a tunnel on the North Circular at Brent Cross aimed at improving facilities for cyclists and pedestrians at ground level while also improving air quality as London's population and therefore its traffic continue to increase.

Into the deep: **underground space can include swimming pools, bike stores and churches**

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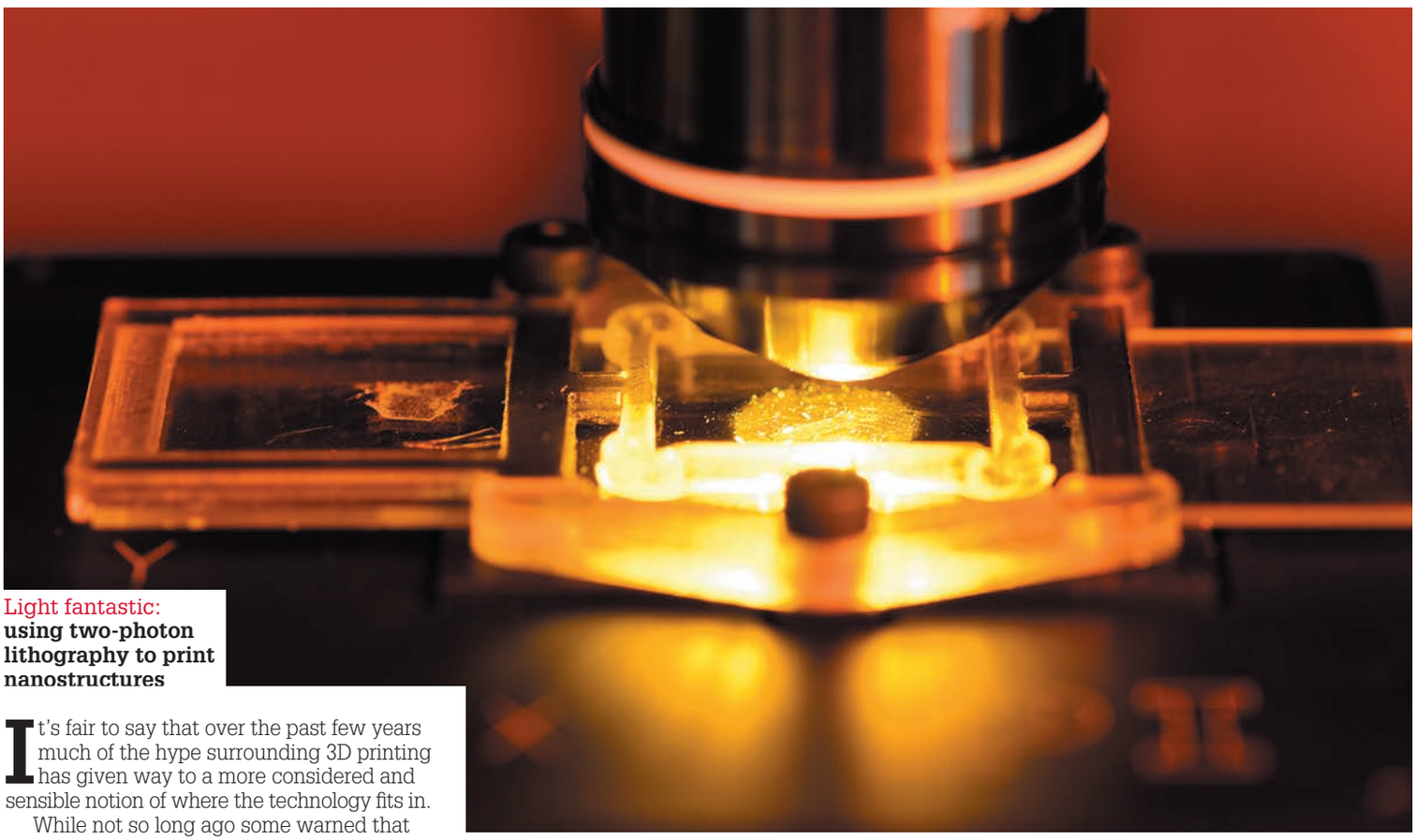
Added functionality

UK-led advances in 3D printing could one day lead to techniques able to produce entire electronic devices in one shot. Jon Excell reports



Light fantastic: **using two-photon lithography to print nanostructures**

It's fair to say that over the past few years much of the hype surrounding 3D printing has given way to a more considered and sensible notion of where the technology fits in.

While not so long ago some warned that so-called additive techniques would usurp incumbent manufacturing processes, today they are increasingly seen as complementary: another tool in the toolbox.

But according to Prof Richard Hague, director of the EPSRC centre for additive manufacturing, fundamental breakthroughs are on the horizon that could ultimately help realise some of the more exotic predictions that have been made for the technology.

Based at Nottingham University, Hague's 70-strong team of researchers is making something of a name for itself in one of additive's most exciting vanguards: the field of multifunctional 3D printing, or 4D printing as it's sometimes called.

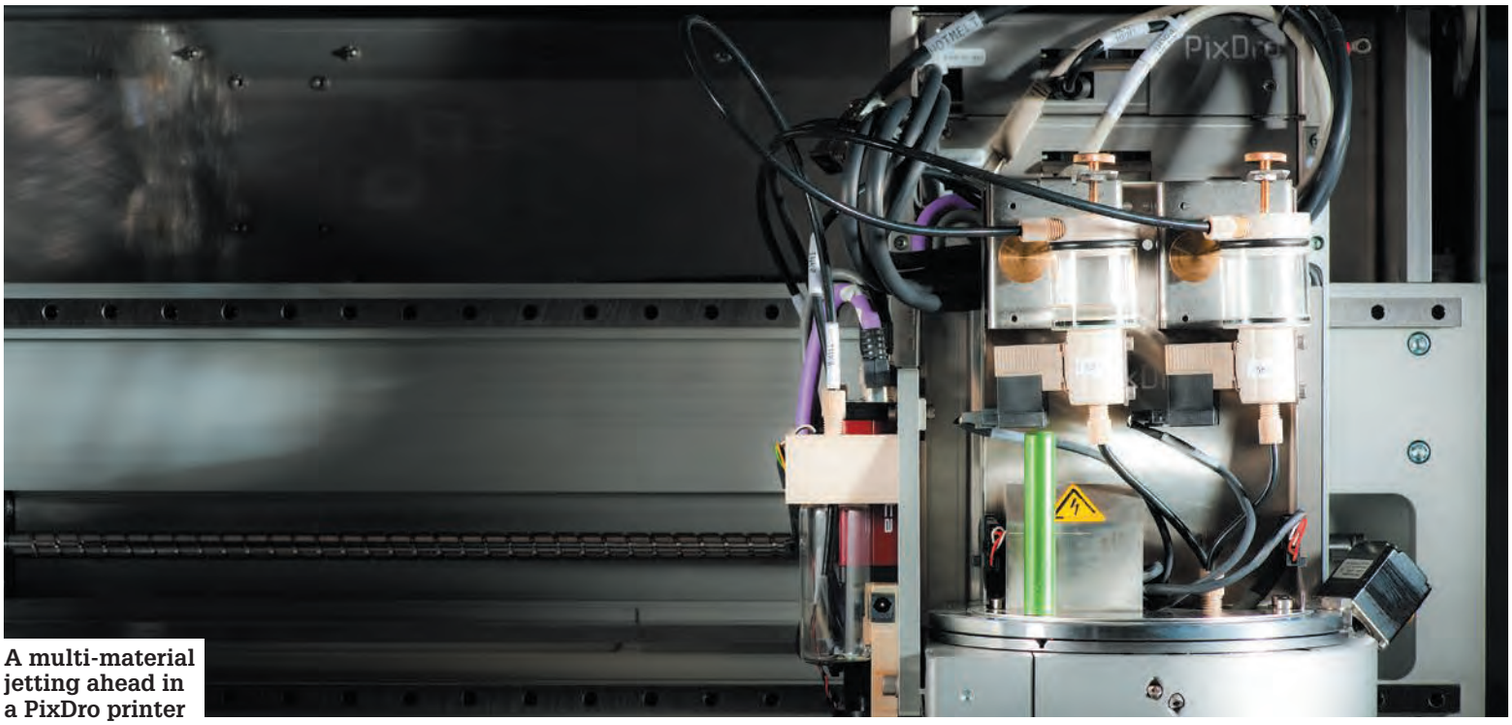
While existing systems typically use just one material, the idea is that multifunctional printers will produce fully functional components from multiple materials, both metals and plastics. It sounds fanciful, but the group has already made significant progress and such techniques could, it is believed, one day enable manufacturers to print entire electronic devices – such as mobile phones – in one go.

"We're not just making clever shapes but we're making them do something." he told *The Engineer*. "We're looking at next-generation multifunctional additive manufacturing, not just printing single materials but putting conductives or pharmaceuticals in the structure."

Hague and his group have a long track record in the field. Before setting up the EPSRC centre just more than two years ago, he led Loughborough University's Additive Manufacturing research group, which has itself made a number of significant advances, including the development of software aimed at helping designers to exploit the full advantages of additive techniques.

But the feel and purpose of the Nottingham facility is very different.

Where the Loughborough lab was home to a large group of engineers and numerous chunks of recognisably industrial equipment, Hague's current home looks more like a pure science lab. Mechanical engineers are outnumbered by white-coated chemists and physicists, while the benches and worktops are adorned with a variety of unusual looking experimental systems. ->



A multi-material jetting ahead in a PixDro printer

It is, said Hague, "a very different beast" and the result of a deliberate decision to step back from the industrial coal face and concentrate instead on advancing the underlying materials science, something that he feels has been lacking in the past, and that has potentially held back the technology. "People working in industry are doing really great stuff but I think historically there hasn't been enough science and basic understanding," he said.

Hague admits that stepping down the so-called Technology Readiness Levels (TRLs) to focus on technology with less immediate commercial relevance is an unconventional move, but believes that in the long term the benefits for the technology, and for the UK, could be significant.

"A lot of the original systems – stereolithography, etc – were developed in companies and all the development and IP was held by those companies," he said. "Universities would buy the systems, work on new materials, clever designs and all that kind of stuff, but in terms of the basic processes themselves all the IP is held overseas. One of the reasons we wanted to go down the TRLs was to develop our own IP for the UK, exploit that and take it forward, and then canter back up the TRLs later on."

> **"With jetting technology, you can selectively deposit different materials**
> Prof Richard Hague

Showing *The Engineer* around his state-of-the-art lab, Hague's breezy enthusiasm makes it sound like it's going to be a walk in the park. "Build a structure, build a function, print it all in one go and off you trot," he said. The reality is that his team is entering largely unchartered territory, and there are some major technical challenges ahead.

Much of the group's research is based around advanced jetting technologies rather than the powder-based sintering techniques more familiar to industry. "With powder-based technology, you're basically laying a whole layer of powder, and there's no differentiation of materials on that layer," explained Hague. "With jetting, you can selectively deposit different materials."

The advantages are obvious, but one of the key challenges is actually getting the material out of the jetting head. The water-like viscosity required to achieve this, explained Hague, means that conventional polymers, for instance, are unsuitable. The group therefore spends a lot of time tweaking the properties of materials: one of the reasons there are so many chemists in the department.

Another potential solution to this problem is a technique known as reactive jetting, which, rather than jetting polymers directly, enables them to be created at the point of deposition. "Because some polymers are too viscous ->

indepth It's not all about jetting

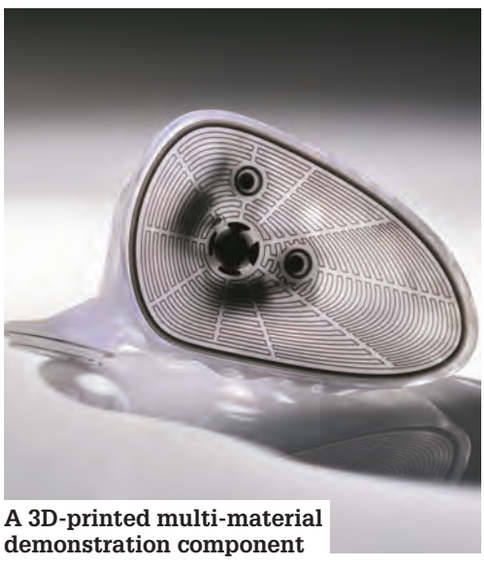
Using a technique known as two-photon lithography, the Nottingham team hopes to pioneer the production of nanoscale multifunctional components.

