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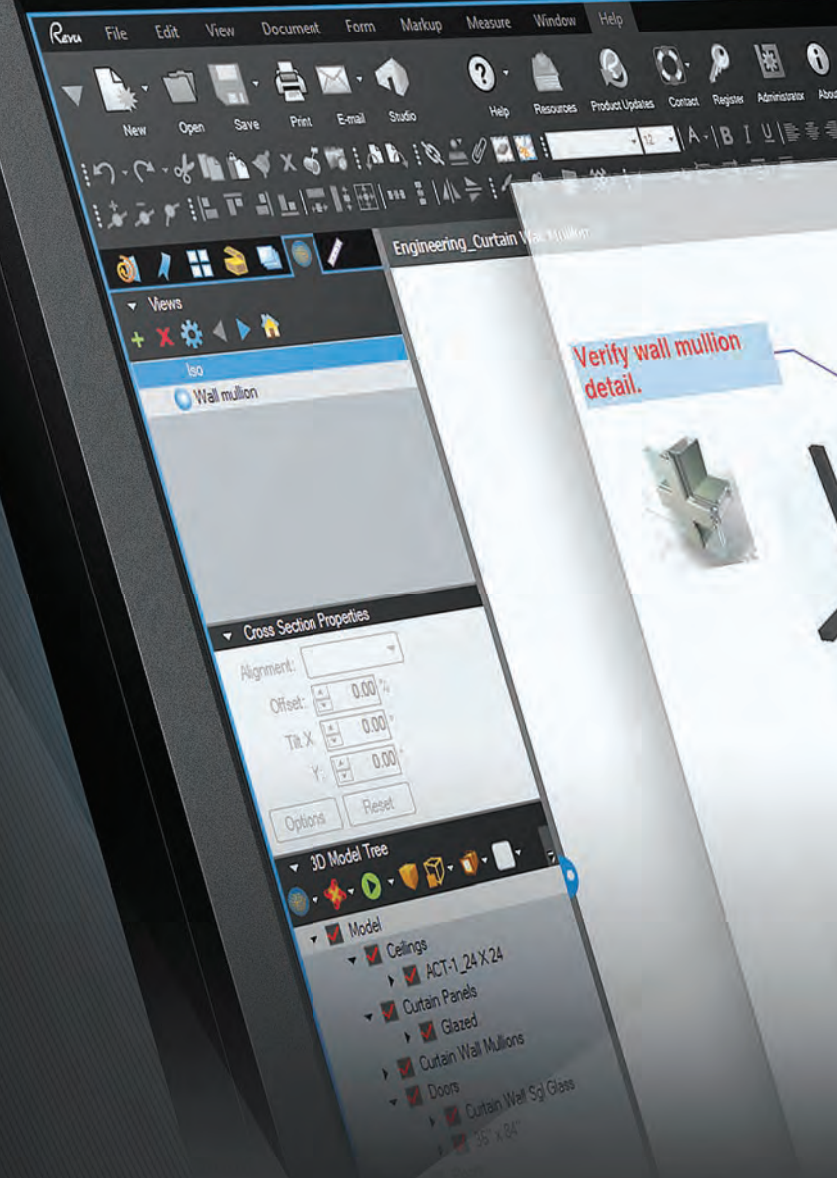
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inour opinion

A divisive issue



Despite years of industry hand-wringing, dozens of targeted initiatives, pressure from government and dire warnings from all and sundry on the consequences of failing to deal with it, UK industry's shameful gender divide shows little, if any, sign of narrowing.

Indeed, according to the Institution of Engineering's (IET's) latest skills report, the percentage of women in technical and engineering roles currently stands at around nine per cent, making the UK's industrial workforce one of the least diverse in Europe. *The Engineer's* 2015 salary survey, which was published earlier this year, painted an ever more concerning picture, with women making up just 5.5 per cent of our survey respondents.

Whenever we write about this issue we're met with a predictable response from a small but vocal minority: stop banging the politically correct drum, they whine; if women don't want to be engineers then don't make them.

Addressing the gender divide is more than about fluffy CSR notions

But as we've long argued, addressing the gender divide is about far more than some fluffy notion of corporate responsibility. Major engineering organisations across the board recognise that not only is diversity at the heart of the most successful and

innovative organisations but, with a skills shortage looming in many key sectors, it is economic folly to ignore the skills of half of the population. What's more, with proportions of female engineers much higher in other parts of the world, and school-age girls regularly outperforming boys in scientific subjects, there's zero evidence that women are somehow less cut out for engineering.

In this issue's special Women in Engineering section (p59), we take a look at some of the reasons for this gender imbalance, and offer some suggestions on how industry might work more effectively to encourage more women into the profession. Unsurprisingly, a major priority in the long term is shifting the apparently widely held perception among school-age girls that engineering is a male profession.