Tucked away in a quiet side room of Hague's laboratory, a technique is under development that could enable the production of functional 3D components that are smaller than a grain of sand.

Like conventional stereolithography, the process, which is known as two-photon lithography, uses light to cure a liquid resin. However, in this case the resin is engineered so that the curing reaction can only be kicked off by two photons of light. This enables extreme levels of precision and, Hague said, makes it possible to produce nanoscale structures at high resolution in comparison with standard additive manufacturing methods.

This is challenging in its own right. But the team has also thrown optical tweezers into the mix, essentially a laser-based technology that can be used to place individual particles at particular sites and tailor the properties in specific areas of the structure. "For instance," said Hague, "by embedding gold and silver particles in a particular area, you can tailor conductivity to make devices such as sensors."

Able to produce structures as small as 150nm, the system is expected to have applications in areas such as optics, metamaterials and biological constructs.

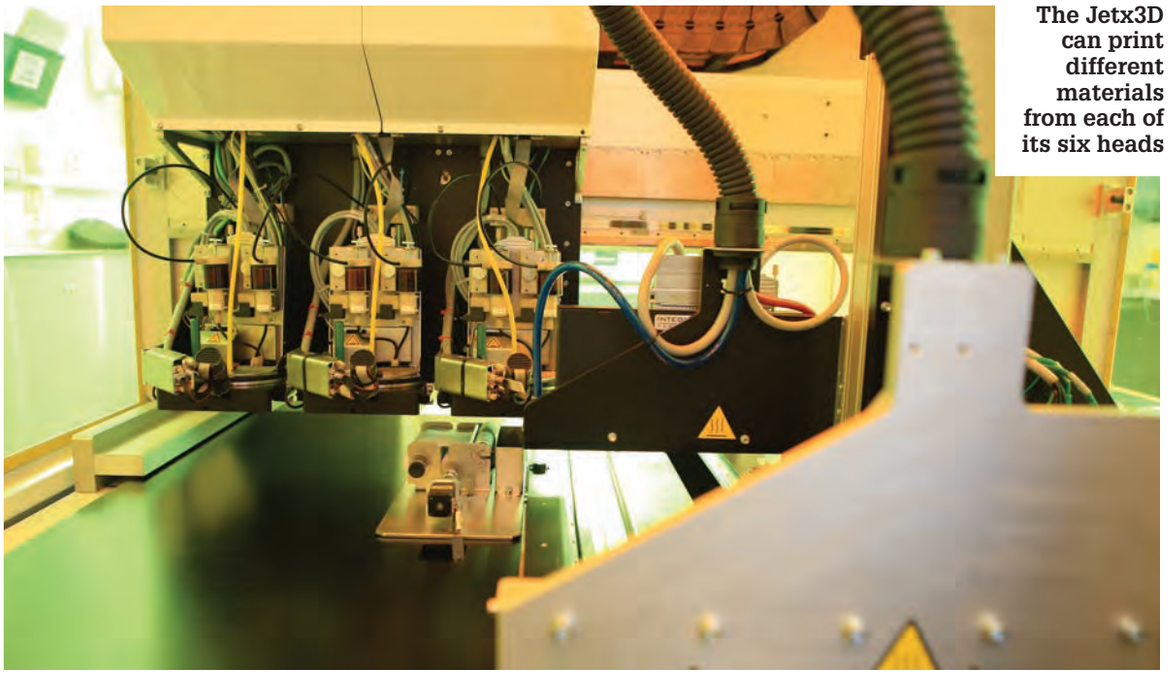


A 3D-printed multi-material demonstration component

indepth Drug delivery

The pharmaceutical industry is eyeing up the potential of multifunctional printing.

Despite the fundamental nature of the team's work, there is nevertheless a high level of industrial interest, and some of it from quite unexpected quarters. Indeed, while the centre's focus on printed electronics remains a major driver, it is also undertaking work for the pharmaceuticals industry, which, said Hague, is very interested in the 3D printing of drugs. "At the moment, drugs are banged out in the gazillions and you might want to do lower volumes or localised production," he explained. What's more, multifunctional techniques could also enable the properties of drugs to be altered. "You might also want to have different drugs at different places within the pill that elute at a different rate."



The Jetx3D can print different materials from each of its six heads

> **"Currently, all the printed electronics stuff is done with nano-flakes of silver that are loaded into a carrier material**
> Prof Richard Hague

when polymers [you can't melt them and then jet them], you might want to jet the monomers, which are often very fluid. You can jet two monomers and a catalyst and at the point at where they drop together you can get in-situ polymerisation," Hague explained.

Meanwhile, the quest for new 'jettable' materials is a painstaking and complex process in which different formulations are trialled and qualified on a range of systems of increasing cost and complexity before finally being trusted on what's currently the lab's ultimate machine: a multifunctional £1m testbed known as Jetx3D.

Purpose built for the centre by Dutch inkjet specialist Roth and Rau, the machine, known internally as 'The Toucan', is effectively a 3D adaptation of technology originally developed for 2D-printed electronics. Specially commissioned by Hague's team, the system has six piezo-electric print heads each equipped with 128 nozzles and can jet a range of materials, including conductive materials such as silver and other metals that are deposited within a carrier material.

It is a unique piece of equipment, said Hague, literally the only one of its kind in the world, and it's expected to help drive some major breakthroughs in multifunctional printing. However, the team is now excitedly awaiting the arrival of an even more advanced piece of equipment that will take the ability to jet metal to the next level.

The Metaljet machine, which is being developed for the group by Dutch mechatronics specialist Demcon, is based on technology developed by yet another Dutch firm, Océ, a jetting specialist owned by Canon. Océ's technology centres around a highly innovative drop-on-demand print head that works at up to 1,800°C and is capable of directly depositing high-temperature metallics in 3D.

Able to jet different metals from its four printheads, the new system is the first of its kind in the world, and, according to Hague, represents a major step towards the dream of 3D printing real electronic devices. "Currently, all of the printed electronics stuff is done with nano-flakes of silver that are loaded into a carrier material that you deposit and then evaporate off the carrier materials. This is very different. Instead of depositing particles suspended in a carrier solvent, it is actually jetting the actual bulk metal and so conductivity is not compromised and no secondary processing is required."

But despite the primary focus on exotic techniques such as this, Hague is also keen to build on his group's hard-won expertise in more established areas of additive technology. To this end, he and a number of colleagues have established Added Scientific, a spin-out company aimed at helping organisations without their own corporate research laboratories to build up their competence in additive techniques.

Since its launch, and in stark contrast to the difficulties Hague had enthusing industry about additive earlier in his career, the company has been inundated with work. "The kind of companies we work with now – 10 years ago I would have bitten your hand off," he said. "We're flooded with companies, and we don't want to turn away the industrial interest. We want to have the industrial interest so we can take through the multifunctional stuff in a few year's time."

This high level of interest is a sure sign that additive is becoming more and more of a mainstream process.

But is it really any closer to becoming the silver-bullet process that some claim will fundamentally reshape manufacturing?

"I would like to say that 3D printing could be used for everything," said Hague, "and we push at a research level that we want to use [it] to do everything. But in reality you're going to have to do some post-processing and some joining with other technology. Generally, additive will be a tool in the toolbox and it won't be used to make absolutely everything of every component ever – we will be able to make systems on these additive processes but whether everything in the phone, car or plane be 3D printed? Probably not. It's going to be used where appropriate."

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SCHUNK

Driving force

rob rickell

President, GKN Driveline

Education

- **Lincoln College of Technology** – OND in Engineering
- **Trent Polytechnic** – BEng Mechanical Engineering
- **Loughborough University** – MEng Engineering design

Career

- Since joining GKN in 1984 as a product engineer in Birmingham, UK, Rickell has worked on a variety of projects at the company's facilities in the UK, Italy, and Lohmar, Germany, and managed GKN Driveline's global Toyota account.
- Previously, he was senior vice-president of global engineering for GKN. He has played a key role in ensuring the sustainable growth of GKN through the development of countertrack constant-velocity-joint technologies; being a key influencer in the decision to grow the AWD business; and positioning GKN as an e-drive hybrid electric systems developer.
- Rickell is a fellow of the Institution of Mechanical Engineers and the Royal Academy of Engineering.

Rob Rickell is at the helm of a company that has grown into an automotive business supplying complete all-wheel drives. Stuart Nathan reports

It is a fact that in the engineering sector, you're only known if you sell direct to the public. The vast array of companies in the supply chain are, with a few exceptions, unknown to the general public unless they are a major local employer. For companies whose contributions are important to the product known by the public, this can be a source of frustration.

"We're definitely trying to be better known," said Rob Rickell, president of GKN Driveline. "It has real advantages, especially when you're trying to be more active in the recruitment field."

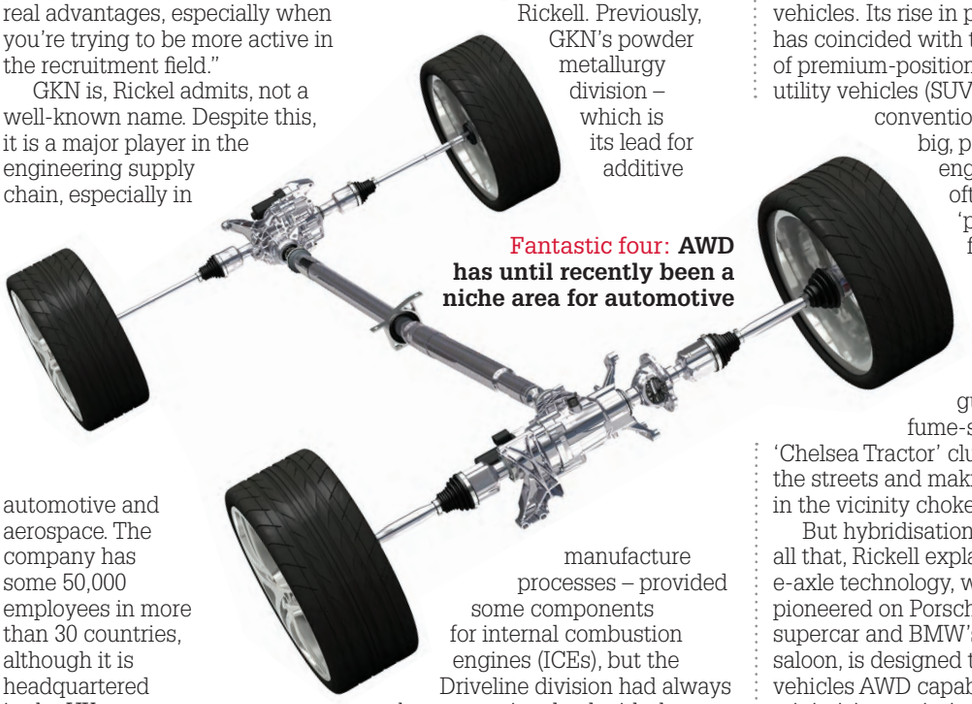
GKN is, Rickel admits, not a well-known name. Despite this, it is a major player in the engineering supply chain, especially in automotive and aerospace. The company has some 50,000 employees in more than 30 countries, although it is headquartered in the UK.

"We supply components or complete systems to pretty much every car maker in the world," Rickell said.

In recent years, the automotive sector has seen some changes for GKN. "What we're very proud of in the last few years is [not only] that we have really moved from being a mechanical engineering company, supplying about half of all the constant-velocity joints of all the cars in the world – which is quite an achievement, of course – but we've now grown much more into an automotive company supplying complete all-wheel drives and hybrid and electric systems.

"Across all the divisions – automotive aerospace and land systems, which is systems such as agricultural but also buses – the move into hybridisation is very important."

Propulsion is a novel area for the company, according to Rickell. Previously, GKN's powder metallurgy division – which is its lead for additive manufacture processes – provided some components for internal combustion engines (ICEs), but the Driveline division had always been more involved with the drivetrain downstream of the engine. What changed all that was the advent of hybridisation.



Fantastic four: **AWD has until recently been a niche area for automotive**

"This is an area that's actively looking for different solutions to the ones that were on the market," Rickell said. "For us, that meant the development of electric axles in one- and two-speed options, and what we call our e-axle solution where you have a conventional engine driving the front or rear axle and are looking for an electric axle to drive the other wheels. This is becoming an increasingly important subdivision of the all-wheel-drive segment, which is itself becoming much more important."

For most of its existence, four-wheel-drive (or all-wheel-drive – AWD – as GKN prefers to call it) has been a rather niche area for automotive, limited to speciality vehicles such as off-roaders and agricultural vehicles. Its rise in popularity has coincided with the launch of premium-positioned sports utility vehicles (SUVs). As AWD conventionally needs big, powerful engines, it is often seen as a 'problem' part for today's automotive sector, with the cliché of the fuel-guzzling, fume-spouting 'Chelsea Tractor' cluttering up the streets and making everyone in the vicinity choke.

But hybridisation is changing all that, Rickell explained. GKN's e-axle technology, which it pioneered on Porsche's 918 supercar and BMW's i8 hybrid saloon, is designed to give vehicles AWD capability while minimising emissions.

E-axle vehicles have electric motors on the axles that the ICE doesn't drive. "The control strategy and software, which we also developed ourselves, gives you the optimum option for the situation," Rickell said. "When you're setting off, it'll often just engage the e-axle, because the electric motor has good torque at low revolutions per minute.

Wheel deal: **GKN pioneered its e-axle technology on Porsche's 918 supercar**

But if you accelerate hard, then the ICE will cut in; if you're driving in slippery road conditions you'll have both systems together for the handling."

But in the city, the system comes into its own and could banish the Chelsea Tractor stereotype for good. "In normal driving conditions, you'd probably use all-electric mode, and if you're in the city where pollution and particulates are an issue you can set it to drive purely on electric. That's one of the options on the dash. Those sorts of options give you the best of all worlds; handling, safety and zero emissions."

Development on such systems is normally in close co-operation with the vehicle manufacturer. "The best systems are always collaborative. With Porsche 918, we were the preferred technology partners; similarly with the BMW i8," Rickell said.

The systems have some common components, such as actuators, electronics and control software, but GKN is not developing an off-the-shelf system for manufacturers to drop into cheaper cars. "We have to be cost competitive, especially as you go into higher volumes. But we have to be clear that this sort of intelligent tech, with the control strategies you need, is fairly high-tech, so it is going to add value to the vehicle. We have a project with Peugeot and Citroën with an e-axle on the back of a mid-range front-wheel-drive model. Front-wheel drive is the most cost-effective way to build a volume car these days, but there are also more rear-wheel-drive platforms coming through."

Car makers are keen to adopt this technology because it helps keep their ranges broad, Rickell explained. "It allows them to have vehicles with higher carrying capacity, larger vehicles and more sporty vehicles, but still have the emissions profile to meet regulations. It's a solution they need to maintain their range."

One technology Rickell is particularly proud of is the two-speed e-axle on the Porsche 918 and BMW i8.

"Normally, electric drives disconnect between 120km/hr and 150km/hr, but the two-speed system allows it to be used all the way up to motorway speed. It's done with a transmission using a lightweight synchroniser, not a dual clutch; any gaps in the torque are filled using the ICE so it's very smooth," he said. "The driver can't feel the shift."

GKN is also looking at lightweight materials, where there is commonality between its automotive and aerospace divisions. "Automotive is the largest part of our business and it's very important to us; about half of what we do is in automotive. But 30 per cent is in aerospace: we're the world-leading supplier for carbon-fibre components for aircraft and we supply all the major companies. We're proud of that because we can meet the requirements of that sector in structures and aero engines."

In the automotive sector, lightweighting for GKN centres around high-strength steels and pressure die-cast aluminium; magnesium is making inroads in the sector at the high end for thin-walled housings, but aluminium is still preferred, Rickell said. "For carbon-fibre, the cycle times still aren't fast enough to meet the 500,000 components per year rates needed in the automotive sector," he said. "In high-strength steel, you can make high-strength steel components in seconds. You need to spend money and invest in a transfer press, but for high volumes that investment makes sense."

In the meantime, GKN is still trying to boost its profile. "We have worked with one or two key universities; we're also actively involved in sponsoring Formula Student, which we see as an excellent way of demonstrating our technologies and working closely with final-year students – we'd like to do even more," Rickell said.

"We'd probably not be able to visit every university, but we'd like to do more with the key universities for automotive and aerospace, such as Cranfield, Warwick and Bath, and one or two others with regards to materials tech and additive manufacturing."

"We have worked with one or two key universities; we're also sponsoring Formula Student, which is an excellent way of demonstrating our technologies

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Hard hitting

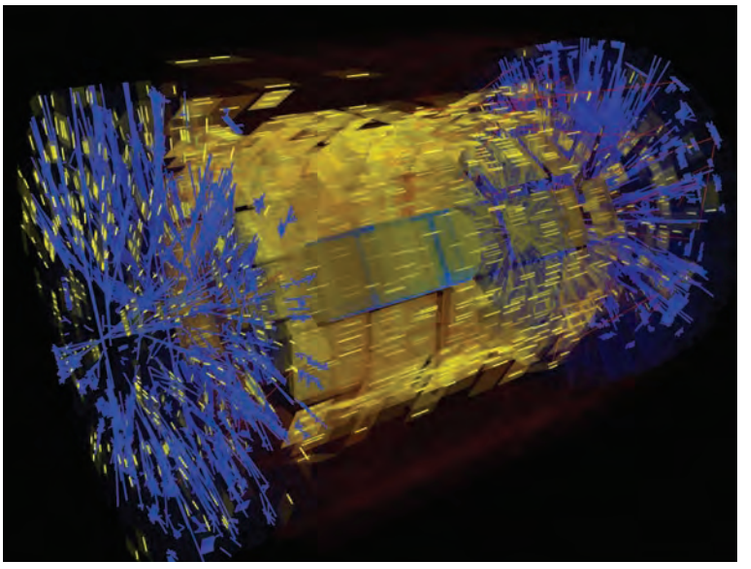
Experts answer questions on the world's most powerful particle accelerator. Stuart Nathan reports

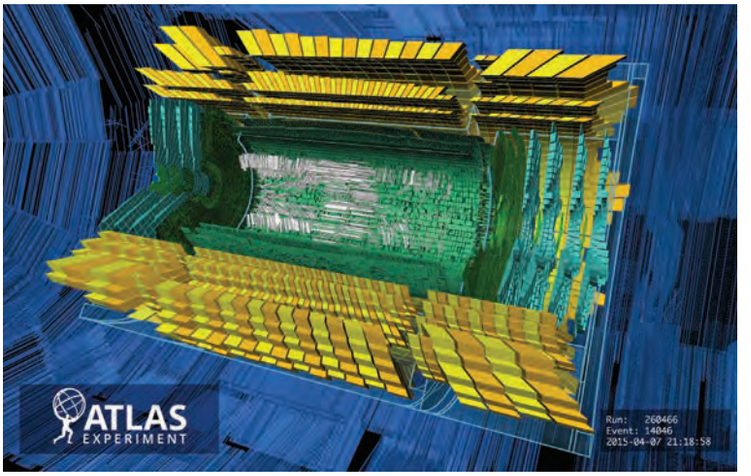
The world's biggest physics experiment, the Large Hadron Collider (LHC) at CERN, straddling the French-Swiss border, is about to begin its second round of experiments since its original start-up in 2008. Now colliding particles at twice the speed as it did before, the LHC teams now hope to uncover the mysteries of dark matter and energy, which are believed to hold galaxies together and power the accelerating expansion of the universe. The LHC and its detectors had to be considerably upgraded to make these experiments possible. Here, CERN's engineers talk about how the upgrades were made, how the engineering enables the exploration of new physics and what might be next for large physics experimentation.

- **Jean-Philippe Tock (JT), senior LHC engineer**
- **Francesco Pietropaolo (FP), neutrino physicist**

As the design of the LHC started way back in 1984 and since then many improvements have been made in the fields of engineering and science and physics, if you had the opportunity do you feel that you could drastically improve the design of the LHC using newer materials and processes? And what would the changes be? And finally what would you predict any such upgrades or changes in design would yield in terms of results?

JT: The first concept of the LHC effectively dates back from the 1980s; nevertheless, the design of its main systems continued up to the end of the 1990s, giving the opportunity to integrate technical developments occurring in between. Also, at the time of its initial concept, in some areas, such as computing, the expected improvements in terms of performance were taken into account, building on future improvements (Moore's law).





Main: **preparing to weld on the LHC beamline**
Right: **'beam splash' in the CMS (above) and ATLAS (below) detectors**

In terms of superconducting magnets, the main LHC components, it is correct that new materials have appeared since then. Niobium-titanium alloy (NbTi) is used for the LHC superconducting magnets. Since then, for example, Niobium-tin (Nb_3Sn) is used as well, a superconductor having higher performance than NbTi. Also high-temperature superconductors (HTSs) are emerging.

It would not be efficient to change all LHC magnets. Nevertheless, CERN plans to take advantage of the enhanced performance of the superconductors in two ways:
1. The HL-LHC (High Luminosity LHC project) is an upgrade of the LHC machine to increase the total number of collisions (luminosity) by a factor 10 in order to further increase its discovery potential beyond 2020. This improvement can be obtained by replacing some LHC NbTi magnets with Nb_3Sn ones.
2. The FCC (Future Circular Collider study) is a study for post-LHC particle accelerator options with an energy of about one order of magnitude higher. High-field superconducting magnets are a key technology for the successor of the LHC. Low-temperature superconductors (LTSs) such as Nb_3Sn and HTSs are considered.