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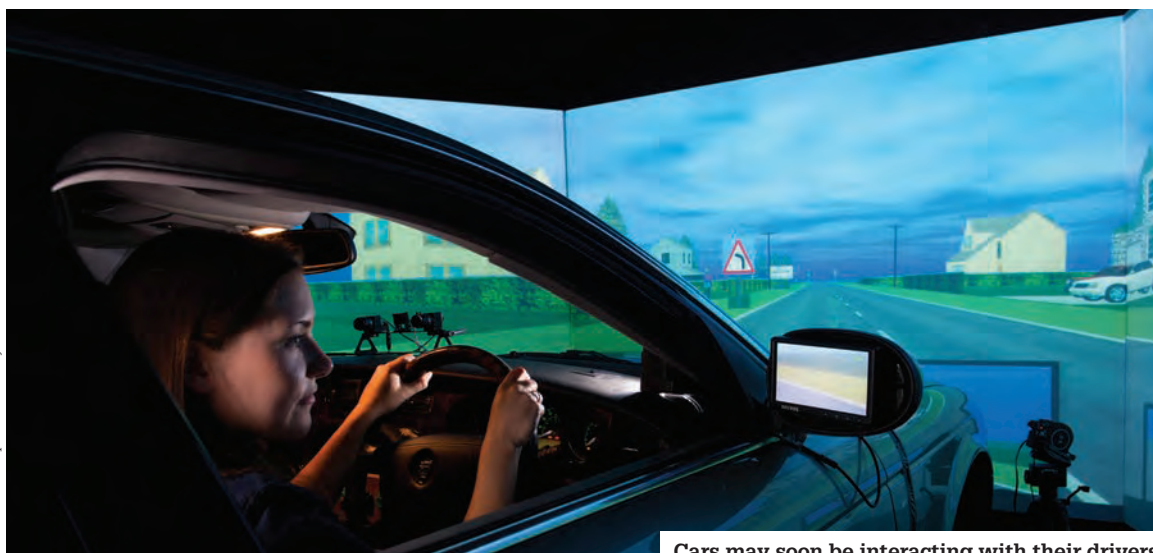
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Cars may soon be interacting with their drivers

AUTOMOTIVE

Smart cars that have a sense of everything

Research teams investigate the autonomous vehicles of the future

BY HELEN KNIGHT

Autonomous cars that map their environment, communicate securely with other vehicles and understand and interact with their drivers could one day be a reality.

This is the aim of an £11m programme jointly funded by Jaguar Land Rover and EPSRC.

It aims to address some of the fundamental challenges on the road to fully autonomous vehicles, including public safety concerns.

The research programme includes projects looking into radar and video sensing technologies, distributed control systems and cloud computing. The projects will also look at how drivers react to autonomous vehicles and how the transition between human control and automated systems should best be managed.

Ten UK universities and the Transport Research Laboratory will collaborate on the programme, called Towards Autonomy – Smart and Connected Control (TASCC).

The Pervasive low-Terahertz (THz) and Video Sensing for Car Autonomy and Driver Assistance project, for example, led by Dr Marina Gashinova at Birmingham University, will use low-THz sensors and advanced video analysis to develop a system capable of mapping a vehicle's terrain and detecting vehicles, cyclists and pedestrians.

Existing sensors used on autonomous vehicles tend to be based on electro-optical technologies, such as LIDAR. These tend to be unreliable when the weather is bad, according to Gashinova, but radar-based technologies, and in particular the proposed low-THz radar, can see through rain, spray or snow.

"Low-THz has never been used for medium and short-range sensing, but with a very small wavelength, we will be able to achieve much higher-resolution images, approaching optical image quality," she said.

Low-THz radar will be combined with video imagery for use in both driver assistance systems and autonomous vehicles.

The technology can also accurately measure the distances between the vehicle and other objects on the road, including their speed, to build up a 3D image of the car's surroundings.

According to Southampton University's Prof Neville Stanton – who is leading a project called Human Interaction: Designing Autonomy in Vehicles – one of the largest gaps in the understanding of vehicle automation is how drivers will react to it.

The project will study a wide range of drivers with different levels of experience and expertise, progressing from a vehicle simulator to a test track. It aims to develop personalised interfaces, which adapt to the driver.

Similarly, a research team led by Dr Dongpu Cao at Cranfield University will investigate the collaboration between humans and autonomous systems, including whether the use of such technology could reduce a driver's attention to the road and how this can be avoided.

The Secure Cloud-based Distributed Control (SCDC) Systems for Connected Autonomous Cars project, led by Dr Mehrdad Dianati at Surrey University, will investigate the use of wireless technologies and cloud computing, to allow vehicles to share information.

A team led by Dr Nathan Griffiths at Warwick University will apply machine learning and data mining and processing techniques to develop cars capable of learning about their occupants and adapting safety systems accordingly, advising them on how best to avoid congestion and even predicting the driver's destination.

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Nuclear finance

The financing deal for Hinkley Point C has been confirmed, with a price tag of £18bn according to French utility and lead contractor EDF. Due for completion in 2025, the facility will see a 33.5 per cent stake controlled by China General Nuclear Power (CGN), which will provide a £6bn investment in return. EDF said it will also consider financing from other areas while retaining a majority share.

Burning ambition

Multifuel Energy has been given consent to construct the Ferrybridge Multifuel 2 Power Station at Knottingley, West Yorkshire. By burning fuel derived from refuse and industrial and commercial waste, such as wood, the plant will be capable of producing up to 90MWe of electricity. About 35 permanent positions will be created once the station is operational.