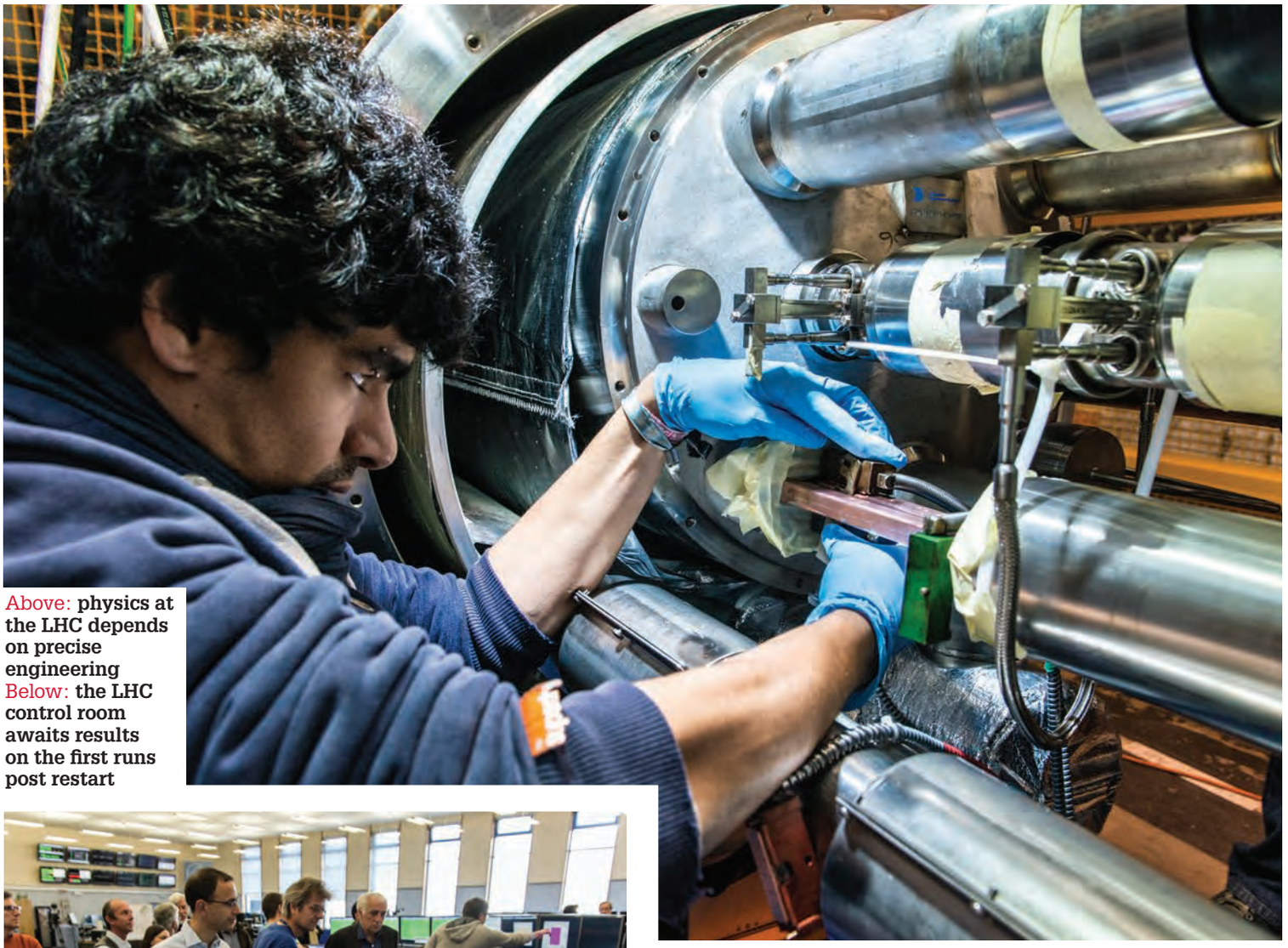
■ **Are there any changes in the physical forces that the structures that make up the LHC experience as a result of the upgrade? If so, what reinforcement was necessary, where was this applied and how?**

JT: During the first run of operation, so before the first long shutdown (LS1) that took place in 2013–14, the LHC was run at a maximum energy of 8TeV centre of mass. It is now running at 13TeV centre of mass, so about double. To achieve this, the current in the LHC superconducting dipole magnets has been increased from 6,700A to 11,000A. At a first approximation, the electromagnetic forces are increasing proportionally to the square of the current, so almost three times larger.

The LHC was designed to operate at 14TeV centre of mass corresponding to a current of almost 12,000A. So there was no need to reinforce its structures except the LHC splices (electrical joints). The LS1 was triggered by the need to consolidate more than 10,000 splices between the superconducting magnets. They were both consolidated electrically and mechanically to withstand safely the higher current.

■ **How do you design a detector for particles that barely interact with matter, if they exist at all?**

FP: The most elusive particles presently known are the neutrinos. The study of their properties will allow us to gain a better understanding and possibly to extend the knowledge of the present standard model of elementary particles. ->



Above: **physics at the LHC depends on precise engineering**
Below: **the LHC control room awaits results on the first runs post restart**

The neutrinos are the neutral partners of the charged leptons (electron/muon/tau), they have a very tiny mass (actually close to zero) and they interact with the ordinary matter only through the 'week force'. They are difficult to detect as they can travel, at the speed of light, practically unperturbed over very long distances even in dense media such as the Earth (mean free path of more than 10^9km) or the Sun.

As a consequence, 'neutrino' experiments have to rely on huge multi-kilotonne detectors coupled with very intense neutrino beams, which can be either artificial (produced as from particle accelerators or at nuclear reactors) or natural (from the nuclear fusion in the Sun, or from cosmic rays interacting in Earth's atmosphere). Artificial neutrino beams are available in Europe (CERN), the US (FNAL) and Japan (KEK, T2K). They produce

"The neutrinos have a tiny mass and they interact with the ordinary matter only though the 'weak force'
Francesco Pietropaolo

~10^{18} neutrinos per day and serve multi-kilotonne detectors located at distances from the production target ranging from few hundred meters to several hundred kilometres.

Only a few neutrino interactions per day are recorded in these detectors. Most of the time, neutrinos interact with ordinary matter, transforming into the lepton partner and transferring energy to the target nucleus. Hence a neutrino detector needs to be able to fully reconstruct the products of the interactions in order to infer the nature of the parent neutrino. This is usually done employing 'imaging' detectors able to provide a 3D picture of any event, with high granularity (~mm) and with excellent 'calorimetric' response, to accurately measure the direction, the energy and the kind of all particles produced in the interaction.

Examples include the Water Cherenchov detector adopted by the 50ktonne SuperKamiokande experiment in Japan, the Liquid Argon Time Projection Chamber (1ktonne ICARUS experiment in Europe), the Photographic nuclear emulsions (2ktonne OPERA/Europe) and the Sampling Calorimeter approach adopted in the US by the Minos and the Nova collaborations.

Given the extremely week neutrino interaction rate, these huge detectors are generally located deep underground, well shielded from the cosmic rays, which can possibly mimic

neutrino interactions, by several kilometres of overburden rock. The latter feature allows us to use these large detectors as observatory of other very rare events such as the proton decay (related to the ordinary matter stability) or even other unexpected phenomena.

■ What changes needed to be made to CERN's accelerators to provide particles with the appropriate energy?

JT: The first LHC long shutdown started in February 2013. It was triggered by the need to consolidate the 13kA splices between the superconducting magnets to allow the LHC to reach safely its design energy of 14TeV centre of mass.

The consolidation of the LHC superconducting circuits were carried out in the frame of the SMACC (Superconducting Magnets And Circuits Consolidation) project. It has principally covered the consolidation of the 10,170 13kA splices but also other activities linked to the superconducting magnets such as the exchange of 18 main cryomagnets, the installation of the additional safety-relief devices, the repair of known helium leaks and other consolidation activities.

In addition, the quench protection system of the LHC's superconducting magnets was also improved. Also, the cryogenics systems that are keeping the superconducting magnets at 1.9K has been maintained and its control systems have been upgraded.

■ Would CERN be able to manage research at any higher energy, if the next round of experiments indicates that this might be necessary? If so, how might this be accomplished?

JT: CERN is already undertaking a design study for the post-LHC particle accelerator at the high-energy frontier: the FCC (Future Circular Collider) study.

It is exploring the potential of hadron and lepton circular colliders, performing an in-depth analysis of infrastructure and operation concepts and considering the technology research and development programmes that would be required to build a future circular collider.

For example, the eight Tesla dipole magnets that are used to steer the 7TeV beam along the 27km circumference of the LHC would need to be replaced by 16 or 20 Tesla magnets to reach the energy of 50TeV per beam in a ring of, respectively, 100km or 80km in length.

> **"CERN is already undertaking a design study for the post-LHC particle accelerator at the high-energy frontier**
> Jean-Philippe Tock

Above: **the upgrade of the LHC doubled the energy available for experiments**
Below: **welding around the LHC's superconducting magnet channels**

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Getting personal

As healthcare providers move towards personalised medicine, manufacturers are beginning to rethink their process solutions. Evelyn Adams reports

Millions of people are taking medication that does nothing to treat their symptoms. Recent studies suggest many of the most popular drugs on the market help only a fraction of the people who use them. But this could be about to change.

Medicine is starting to get personal, and patients are increasingly demanding customised treatments with better results and fewer side effects. The trend has largely been driven by improvements in genome sequencing, which has become much cheaper and more effective. Storing huge amounts of data on health conditions has also become easier, and the world is far better connected on mobile platforms.

Combined, these factors are changing the way healthcare is delivered. "One major area of development is in companion diagnostics, which are used to identify the patients who will respond to a particular treatment," said Richard Alldred, head of innovation at the Centre for Process Innovation (CPI). "A good example of the evolution of stratified therapies is in breast cancer treatment, where genetic data is being used to identify patient groups likely to respond to particular treatment regimens."

The drive towards personal healthcare means the way medicines are being manufactured is also changing. There has been a shift away from creating small molecules to one in which treatments are a combination of small molecules and cell and gene therapies. To produce these personalised drugs cost effectively, engineers are looking at ways to replace inefficient large-scale batch production with investment in new technologies, such as continuous manufacturing.

Batch production and the centralised manufacturing systems are slow paced, inventory heavy and increasingly considered to be inflexible and unsustainable. What the industry needs now is a real-time demand-based supply chain. "Continuous manufacturing will undoubtedly be a major factor that can bring about change," said Alldred. "It is likely to be the key to solving many of the manufacturing issues by enabling intensification, plant flexibility and improved control over product quality and characteristics."

But some believe the manufacturing industry isn't moving fast enough. "While demand for personalised medicines has increased fairly dramatically in recent years, when seen within the context of the entire healthcare market it is still in its infancy," said Alan Johnston, pharmaceutical and life sciences business manager of Siemens. "Some of the industry's processes would benefit from optimisation strategies as technology has moved on since they were originally designed."

Alldred added: "The industry needs to find more efficient, cheaper and faster ways of discovering and developing new drugs and needs to find better and more flexible ways to manufacture successful treatments. A particular area that will need to be addressed is how an increasingly diverse portfolio of personalised and stratified therapies are regulated; current processes are not well suited to this." ->

Popping pills: **most popular drugs help only a fraction of the people using them**

> **"Continuous manufacturing supports a cleaner and more flexible process and can optimise capital costs**
> Alan Johnston, Siemens

Johnston believes there are four key challenges in rolling out personalised medicine to the wider public; tackling efficiency issues during the production process; getting companies to be bold in introducing change within a highly regulated healthcare environment; dealing with the increased costs involved with personalised medicines; and introducing completely new process technologies.

He also believes continuous manufacturing may help address some of these challenges. "It can drive a marked increase in product quality consistency and help reduce both manufacturing costs and inventories," said Johnston. "It also supports a sustainable, cleaner and more flexible process and can optimise capital costs such as reducing inventory. Finally, it supports real-time process analysis and product release, for instance through a 'quality by design' strategic approach."

Manufacturers are beginning to adapt. For instance, research on continuous solid-dosage manufacturing has already been transferred from university-based research groups to the pharmaceutical industry. One project involves researchers at Rutgers, the State University of New Jersey, in the Engineering Research Center for Structured Organic Particulate Systems (C-SOPS), who have been working on a continuous direct compaction tableting process.

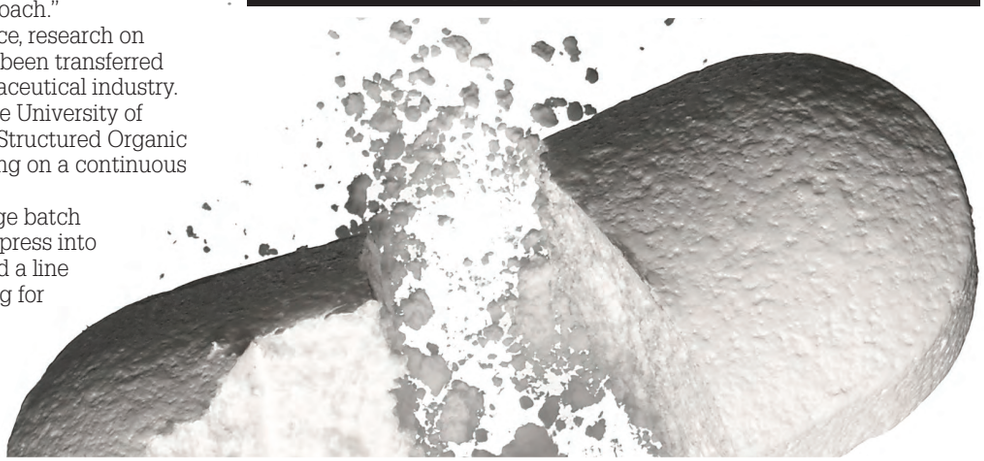
The technology replaces the traditional multi-stage batch process by integrating feeders, mills, blenders and a press into a single process. Janssen Pharmaceutica constructed a line based on this design, to help speed up manufacturing for personlised drugs. And the trend is set to continue, according to Alldred. "The industry is increasingly investing in the development of personalised and stratified therapies and adopting business models less reliant on the blockbuster drug model." Some groups are looking towards technologies such as 3D printing to provide a solutions. Last year, the University of Central Lancashire (UCLan) filed a patent application for a system that uses a 3D printer to 'print' a tablet of medicine with realistic quantities that can be taken by a patient. The printer can replicate drugs already available in pharmacies and hospitals, but can also tailor medicines directly to an individual patient's needs.