Easy virtues

The World Bank's ease of doing business index places the UK sixth out of 189 countries, ahead of the US, Germany and Japan. Actions to improve the ease of doing business include boosting skills and productivity by raising the quantity and quality of apprenticeships in England to three million starts by 2020, and investing £6.9bn in UK research infrastructure up to 2021.

Third way

The Office for Nuclear Regulation has completed Step 3 of the Generic Design Assessment of Hitachi-GE's UK Advanced Boiling Water Reactor nuclear power station design. The third phase of GDA looks at the safety justifications, with the ONR concluding that satisfactory progress has been made by Hitachi-GE to move into the final assessment stage, which Hitachi-GE expects to complete in December 2017.

TRANSPORT

In the Hyperloop

760mph pods 'could shoot from London to Glasgow in 30 minutes'

BY CHRIS PICKERING

Britain could be a prime candidate for Elon Musk's Hyperloop mass transportation concept, according to a key figure behind the project.

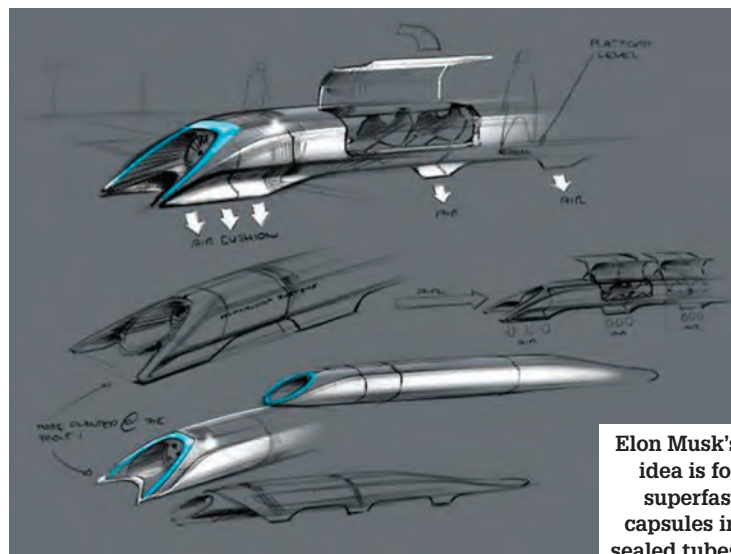
Bibop G Gresta, chief operating officer and deputy chairman of Hyperloop Transportation Technologies (HTT), told the Construct//Disrupt conference, hosted by BaseStone in London, that the 760mph system could soon be a reality.

"We see the UK as one of the first possible candidates for the construction of a full-length Hyperloop," he said, adding that the company had the technology "to connect London to Glasgow in as little as 30 minutes. And we could build it within five years."

The idea of the Hyperloop was put forward in a white paper released by Musk in 2013. A number of companies, including HTT and Hyperloop Tech, have been established to develop the concept.

The idea is that pods will run in sealed tubes kept at very low pressure (about one millibar) by a series of pumps. A cushion of high-pressure air will support the pods without the need for conventional rails or magnetic levitation. This cushion is generated by a compressor, aided by aerodynamic effects from the pod's motion.

The same compressor will suck air away from the front of the pod, which is then expelled out the back. Linear induction motors will accelerate



Elon Musk's idea is for superfast capsules in sealed tubes

the pod initially, with boosts every 70 miles or so.

For the pod to move at 760mph, Musk suggests mounting the Hyperloop on 6m pylons to minimise turns and elevation changes.

BaseStone founder Alex Siljanovski said it may be possible to construct such a structure in five years. "One of the key advantages of Hyperloop is that it's designed to be run on pillars rather than through tunnels. Also, the use of a tube with a regular diameter across the entire length lends the construction of the structure to off-site modular building, which, depending on how much happens in parallel, could result in a fast delivery method."

PHARMACEUTICALS

Keep an eye on bioreactors

Researchers in Ireland develop moving sensor capsule

BY HELEN KNIGHT

A sensor capsule designed to move through bioreactors, monitoring their environment, could improve the quality of biopharmaceutical treatments.

Biopharmaceuticals – treatments such as vaccines and gene, cell and protein therapies derived from biological materials – comprise a growing area of medicine. But producing medicines from materials such as living tissue and cells within bioreactors requires careful monitoring.

Wireless sensor capsules being developed at the Tyndall National Institute, Cork, and the National Institute for Bioprocessing Research and

Training (NIBRT) in Dublin are designed to move around the bioreactor, monitoring factors that might affect product quality or yield.

By contrast, existing sensors are fixed, meaning they can monitor only material that passes directly over them, according to Dr Karen Twomey, staff researcher at Tyndall.

The capsules contain sensors and associated circuitry, encapsulated in a biocompatible packaging.

In the first generation of the device, which has been built, an interface circuit connects to the different sensors, which are also connected to a power supply and microcontroller.

A miniaturised RF transmitter allows the device to communicate wirelessly with an external receiver.

By continuously monitoring the environment in the bioreactors, the capsule will help biopharmaceutical manufacturers to more precisely control the process, said Twomey. This could improve their ability to produce therapeutic proteins.