This technology will potentially reduce the cost of manufacturing tablets for individual patients. Dr Mohamed Albed Alhnan from the School of Pharmacy and Biomedical Sciences alongside his team developed a drug-polymer filament system that can replace the original filaments in a 3D printer. The team discovered that the new pharmaceutical 'ink' allowed them to print a challenging tablet design with significant improvement of appearance and high accuracy of tablet weight and dose.

"In my view, the future will see an explosion in the number and diversity of therapies available. Many of these will have been developed for very specific, often small, patient cohorts," said Alldred. "There will be a corresponding increase in the type of facilities used to manufacture medicines from large plants much like those of today to smaller, flexible units and even small-scale, fully enclosed, bench-top production units.

"A potential scenario will be that a patient attends a surgery, a number of rapid diagnostic tests are applied to determine the best treatment, which is then manufactured and formulated in a fully enclosed, small-scale manufacturing unit located close to the patient." While a heavily regulated healthcare industry finds it harder to embrace change, Alldred believes the benefits of personalised medicines will spur more action in the coming years.

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



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Silent flight

Siemens and Airbus are on a mission to introduce hybrid aircraft that can carry up to 90 passengers by 2035. Helen Knight reports

Hybrid hopes: **the lightweight electric motor generates 200kW**

Imagine living next to an airport where the aircraft are taking off and landing all night, but you never hear a thing?

That is the promise of hybrid aircraft, in which a small jet engine is combined with a battery and an electric motor to drive the propellers. Such aircraft could also consume up to 50 per cent less fuel, according to Siemens.

The company, which is working with Airbus, ultimately hopes to launch 90-seater civilian hybrid-electric aircraft into the skies by 2035.

But the technology must first be proven on smaller aircraft. To this end, Siemens has recently developed an electric motor with a weight of 50kg and a continuous power output of 260kW – enough to fly a four-seater aircraft with a take-off weight of two tonnes, when used in conjunction with a small jet engine.

The motor has a power-to-weight ratio of 5kW/kg, said Frank Anton, head of electric aircraft at Siemens. "That is a factor of five higher than a normal industrial motor."

A hybrid design would allow aircraft to receive an additional power boost from the battery during take-off and climb. Not only would this reduce the size of the engine needed for cruising, when the power demand is much lower, but it would also allow it to operate constantly at its most efficient speed, according to Anton.

"Overall, we would expect a reduction of fuel consumption of 25 per cent," he said.

The motor also has a rotational speed of 2,500 revolutions per minute, allowing it to drive the propellers directly. This offers greater flexibility when distributing the propulsion system around the aircraft, added Anton, including the location of the propellers themselves.

> **"There is an electric aircraft called e-Genius, where the propeller is on top of the stabiliser**
> Frank Anton, Siemens

"So, for example, there is an electric aircraft called the e-Genius [developed by researchers at the Institute of Aircraft Design at Stuttgart University], where the propeller is on top of the stabiliser at the tail of the aircraft," said Anton. "This is very good from the point of view of propeller efficiency, and also allows the propeller to be larger than normal and turn more slowly, which also makes it much more efficient." This could reduce fuel consumption by a further 25 per cent, he explained.

What's more, larger propellers that turn more slowly are much quieter than conventional designs, Anton added. "So if you start purely electrically, and only switch on the combustion engine after some time, you will have no noise from the battery, and only a little propeller noise, which you can reduce by turning the propeller more slowly," ->

"Then again, while you are improving the magnetics, you need to carry stronger forces, so you need more material
Frank Anton, Siemens

he said. "In this way, you can make a really very quiet aircraft."

To design the synchronous motor, the company used advanced simulation tools, allowing its engineers to trade off improvements in one aspect of its operation with compromises in other areas.

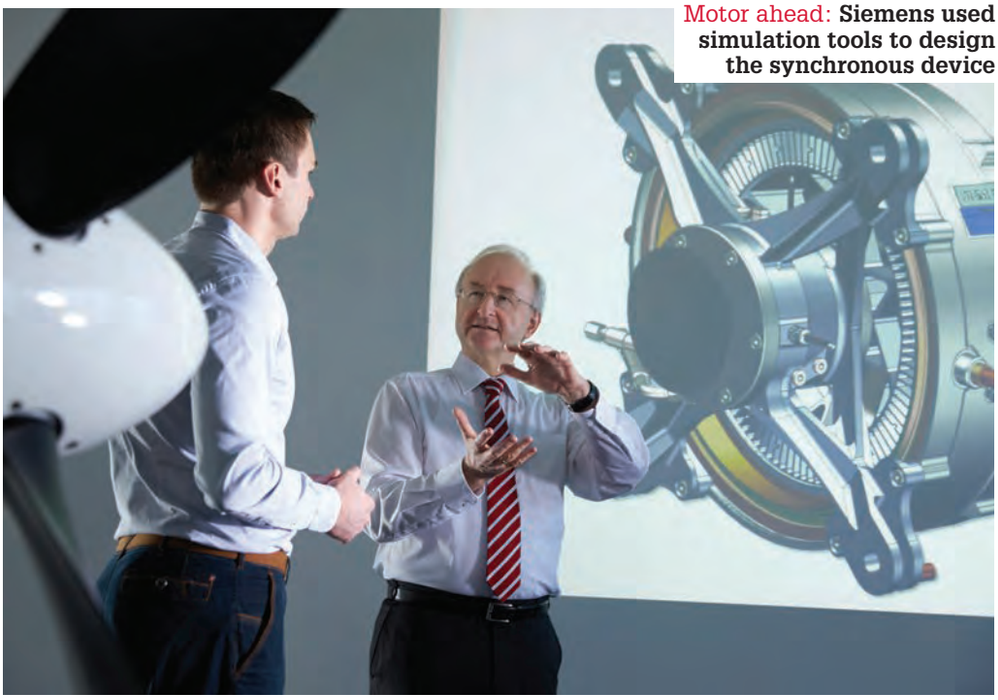
"So while you are optimising the magnetics, you have to think about how you can cool them, and if you optimise the cooling, you need more space so you have to compromise on the magnetics," Anton said.

"And then again while you are improving the magnetics you need to carry stronger forces, so you need more material, and the motor becomes heavier, so then again you have to work on the mechanics, on the structural analysis."

To reduce the weight of the motor, the device's four permanent magnets are arranged next to each other in such a way as to ensure that the orientation of each field is in a different direction. This arrangement, known as a Halbach Array, allows the magnetic flux to be directed so as to achieve the highest power output with minimal use of material.

To reduce the weight of the motor's cooling systems, the company also used direct-cooled conductors. Any heat lost from the copper conductors is discharged directly into an electrically non-conductive cooling liquid, such as silicone oil.

The motor appears to have a good power density, according to Christopher Gerada, professor of electric machines at Nottingham University. "It is very encouraging to see large manufacturers taking an interest in more electric technology," he said. "Clearly they are making significant developments."



Motor ahead: **Siemens used simulation tools to design the synchronous device**

A great deal of work is going on among the research community and industry to improve the power densities of electric motors, said Gerada. "High power density and torque density are critical, because you can save material and get more power," he said. "And for any transportation system, any weight saved is less fuel spent."

To this end, he and his colleagues have developed a motor with a power density of approximately 30kW/kg. The motor was developed for use as an electric starter-generator in a project with French business jet manufacturer Dassault Aviation, as part of the European Commission-funded Clean Sky programme.

The researchers are also working on a number of other projects to develop more electric aircraft. One way in which electric motors can be used to reduce fuel consumption and emissions, for example, is while aircraft are still on the ground.

Working with aerospace component manufacturers Honeywell and Safran, the researchers have developed an electric motor that is integrated into one wheel on each of an aircraft's main landing gear, to provide power during taxiing on the runway. The system, known as EGTS, is powered by the aircraft's auxiliary power unit (APU).

Gerada and his team are also working with Safran on a future version of the ETGS system.

"Today, most movement on the ground is powered through the main engines, but these are designed to operate at 30,000–40,000ft," said Gerada.

The higher air density on the ground, coupled with the fact that the engines are only operating at idle speed when moving around the runway, means that they are working very inefficiently.

"So they are wasting fuel, and making noise and pollution on the ground," he said. "With the forecast increase in air traffic over the coming years, trying to reduce emissions while the aircraft is on the ground and maneuvering is quite critical."

Having a motor integrated into the wheel of the aircraft, and powered by the APU, can reduce fuel consumption and pollution levels significantly, he added.

Ultimately then, the next generation of high-density electric motors could allow aircraft to move around much more quietly and cleanly – both on the ground and in the air.

Silent treatment: **the aim is create a very quiet aircraft**

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

A showcase for design professionals

The Engineer Design & Innovation Show 2015 will feature high-end products and services, as well as components, materials and more

Running from 2–4 June at the NEC in Birmingham, The Engineer Design & Innovation Show (TEDIS) has been established to showcase everything that an engineering designer needs to do their job: everything from high-end products and services used to realise their concepts, such as new design software and 3D printing, to the components, materials and innovative technologies that go into these next-generation products.

Exhibitors at TEDIS 2015 are set to include Warwick Manufacturing Group, Proto Labs, JMP (a division of SAS Software), Panasonic Electric Works, Laser Lines, Spaceclaim Corporation and Tharsus.

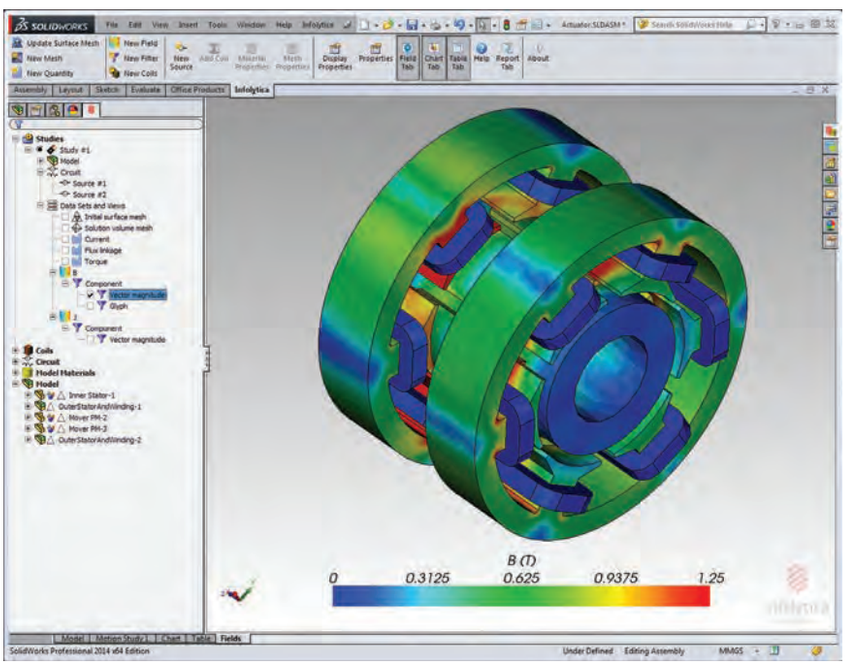
Innovation hub and advisory drop-in centres

Special features this year include an advisory drop-in centre where visitors will be able to get help with issues relating to their business and an Innovation Hub that will give visitors the chance to talk to companies that have successfully built their business.