Researchers now plan to redesign the sensor instrumentation and optimise it for use in the capsule. Enterprise Ireland is backing the project, known as the Process Analytical Technology Sensor Capsule (PATsule).



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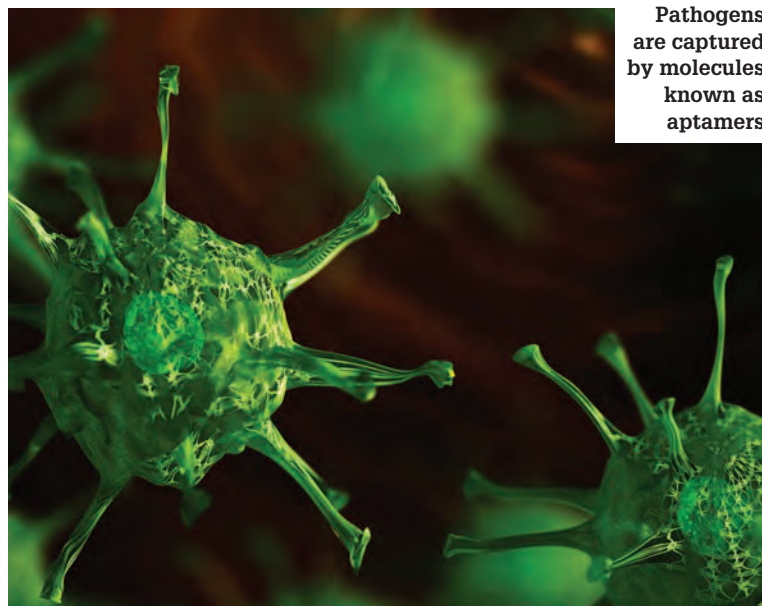
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Pathogens are captured by molecules known as aptamers

MEDICAL

How bad can it get?

Doctors design portable sensor to predict diseases' severity

BY HELEN KNIGHT

A portable device designed to detect not only the presence of an infection, but also how a patient's immune system is responding to it, could help doctors predict the likely severity of a disease.

The point-of-care sensor, being developed by an EU-funded consortium, can detect invading pathogens, plus small molecules produced by the immune system in response to the disease.

This can be used to predict how the disease will evolve in a particular patient, according to Leopold Georgi at the Technische Universität Berlin, who is co-ordinating the Platform for Ultra-sensitive Point-of-Care Diagnostics for Infectious Diseases (PoC-ID) project.

A prototype paediatric device is being developed to detect the presence of respiratory syncytial infection (RSV).

The RSV virus, which mildly infects nearly all children before their third birthday, can occasionally lead to bronchiolitis and pneumonia.

"It's quite hard to say with RSV if it will be severe enough for the infant to be hospitalised, or if it will be just a small fever," said Georgi. "That is why we want to measure the immune response, because our immune system has the best biosensors

you can have...so we want to combine the sensor technology of the body with sensors to identify the pathogen itself."

Pathogens and small molecules within a patient sample are first captured by RNA oligonucleotide molecules known as aptamers. The researchers chose aptamers rather than antibodies as they are able to capture smaller molecules, making them more suitable for identifying an immune response, said Georgi.

"They are also easier to handle during production, because antibodies typically cannot survive temperatures of 45°C or higher, while aptamers are much more stable, and they are also more stable against enzymes in the body."

The aptamers are placed on top of a graphene sensor, which can detect small changes in the electrical charge along its surface caused by the presence of pathogens and small molecules.

However, since graphene is a two-dimensional material that is very difficult to bind to other surfaces, a layer of carbon nanomembrane is first placed in between. This 2nm-thick membrane sticks tightly to the graphene as a result of intermolecular forces. The aptamers are then attached to the membrane.

MANUFACTURING

Follow that lizard

Geckos may hold the key to new adhesives

BY CHRIS PICKERING

Ford is delving into the growing field of biomimicry in a search for new adhesive materials that will help it toward more sustainable manufacturing.

Existing solutions for gluing foam materials to metals and plastics can make it virtually impossible to disassemble the parts for recycling. Now, Ford is looking to the gecko for inspiration as part of a research project with Procter & Gamble.

The gecko's ability to adhere itself on to many surfaces has been known for centuries: a large lizard weighing about 150g could theoretically support upwards of 40kg if it gripped with all four feet.

The gecko's ability is well documented, but it wasn't until 2002 that researchers fully understood it. The answer lies in millions of hair-like structures, known as setae, found on their feet. The molecules within these have an imbalanced distribution of electrons; their overall charge is neutral, but they can generate an attractive force when placed near other imbalanced molecules.

These so-called van der Waals forces are relatively weak in isolation, but they become significant when spread across millions of points.

More importantly for Ford, and other companies that are engaged in this research, the gecko can overcome these forces at will.

The race is now on to replicate this behaviour synthetically. Ford is by no means the only company looking into it, and potential solutions include synthetic setae made from polymers or carbon nanotubes.

"Solving this problem could provide cost savings and certainly an environmental saving," said Debbie Mielewski, senior technical leader for plastics and sustainability research at Ford.

"It means that we could increase the recycling of more foam and plastics, and further reduce our environmental footprint."

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RENEWABLES

Wave goodbye?