The drop-in centres will give small and medium-sized (SMEs) direct access to expert advice from the organisations including the Business Growth Service, the High Value Manufacturing Catapult and the EIA on topics including skills, innovation, access to finance and building business in export markets.

Meanwhile, the Innovation Hub will provide a showcase for some of the products and technologies that are shaping the future of manufacturing.

Participants are set to include The Proving Factory, Reaction Engines, The National Graphene Institute at Manchester University, and the team behind the wheels that will hopefully propel Bloodhound SSC into the record books later this year (covered in detail on p84).



Field simulation: **Infolytica will present MagNet for SOLIDWORKS at the event**

Elesa: T119
Elesa will be showcasing a few of its many new products including the PR-CH flush pull handles, which save time and money on assembly of the sheet-metal lift-off panels and doors commonly used on machinery of many types to cover equipment as a protective element. They are suitable for machine access panels and guarding – as well as for maintenance doors covering internal mechanisms or electrics – so preventing unauthorised personal interaction with dangerous moving parts or electrical systems.

Panasonic Electric Works UK: T132
Panasonic Electric Works UK will show its newest additions and technological innovations including two production methods for 3D-moulded circuit solutions known as MIPTEC and LDS. Other innovations on show will include the company's next-generation MOSFET technology relays in its ultra-small TSON package and the HE series PCB relays that could eliminate small contactor needs and costly wiring installations.

Eplan: T4
EPLAN is an electrical engineering design programme (CAE), offering innovative options for the planning, documentation and management of electrical design projects. The EPLAN 'platform' supports interdisciplinary work, from fluid and process engineering to harness and enclosure design.

Infolytica: T209
MagNet for SOLIDWORKS is Infolytica's electromagnetic field simulation add-in. SOLIDWORKS users who need to design and analyse electromagnetic or electromechanical devices can use this new embedded 3D electromagnetic field solver tool directly in their preferred CAD environment. The simulation and analysis of any electromagnetic device can be performed completely within the SOLIDWORKS environment, making it simpler than ever to set up complex design problems. This includes applications such as transformers, sensors, MRI, actuators, solenoids and more.

A celebration of innovation

The Engineer Conference 2015 will provide a stage for some of the country's best engineers and most exciting projects

From the Rosetta mission and the UK's new aircraft carriers to Industry 4.0 and the rise of reshoring, The Engineer Conference 2015 boasts an unmissable mix of inspiring projects and industry big hitters.

Since its launch in 2013, the conference has provided a platform for some of the UK's top engineers and some of its most exciting and innovative engineering projects. This year's instalment promises to be better than ever.

Running from 2–4 of June at the NEC in Birmingham, the 2015 conference features three streams covering the latest thinking and the most exciting UK developments from the worlds of engineering design, manufacturing and supply chain management.

As always, throughout the event there will be a major focus on some of the key issues that are dominating industry debate: from Industry 4.0 to the welcome, and much trumpeted, phenomenon of reshoring.

> **"As always, there will be a major focus on the key issues dominating industry debate**

Thanks to presentations from ADS Group and the recently launched Proving Factory, there will also be plenty of useful advice to small and medium-sized enterprises (SMEs) on how to engage with OEMs, as well as first-hand accounts from small companies – such as Magna Parva – that have managed to attract interest from the UK's biggest hitters.

On the technology side, there's plenty of emphasis on the ever-popular topic of 3D printing, with Prof Richard Hague, one of the UK's leading experts in the field, making a welcome return alongside some fascinating real-world case studies from teams at Renishaw and BAE Systems

We will also be taking a look at the way new materials are affecting the design and manufacturing worlds: from the untapped potential of graphene to the various applications of composites and the innovations in lightweighting that are helping some of our biggest sectors lead the world.

Flying solo: **hear how engineers have recreated the legendary Bugatti 100P**

As always, the conference will also shine the spotlight on some of the UK's most challenging and inspiring projects.

David Downs, the engineering director of the Aircraft Carrier Alliance (and regular blogger for *The Engineer*), will be talking about the challenges of building the UK's new Queen Elizabeth (QE) -class aircraft carriers, while Ian Costello, deputy engineering manager for Rosetta at Airbus Space & Defence, will be talking to us about the UK's role in last year's astonishing comet landing.

In depth: **delegates will hear about the production of the QE carrier**

We are also particularly looking forward to hearing from UK engineer John Lawson about how he and an international group of like-minded enthusiasts have recreated the only aircraft built by legendary car designer Ettore Bugatti.

Other presenters over the course of the three days will include: Dick Elsy, chief executive offier of the High Value Manufacturing Catapult, AMRC programme manager Dr Peter Osborne and Simon Black, senior manager of body structures at Jaguar Land Rover.

The Engineer Conference runs alongside Subcon, The Advanced Manufacturing Show, and The Engineer Design & Innovation Show.

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A focus for UK manufacturing

This year's Subcon show will feature a range of new and returning exhibitors – more than three quarters of which will be UK based

More than 300 of the world's leading subcontractors will be showcasing their capabilities at Subcon from 2–4 June at the NEC in Birmingham.

Subcon provides the UK's foremost showcase of companies offering contract and subcontract manufacturing services and will run alongside the Advanced Manufacturing Show The Engineer Design & Innovation Show.

The increasingly buoyant manufacturing sector is reflected in the growing strength of the Subcon show, which this year features many new and returning exhibitors.

Subcon is the UK's only event that is completely focused on contract and subcontract manufacturing, including machining, moulding, fabrication, electronics assembly, finishing and treatments.

The solid core of the Subcon show is its UK exhibitors, who make up more than three quarters of the exhibitors.

Subcon also offers access to global markets, with 15 overseas countries represented in 2015, including pavilions for Denmark, Portugal, Italy, Hungary, China, India, Spain, Ukraine, Latvia and Taiwan, as well as individual exhibitors from Belgium, the US, Greece, Slovenia and the Republic of Ireland.

Exhibitors include the Midlands Assembly Network, Lipco, WEC Group, Tata Steel, Gee Graphite, Tridan, Muller England and Mini Gears. See below for profiles of some of this year's key exhibitors.

At the show: **Darian will launch its sheet metal and plate fabrication service**

Mini Gears: S42

Mini Gears will highlight its recently added large turning and milling capacity. Just installed is a Leadwell LTC 35C turning centre with a huge torque and turning diameter up to 420mm.

Based in Stockport and employing more than 80 people, the multi-award-winning company is often associated with small components and gears due to the 'Mini Gears' name. However, over the last three years the company has moved into aircraft seating components, the nuclear industry and specialist parts often machined in exotic materials for the oil and gas industry.

Darian: S130

Darian will be launching its sheet metal and plate fabrication service. The company supplies machined grey iron and steel castings, pressure die castings, forgings, CNC-machined items, pressings and stampings to the UK and German market, and this is now complemented by the new addition to its product range.

The Midlands Assembly Network: S442

The Midlands Assembly Network (MAN) features eight subcontract manufacturers, a design agency and academic partner Warwick Manufacturing Group and offers customers a single point of contact to their engineering requirements, removing costs, reducing lead times and delivering world-class complex parts.

Working across 12 state-of-the-art factories, the collective has created an enviable reputation for providing a total manufacturing solution, from initial prototyping, fabrication and precision machining to chemical etching, injection moulding and PCB development.

The MAN line-up consists of Advanced Chemical Etching, Alucast, Barkley Plastics, Brandauer, Grove Design, Mec Com, Muller Holdings, PP Electrical Systems and SMT Developments.

Timsons Engineering: S112

Timsons Engineering offers a one-stop shop for all subcontract engineering services, including both foundry and machining services, which it offers on a complete supply or individual basis.

At Subcon 2015, it is launching a mechanical and electrical fitting service, with a huge fitting area of more than 2,500m^2 as well as a maximum crane capacity of 30 tonnes, with an under hook height of up to 4.7m.

Staying ahead of the game

This year's Advanced Manufacturing Show is set to highlight the critical technologies that UK companies need to invest in

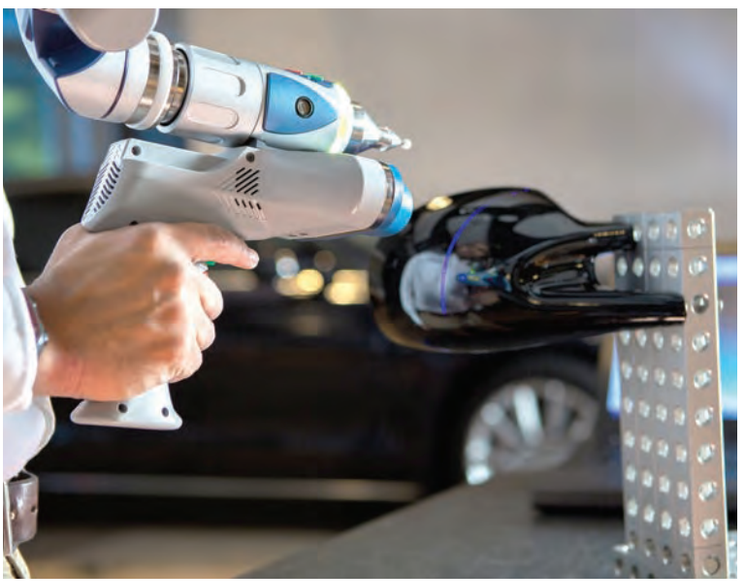
Following its successful launch in 2013, the Advanced Manufacturing Show (AMS) returns to the NEC on 2–4 June.

Featuring more than 50 manufacturers and suppliers of advanced production engineering technology, the exhibition will highlight the critical advanced manufacturing technologies that UK companies need to invest in, in order to stay ahead of the game in international markets.

These include machining and turning centres, sheet-metal working, metrology, tooling, workholding and CAD/CAM software. The show will feature live machining demonstrations and new product launches highlighting the technologies that UK companies need to stay ahead of the game in international markets.

Nigel Atherton, managing director of XYZ Machine Tools, said: "We had a very positive response at the Advanced Manufacturing Show in 2013 and this encouraged us to rebook for 2015, when we will have new products to show, such as the innovative XYZ 2-OP portable vertical machining centre."

Alongside XYZ, other exhibitors will include Matsuura, Delcam, Renishaw, Hexagon Metrology, FARO, Kasto, Trumpf, Vero and OGP. This free event runs alongside Subcon, The Engineer Design & Innovation Show and The Engineer conference.



Left: **XYZ will show the 2-OP vertical machining centre**
Right: **FARO is set to present the Freestyle3D scanner**

AMS exhibitors will be showing off a wide range of different manufacturing technologies from the latest CNC machines and tooling to measurement systems and the latest CAM software. Here's a flavour of what visitors can expect to see:

XYZ: A106
XYZ Machine Tools will be demonstrating a wide range of machines with particular focus on the productivity gains that can be achieved by introducing the XYZ 2-OP to your production mix. Visitors will have the opportunity to witness the potential time savings and cost reductions possible through the implementation of this new portable vertical machining centre.

Aberlink: A129
Aberlink Innovative Metrology will have an advanced new shop-floor vision measuring system making a debut at Advanced Manufacturing. Featuring Aberlink's powerful vision software, plus a host of easy-to-use inspection tools, the innovative new Aberlink machine is designed to deliver high levels of accuracy, faster component throughput and enhanced ease of use.

Zoller: A126
Zoller UK will be demonstrating a range of pre-setters to suit all budgets and situations. Whatever the user's individual requirement the Venturion is available in an optimum configuration. The Venturion is able to accommodate large, heavy tools while maintaining the highest-precision demands, making it suitable for CNC production situations.

Vero Software: A26–4
Vero will be demonstrating latest releases of its three core CAD/CAM brands: VISI, Edgecam and Radan. Visitors will be able to see how Edgecam can be used to create optimised toolpaths; they will learn about the latest enhancements to VISI (the company's mould and die solution); and they will see first hand the 180 items of new functionality in Vero's Radan software.