Wave energy developer calls in administrators for possible sale

Aquamarine Power has gone into administration due to a lack of private sector backing to supplement public funding support.

The Edinburgh-based company, which developed the Oyster wave power concept, says it has called in administrators to manage the business and to seek a sale or investment.

The wave energy developer has been testing its full-scale Oyster wave energy machines at the European Marine Energy Centre (EMEC) in Orkney.

The concept itself is a buoyant, hinged flap that is attached to the seabed

approximately half a kilometre from the shore. The movement of the flap pushes high-pressure water to drive an onshore hydroelectric turbine.

Paddy O'Kane, Aquamarine Power's CEO said: "Oyster is the only wave technology to have proven it can operate in all ocean conditions...[This] news underscores the financial, as well as technical challenge in bringing an entirely new form of energy generation to commercialisation. New private sector funding is required now to deliver our technology roadmap." **JF**

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IMAGING

Hard core imagery

Camera can remotely image radiation

BY HELEN KNIGHT

UK researchers have developed a camera that can image the radiation emitted by a nuclear reactor from outside its core.

The camera, which can simultaneously image high-intensity "fast neutrons" and gamma rays, could monitor the burn-up of fuel in nuclear power plants to ensure they are operating efficiently. It could also allow clean-up crews to remotely detect the source and location of radiation within a reactor, in the event of a nuclear disaster such as that at Fukushima Daiichi in 2011.

The camera was developed at Lancaster University by research student Jonathan Beaumont and Malcolm Joyce, a professor of nuclear engineering, and details were published in the journal *Nature Communications*.

Conventional nuclear reactor detectors are installed inside the core itself and do not tend to survive over the lifetime of a power plant. But the devices can be difficult to reach in order to check or replace, according to Joyce. "You would typically have to switch off the reactor in order to gain access to the detectors," he said.

In the event of an accident such as the one that took place at Fukushima, these detectors

are likely to be destroyed completely, he said.

The cat's eye camera, which weighs 20kg and can fit inside a suitcase, could be carried to the site and operated remotely, generating images in near real-time. The camera, developed with Cumbria-based Createc, consists of a detector plate located behind a collimator, a type of filter, which has a slit-shaped hole similar to a cat's pupils. This limits the amount of radiation that can hit the detector.

Without the slit collimator, radiation emitted from the reactor would hit the detector from all directions, said Joyce. "If you use a traditional collimator, which is essentially just a pipe, then it can be swamped," he said. "It would be like looking at the sun."

What's more, the slit shape makes it quicker and easier to find the 'sweet spot' for imaging the level and direction of radiation inside the core.

That is because conventional tube-shaped collimators must be scanned across every position along the horizontal and vertical axis in order to find the radiation source. In contrast, the slit-shaped collimator allows operators to look along a line across the core, said Joyce.

ELECTRONICS

Measurement gets down to nanoscale

New technique has been designed to manipulate terahertz radiation

BY HELEN KNIGHT

The high-frequency electronic properties of single nanoscale objects can be measured with a technique designed to manipulate terahertz radiation.

Carbon nanotubes, quantum dots and other nanoscale objects are so small that it has previously been impossible to study them individually with terahertz radiation. Instead, researchers have had to study the objects in bulk, according to Prof John Cunningham of Leeds University, who led the research.

But if industry is to continue producing smaller electronic systems, it will need to understand exactly how they work at the nanoscale.

The team, with funding from EPSRC and Leeds University, has developed a technique in which a nanostructure is used to filter the terahertz waves. By passing the terahertz radiation through a tiny region of semiconductor, with gates on its surface, the researchers can control the spectrum of the radiation passing through it.

The device consists of a nanostructure embedded within a microscopic waveguide, where it is split into three cavities.

A voltage is applied to the device, which controls how electrons inside the cavities oscillate. This in turn determines the frequency of electromagnetic radiation that each cavity can transmit.

"We can control the properties of the terahertz radiation moving through the object using the gate," said Cunningham.

This allows waves to be shaped and modified, which means that information can be encoded in the signal, he said. "When the terahertz radiation is passed down the waveguide, it interacts with the nanoscale object."

Cunningham added: "The technique in principle allows you to measure almost any nanoscale electronic object."

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AUTOMOTIVE

Four-door turn-on

Aston Martin considers electric concepts

Aston Martin has unveiled a fully electric concept version of its Rapide S four-door sports saloon.

The RapidE concept has been developed in collaboration with Williams Advanced Engineering in a project that was partly funded by venture capitalist firm ChinaEquity.

During a launch event in London, Aston Martin and Chinese investment group ChinaEquity announced an agreement to explore development of a production version of the RapidE concept. If successful, the new luxury sports car would be constructed at Aston Martin's HQ in Gaydon, Warwickshire, and could be brought to market in around two years. The company has not yet revealed performance specs.

Dr Andy Palmer, CEO of Aston Martin, said: "We see luxury electric vehicles as an intrinsic part of our future product portfolio and welcome ChinaEquity into the next phase of study for the project development. The exciting RapidE concept tangibly demonstrates the capability and ambition of Aston Martin towards developing low- and zero-emission sports cars." **JE**



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Prof Yiannis Vardaxoglou plans to build PCBs without using harsh processes

ELECTRONICS

PCBs go greener

Team develops new manufacturing method

BY HELEN KNIGHT

A more environmentally friendly way to manufacture printed circuit boards for mobile phones and other electronic devices is being developed by researchers in the UK.