FARO: A37
FARO UK will be giving an Advanced Manufacturing Show debut to the company's new FARO Freestyle3D. This handheld laser scanner is the only industrial-grade handheld device that allows users to scan almost any sort of surface in nearly any kind of environment.

PDM celebrates 10th anniversary

The Plastics Design and Moulding Exhibition and Conference 2015 has already attracted more than 100 exhibiting companies

The Plastics Design and Moulding Exhibition and Conference (PDM15) is celebrating its 10th anniversary as the UK's premier annual event for the plastics industry.

Returning to the Telford International Centre on 16–17 June, the event will be co-located with the second Plastics Recycling Expo and the new Plastics Packaging Show, and has already attracted more than 100 exhibiting companies.

Major names from every part of the UK plastics community have confirmed their presence at PDM15, including Distrupol, Plastribution, Negri Bossi, Premier Moulding Machinery, Billion UK, BMB Plastics Machinery, Kuka Robotics, Luxus, Mouldshop, Rutland Plastics and Chess Plastics.

Companies exhibiting at PDM for the first time in 2015 include Igus UK, Cad2parts, South West Polymer Supplies, Hotset UK and Kongskilde UK. Other exhibitors will include product design companies, rotational and blow moulding machinery suppliers, toolmakers, rapid prototyping specialists, moulders and mouldmakers, masterbatch specialists, software suppliers and materials testing specialists.

Exhibitor highlights include Rainford Precision, which will be exhibiting its drilling products for truly hard materials, and Renishaw, the UK's only manufacturer of metal-based additive manufacturing machines that print metal parts, which will be showcasing its collaboration with bicycle company Empire Cycles on the world's first 3D-printed metal bike frame.

Elsehwhere, TRUMPF laser metal deposition welding (LMD) will provide a quick and economical solution to modifying or re-manufacturing a mould tool. This is a surface treatment process that adds a layer or layers of material onto the substrate. The laser melts a pool of metal on the surface and metal powder is deposited through a nozzle into that pool, creating a new surface.

Alongside the exhibition, a two-day conference will focus on a range of the industry's most topical issues including skills shortages, EU membership, sustainable design, automotive lightweighting and 3D printing. Highlights include:

- 'An overview of the UK auto industry' by Luke Hampton, supply chain director at the Society of Motor Manufacturers and Traders (SMMT)
- 'Plastics, lightweighting saviour; welding of automotive plastics components. Best practice and assessment of joint integrity' by Farshad Salamat-Zadeh, chartered polymer and adhesive engineer and senior project leader at TWI
- 'Failure in polymer products – it doesn't just happen' by Justin Taylor, principal consultant, ipolytech, Telford
- Material innovations in injection moulding by Dr Mark Barnett, head of Warwick Scientific Services

There will also be a number of 'shop-floor' sessions for engineers, providing practical expertise in areas such as moulding techniques and machine care.

A popular feature of previous shows that returns for 2015 is the Plastics Consultancy Network's Plastics Surgery. Visitors are invited to bring along questions that they may have relating to plastics design and moulding and PCN's consultants will be on hand to offer effective, creative and cost-effective advice and solutions.

Theatre ticket: **a two-day conference will run alongside the exhibition**

"A conference will focus on some the industry's most topical issues including skills shortages

Running alongside PDM, the Plastics Recycling Expo (PRE) exhibition and conference will bring together key players in order to learn, network and capitalise on the business opportunities plastic recycling offers.

Over two days, the PRE conference will explore how the industry can boost plastics recycling, as well as the use of recycled plastics. Speakers include sustainability experts working for major brands including Unilever, IKEA and Marks & Spencer.

Exhibitors already confirmed for PRE include Axion Recycling, Biffa Polymers, Cherry Plastics, CK Compounds, Impact Air Systems, Plasgran, Moulding Solutions, STEINERT Elektromagnetbau GmbH and Veka Recycling.

To register to attend PDM15, please visit: www.pdmevent.com.

Registration will also allow free access to the co-located Plastics Recycling Expo and the Plastics Packaging Show.

Lessons learned

A new university has been proposed that aims to create a supply of work-ready engineers to support local companies in Herefordshire

New take on teaching: **NMITE will eschew a traditional programme of engineering lectures**

The engineering skills problem isn't going away. Despite the efforts of various outreach programmes, publicity campaigns and government initiatives, the number of businesses complaining about the quality and quantity of engineering graduates remains stubbornly high.

While the number of engineering students has grown in line with the wider take-up of higher education, the latest skills survey from the Institution of Engineering and Technology (IET) found around 40 per cent of engineering firms struggle to recruit graduate engineers, with 54 per cent saying graduate skill levels did not meet reasonable expectations.

So is it time for a revolution in the way we teach engineering in the UK? A group proposing to build the UK's first new university in 30 years believes so and plans to initiate just that. Called the New Model in Technology & Engineering (NMITE), the private university aims to create a supply of work-ready engineers to support local engineering firms in its planned home in Herefordshire from 2017.

Although it is being advised by Bristol and Warwick universities, NMITE will eschew a traditional programme of engineering lectures. Instead it will teach students through a series of real-world problems supplied by businesses, a six-month work placement and an additional taught curriculum covering non-engineering subjects including arts and humanities to promote critical thinking and cultural awareness.

"Universities' fundamental purpose is to teach you how to think," said David Sheppard, co-leader of NMITE's development team. "Being a fully rounded engineer is not just a matter of understanding the physics and maths… To be a really effective, innovative, problem-solving engineer, you need a broader base on which to operate. Most of the problems coming down the track are going to need an interdisciplinary approach and that's what we're doing.

> **"If you're going to try to tackle the numbers, you have to look at new ways to engage people in the profession**
> Karen Usher, NMITE

"But the teaching is also informed by industrial partners providing you with real problems. So rather than say 'it's week 13 of the programme; this is when we do the second law of thermodynamics', the teaching is done by putting a problem on the table and using various engineering tools to try to find the solution."

This approach is inspired largely by Olin College of Engineering in the US, a small private university founded in the 1990s that focuses solely on producing the leading engineering innovators of tomorrow. It's a highly selective institution that's been dubbed one of the 25 'New Ivy League' colleges and reached number three in one league table of US engineering schools last year.

The hope is that NMITE can emulate this success in a way that both produces higher-calibre engineering graduates and attracts more people to the profession. "If you're going to try to tackle the numbers, you have to look at new ways to engage people in the profession," said Karen Usher, NMITE's other co-team leader.

"Getting an opportunity to work for months if not years in an industry sector where you're actually learning by working on problems in that industry hooks men and women into the sector and the profession… The engagement with that sector, the real understanding of what it is and what the work is about, changes how you think about the job hunt. It makes it more appealing... and you're more engaged with the choice."

The aim is also to use the broader curriculum to show students the sheer breadth of ways engineering can be applied in the real world, which, said Usher, could be particularly effective in encouraging women to start engineering careers.

"Part of engineering could be working for Oxfam and working with women's microbusinesses to help them design new [water] pumps. [Demonstrating this is about] opening up and helping them to understand that the career of engineering is about problem solving, people management [as well as] the application of technical engineering."

Although it's not obvious how studying English literature will open women's eyes to the variety of the profession, the model has certainly worked for Olin, where 50 per cent of students are female compared with the average of around 16 per cent in UK engineering departments. Usher said this is down to establishing a culture in which women feel welcome but also about broadening the admissions process.

As such, NMITE plans to recruit students without A-level maths and/or physics (subjects in which women are minorities) and give them adequate support to study the topics in remedial classes. "Why could we not look at a young woman, for example, who has studied biology, history and English and say if she's got the right grit and passion and she's prepared to engage with the maths that's needed, could

she not pursue engineering?" said Usher. Some traditionalists might be horrified by this idea. They might also be unsurprised to know that the neither of the people proposing this model have previous experience of engineering or engineering education in the UK (Usher is a human resources professional and Sheppard is a retired marketer and management consultant).

The idea for NMITE arose not from a desire to reform how engineers are educated, but from a local working group hoping to improve the economy of Herefordshire. As the county is one of the few in England not home to a university, the group decided founding one would increase the local skills base and attract investment and young people to the area. As many local businesses specialise in technology, particular in the defence, agriculture and low-carbon sectors, it was felt an engineering university would be particularly beneficial and the group set about investigating the best way to create one.

Despite this lack of direct educational experience among NMITE's founders, the public reaction from the existing university sector has been positive. True, Warwick and Bristol are only advising NMITE at this time and have not yet agreed to award degrees for the new institution, as has been incorrectly reported.

Indeed, a spokesperson for Warwick said the university couldn't yet comment on the viability of the venture. (A spokesperson for Bristol was willing to be interviewed but was unavailable before the deadline of this article). However, the fact that both universities were prominently involved in NMITE's launch announcement suggests they are confident enough in its proposals to be publicly associated with them.

Other academics *The Engineer* spoke to were similarly positive about the idea and the source of its inspiration, Olin College. "It's a very interesting idea to shake things around a bit as the UK engineering curriculum on the whole is quite traditional, said Catherine Hobbs, head of department for engineering at the University of the West of England (UWE). "I can understand how their aim to appeal more widely could be achieved by this really quite different take on engineering curriculum."

One issue with teaching engineers to degree level while introducing both more practical skills and a broader range of academic subjects will simply be fitting it all in. NMITE plans to do this with working hours and holidays closer to those of a conventional company than a term-based university, a move that will be helped by the fact its lecturers won't be balancing teaching with their own research.

"Grand challenges require a whole spectrum of people from researchers to technicians, but day-to-day commodity projects require different engineers
Elena Rodriguez-Falcon, Sheffield University

It will also have the added bonus of drawing up a curriculum from scratch rather than accommodating the existing interests of its staff, according to Elena Rodriguez-Falcon, professor of enterprise and engineering education at Sheffield University. "We are trying to develop an interdisciplinary approach to learning and teaching but we haven't got there yet," she said.

The problem might come not from the teaching itself but the need for engineering degrees to be accredited by a professional institution in order to count towards an engineer's chartership. "These guys will be starting at a disadvantage because you can't get accreditation, generally, until you have some graduates, which gives you a three- or four-year run-in before you can say 'this is an accredited programme'," said Hobbs.

"The barrier for a lot of existing courses is that if you want to make a radical change to your curriculum you have go through the accrediting bodies, and they have a reputation for being very conservative and fiercely protective of their discipline, making sure you have particular subjects included." However, this doesn't mean that NMITE faces an insurmountable task. "Actually, if you look at the [accreditation] literature… it's extremely broad and doesn't go down to a very detailed level," added Hobbs. "If I were them, I would be trying to work with the accrediting bodies now."

Recruiting students without A-level maths or physics will also inevitably create extra difficulties that can really only be addressed by investing heavily in a high ratio of staff to students. And even then, there's no guarantee it will work. UWE, for example, used to accept non-maths students onto its robotics degree and as a result recruited more creative people, but ultimately it wasn't sustainable, said Hobbs. "It was really difficult to get people from a non-A-level background up to speed in three years… We had people who found it wasn't for them because it was a very technical degree."