The SYMETA – Synthesising 3D metamaterials for Radio Frequency (RF), microwave and Terahertz (THz) applications – programme, being funded by a £3.9m grant from EPSRC, is aiming to develop a new way to design and fabricate high-frequency communications circuitry and transmission lines.

Existing methods used to manufacture and assemble printed circuit boards, such as etching, are extremely damaging to the environment, involving harsh chemicals, high temperatures and high volumes of water.

By using metamaterials – engineered composites with electromagnetic properties not found in nature – the research team, led by Prof Yiannis Vardaxoglou at Loughborough University, plans to build circuits without the use of these harsh processes.

The researchers plan to develop materials capable of being printed onto a surface through a nozzle.

Using 3D-printing techniques to build high-frequency circuits with metamaterials should reduce the number of manufacturing stages that are involved, and

also the number of components that are needed.

The technique will also allow the researchers to produce circuit boards with unusual shapes.

Metamaterials have complex internal structures on scales smaller than the wavelength of the light they interact with, allowing them to produce unusual effects.

The materials give researchers a new platform to create functional properties, said Prof Ian Reaney at Sheffield University, who is involved in the project, which also includes the universities of Exeter, Oxford, and Queen Mary University of London.

“The metamaterial can create new functionalities, so it can create different frequencies for an antenna, for example, or we can do things in a much more confined space that would take a large volume to do with a conventional material,” he said

“It gives you a new toolkit, particularly if you are dealing with optical and RF devices, which rely on the interaction of electromagnetic radiation with matter.”

The metamaterial circuitry could be used in industries such as aerospace, space, healthcare and defence.

The programme is part of a £21m investment by the EPSRC into research that has the aim of tackling some of the major challenges facing science and engineering.

AUTOMOTIVE

Doubling up for the output of fuel cells

Electric compressor design delivers air at high pressure and efficiency

BY CHRIS PICKERING

A UK-based technology company has developed a new electric compressor design, which could double the output of a hydrogen fuel cell.

Fuel cells require a constant source of oxygen to sustain the chemical reaction that they use to release positively charged hydrogen ions. Supplying the hydrogen at high pressure is not generally a problem, but the flow of air can be a limiting factor.

“Our proprietary high-speed motor and control technology allows us to deliver air at a much higher pressure [than existing systems],” said Bryn Richards, Aeristech CEO. “No other motor control arrangement is able to deliver at this pressure with such a high efficiency.”

The company has yet to release specific technical details, but the system is understood to use a sophisticated control system capable of maintaining a very consistent torque output. This allows the motor to be

powered directly by the fuel cell without the use of an intermediate voltage regulator. Aeristech has claimed the design could cut the mass of a complete motor, compressor and control unit package by as much as 70 per cent.

“Traditional switched reluctance type high-speed motors would be unable to operate continuously at such high continuous power levels because of thermal management issues,” said Richards. “Our competitors tend to use heavy low-speed permanent magnet motors with step-up transmissions to run their compressors, which creates a bulky system.”

In 2011 Aeristech was funded by Innovate UK for feasibility studies into disruptive low-carbon vehicle technology. This contributed to the development of a 10kW compressor, which is currently undergoing testing.