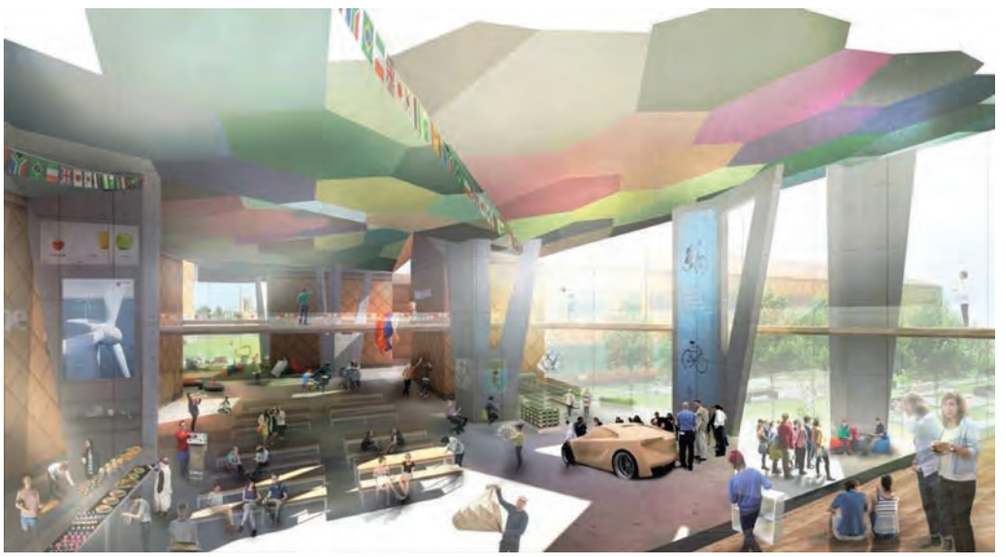
Perhaps the biggest question remains whether this kind of curriculum will produce the type of engineers the UK needs. Education, after all, is not the same as training. It arguably shouldn't be the job of universities to produce 'oven-ready' workers with the employability skills equivalent to several years' experience on the job, but rather engineers with a deep understanding of fundamental principles that they can apply to a range of technical problems. If companies want engineers trained in the practical aspects of their particular line of work, they should arguably hire more apprentices and sponsor their part-time university study.

"Current knowledge is very important but innovation is occurring at a speed that has never happened before," said Rodriguez-Falcon. "We're training engineers for jobs that don't exist yet that will use tools that haven't been invented. So the most important thing is that they have the principles and the mindset to tackle problems they haven't even imagined."

This doesn't mean, however, that practical assignments based on current real problems from industry can't form the basis of study at degree level. Indeed, project-based learning is very common even at the most academic universities. What an increase in this type of study may do is produce a type of engineer that is more focused on specific company problems rather than the biggest engineering problems of our age, but ones that are no less important to UK industry. "Grand challenges such as energy and water require a whole spectrum of people from in-depth researchers to technicians, but day-to-day commodity projects require different engineers," said Rodriguez-Falcon.

Ultimately, the UK's engineering skills issue isn't going to be solved by any single measure because the sector doesn't require a single type of engineer. It needs more people to come through the apprentice route who know a company's working practices inside out by the time they study degree-level engineering. It needs more top academic graduates to tackle complex technical and system-wide problems for the country's most innovative firms. And it needs engineers who are prepared to go into small and medium-sized companies in quiet, rural locations such as Herefordshire, bringing new energy and ways of thinking with them.

"Everybody's been saying this for more than a decade: the curriculum needs more women, it needs to be modernised, it needs to be more interdisciplinary and it needs additional skills to make young people more employable," said Usher. "This is a once-in-a-lifetime opportunity to bring industry and academia together, strip curriculum apart and say 'how can we build a modern, sector-focused curriculum that's fit for purpose and has the necessary quality?'"



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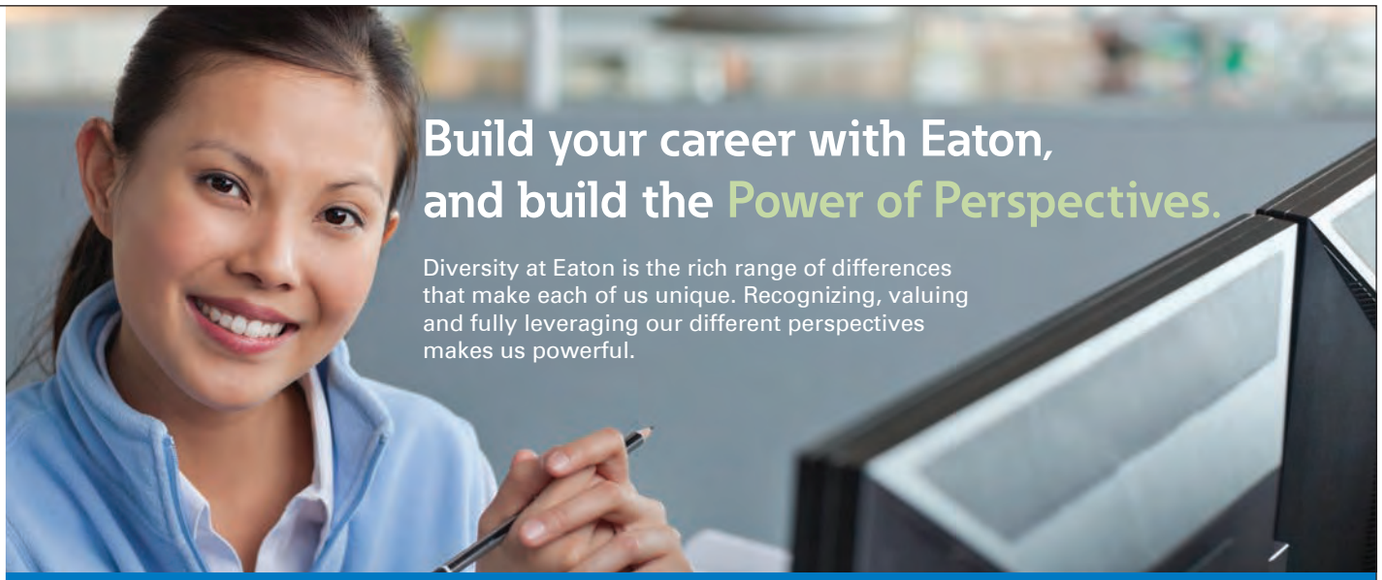

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Obituary of Edmund Beckett Denison, designer of the clock of the palace of Westminster

As the general election looms and the thoughts of the nation turn, however reluctantly, to Westminster, we can be certain that we are going to see the most distinctive feature of the Houses of Parliament, the clock that we're not supposed to call Big Ben, ever more regularly on our TV screens and newspapers.

The engineer who designed that clock, and the mechanism that produces its evocative chimes, was Edmund Beckett Denison, later raised to the House of Lords as the first Lord Grimthorpe, whose brief obituary appeared in *The Engineer*.

For our predecessors, Grimthorpe was notable for his clock making: he revolutionised the building of large public clocks. He invented a system that more or less eliminated friction in the clock's escapement – the component of the mechanism that converts the oscillation of the pendulum into the rotation of the escape wheel, the largest of the clock movement's gears.

Previously, large pendulum clocks used a system called a remontoire escapement, which used a secondary source of power to drive the clock's escape wheel. Every half-minute, the clock's pendulum mechanism winds up this secondary power source, so the clock's arms are isolated from the movement of the pendulum and vice-versa.

Grimthorpe took that idea further. He devised a system of suspended weights placed on either side of the pendulum rod, placed so that one of the weights was always "elevated in advance of the rising pendulum". In falling, it helped the pendulum to return to the other side of its arc, ensuring that it always had exactly the same driving effect. "The mechanism is exceedingly simple; it is very easy to make and need not be very accurate," *The Engineer* said. "Clocks fitted with it are therefore splendid timekeepers."

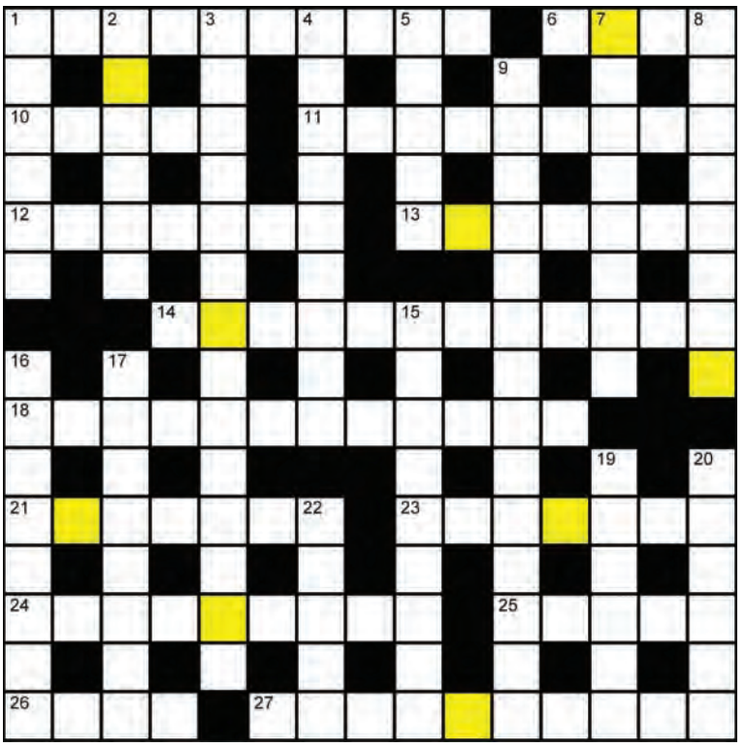
> **"Grimthorpe's system more or less eliminated friction in the clock's escapement**

Grimthorpe designed the Westminster clock in 1851; he was elected to the Royal Astronomical Society in 1866, and two years later was elected president of the British Horological Institute on the condition that he wasn't asked to attend dinners. We can only speculate whether it was the quality of the food or the company he objected to, but he was re-elected every year until his death. ***SN***

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

prizecrossword

When completed rearrange the highlighted squares to spell out a structure consisting of a row of evenly spaced columns. The first correct answer received will win a £20 Amazon voucher. Email your answer to jon.excell@centaur.co.uk



ACROSS

1 Happening by chance (10)
6 Unusually great in size (4)
10 Separate into parts (5)
11 A difficult problem (9)
12 Hole used to collect waste fluids (4,3)
13 Terrier with erect tail and ears (7)
14 Weight that balances another (12)
18 Establishments for higher learning (12)
21 Encloses in a container (7)
23 Poisonous metallic element (7)
24 High in price (9)
25 Solder together with highheat (5)
26 Large holding vessel (4)
27 Community of people smaller than a town (10)

DOWN

1 Evaluate the quality of (6)
2 A tall vertical cylindrical supporting structure (6)
3 Series of complex computer operations (4,10)
4 Alkaloid poisons that occur in tobacco (9)
5 Sisters of father or mother (5)
7 Landing area for aircraft (8)
8 Made hard or resilient especially by heat treatment (8)
9 Incapable of being pressed together (14)
15 Being concerned with the social and physical environment (9)
16 Most tranquil (8)
17 Rod used to hold a wheel on an axle (8)
19 Opening through which fluid is admitted (6)
20 Special importance or significance (6)
22 Move smoothly along surface (5)

Last issue's highlighted solution was ELECTRUM. The winner is Simon Williams.

origineering Anthony Poulton-Smith explores the origins of everyday engineering terms

Look up **'engine'** in the dictionary and it is defined as 'a device that converts energy into mechanical power'. Thus there were no engines before the 18th century and the birth of industry.

Yet there are records of it by 1300 and it was used to refer to 'a mechanical device' and particularly one used for warfare.

We also find the term used at least a century earlier. These earlier references use it in a variety of senses, including 'skill', 'craft', 'innate ability' and 'deceitfulness' or 'trickery'. These are the original usages, all derived from old French 'engin', meaning 'skill, wit, cleverness' in some instances and more often as 'trick, deceit, stratagem'.

Further back, we find late Latin 'ingenium' 'war machine' and earlier still 'inborn qualities, talent'. It is the earlier use of ingenium that most interests us as this has also resulted in the word 'ingenuity'. When we hear both words the link is clearer than seeing it in writing. I know of no engineer who will not be delighted to learn his job title is, at least etymologically speaking, akin to that of a genius.

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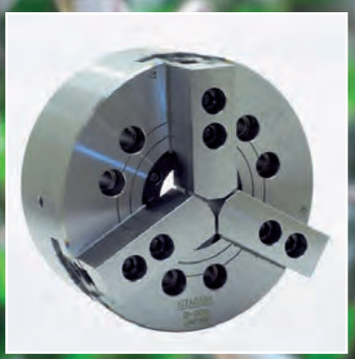

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