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AUTOMATION

Seems a sound move

Sound waves can pick up small objects

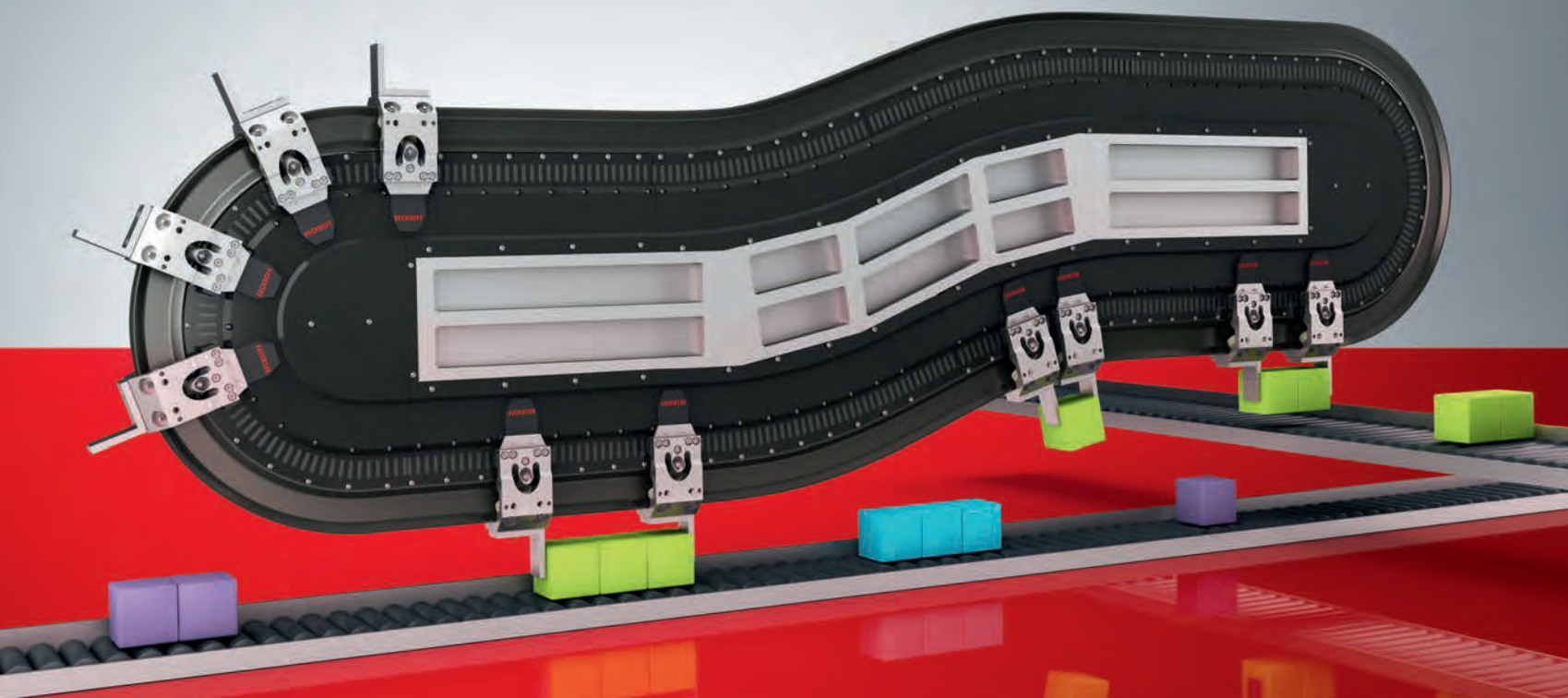
Researchers have built a working tractor beam that uses high-amplitude sound waves to generate an acoustic hologram that can pick up and move small objects.

The technique, developed by researchers from the universities of Bristol and Sussex in collaboration with Ultrahaptics, could be developed for applications including a sonic production line to transport and assemble delicate objects without physical contact.

The researchers used an array of 64 miniature loudspeakers to create high-pitch and high-intensity sound waves. The tractor beam is said to work by surrounding the object with high-intensity sound and this creates a force field that keeps the objects in place. By carefully controlling the output of the loudspeakers the object can be held in place, moved or rotated.

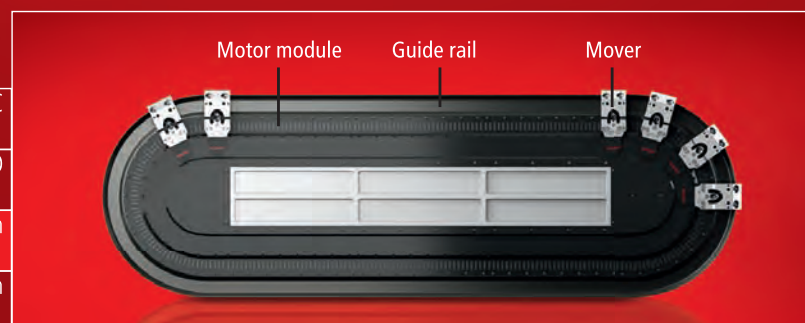
Bruce Drinkwater, professor of ultrasonics in Bristol University's Department of Mechanical Engineering, said: “We all know that sound waves can have a physical effect. But here we have managed to control the sound to a degree never previously achieved.” **JF**

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New Automation Technology **BECKHOFF**



Freevolt arrays could be used to power a digital display

POWER

Harvest time for low-energy devices

Drayson Technologies hopes device will help power Internet of Things

BY ANDREW WADE

Drayson Technologies has launched Freevolt, a device that is able to harvest ambient radio frequency (RF) waves in order to power low-energy connected devices.

Former government science minister Lord Drayson, CEO of the firm, hopes the device will help power the Internet of Things (IoT).

"Companies have been researching how to harvest energy from WiFi, cellular and broadcast networks for many years," said Drayson. "But it is difficult, because there is only a small amount of energy to harvest and achieving the right level of rectifying efficiency has been the issue – up until now."

Freevolt's patented technology was developed by an international team from Drayson Technologies and Imperial College London. The device uses a multi-band antenna in combination with an "ultra-efficient rectifier", converting the alternating current to direct current. The third core component is a power management module that tracks the power, enhancing the efficiency of the energy collection.

Although the amount of energy harvested by Freevolt is relatively minor, there are

a host of low-energy connected devices that it could potentially power, including smoke alarms, building sensors, retail beacons, basic CCTV and wearables. According to Drayson, the technology is also scalable, opening up the possibility of more advanced devices being powered in the future.

"The amount of energy that Freevolt can harvest is proportionate to the size of the harvesting antenna, and the number of harvesters we use," he said. "As we increase the size and number of harvesters – a bit like is done in a solar-panel array – the amount of power we can harvest goes up."

Drayson said Freevolt arrays could be used to panel the side of a house, or power an advertising display. Because they rely on radio waves rather than light, they don't have to be orientated in a specific direction in order to function. This also means they can be hidden from sight for aesthetic purposes.

"Unlike a solar panel that has to be on the outside to see the sun, these harvesters can be inside the brickwork," said Drayson. "This is something we may well see in the future."

MEDICAL

Tags have dedication for daily medication

System tells people when it is time to take prescribed drugs

BY HELEN KNIGHT

A system has been developed that will help elderly patients to remember when to take their medication.

Dubbed My Health Tags, the system consists of a reminder device with a display, which tells people it is time for their medication, and sensor tags

crystals, inside which are coloured dye molecules. To display a message on the screen, the liquid crystals simply rotate the dye molecules, according to Steve Kitson, CEO of Folium Optics. "So depending on how we rotate the crystals, you either see the colour or you don't."

If the user does not respond to a message to take their medication within a set time, the display will begin to flash, followed by a beep if that prompt is also ignored.

Once the user does go to their medicine cabinet, each of their drug packets will be fitted with a smart tag, which either display the message 'don't take now' or 'take now'.

The tags are equipped with a sensor to detect when the packet is picked up, at which point the display changes to prompt the user to press a button when they have taken their medication.

"The whole system is connected together wirelessly, so that information can be sent to the cloud, to be shared with a pharmacist, doctor, or loved one," said Kitson.

“The system is connected together wirelessly, so that information can be sent to the cloud or shared with doctors

fitted to each packet that register adherence.

The display and tags are being developed by start-up Folium Optics with £1m funding from the Small Business Research Initiative for Healthcare.

The reminder device is in the shape of a photograph holder, with a flexible plastic display screen. The display consists of a layer of liquid

ROBOTICS

All hail the robo rider

Motobot heads for motorcycle racetrack

Yamaha has developed Motobot, a motorcycle-riding robot that it hopes will one day match world champions on the racetrack.

Under the banner of 'Beyond Human Capabilities', Yamaha said it is using its knowledge of industrial robotics and motorcycles to develop Motobot, which will inform future autonomous systems.

The company said mechanism improvements, algorithm enhancement through machine learning and other factors required for high-speed track riding will eventually make other types of high-level riding possible.

The prototype Motobot analyses data for vehicle speed, engine rpm, and machine attitude to control its six actuators – for operating the steering, throttle, front brake, rear brake, clutch and gear pedal – when riding an unmodified R1M motorcycle. Yamaha believes that technology for machine position recognition will be utilised by Motobot to autonomously manoeuvre around a racetrack at the limits of the motorcycle's performance so it can improve lap times. **JF**



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Driver assistance systems protect pedestrians

AUTOMOTIVE

Pedestrian affair

Protection system could appear on cars

BY CHRIS PICKERING

Bosch has plans for a pedestrian protection system that could be fitted to production cars as early as 2018.

The system, developed at Bosch's R&D centre at Renningen, Germany, will automatically intervene if it senses the driver's own evasive action will not be enough to prevent a collision.

It uses an existing stereo video camera to monitor pedestrians and oncoming traffic. An onboard computer plots the likely trajectory of pedestrians within the camera's field of view.

If a collision is thought to be likely the system will calculate the best way to take evasive action. But it doesn't activate until changes to the steering angle, vehicle speed and yaw rate indicate that the driver has initiated a manoeuvre. From that point, the system can brake or steer as required to prevent the collision, although the steering assistance is such that the driver can override it.

According to Dr Thomas Gussner from Bosch's corporate research and advanced engineering department, provided the driver reacts at least half a second before a potential collision, the assistance system can help avoid it in 60 per cent of cases.

The hardest part of the project is correctly interpreting the images from the camera.

Gussner said: "Pedestrians can change their state of motion very quickly. For example, they might suddenly stop or walk back or – worst of all for an evasion system – start running.

"To address these challenges we developed a pedestrian model jointly with Bosch accident research, which is based on the evaluation of a large database containing real pedestrian accidents that were recorded by dash cameras. This model allows us to predict the likely future position of a pedestrian depending on the current situation and plot the evasion trajectory accordingly."

Another crucial factor is

ensuring that the area the car moves into is clear of potential danger. "[The system will only trigger] if the evasion path of the

vehicle is clear and will remain clear," said Dr Gussner.

"This includes some very pessimistic assumptions about the trajectory of potentially dynamic objects, such as pedestrians or oncoming traffic. For example, we consider the case that a pedestrian standing on the other side of the street might unexpectedly start running into the road."

“ Pedestrians can change their state of motion very quickly

AUTOMOTIVE

Flax fibres geared up for roof panels

Hybrid structures set for use on vehicles

BY CHRIS PICKERING

A group of UK engineering companies has developed a prototype roof panel to showcase the benefits of flax fibres in automotive manufacturing.

The CARBIO project includes representatives from Jaguar Land Rover, plus composite materials companies, engineering consultancies and academic facilities. It was formed to investigate the potential of carbon-flax hybrid structures for automotive use.

The prototype roof is constructed from the Biotex Flax material developed by CARBIO member Composites Evolution. It uses a 50:50 carbon/flax hybrid biocomposite, which is said to be around 15 per cent cheaper than traditional carbon fibre and seven per cent lighter for a comparable bending stiffness.

Various members of the CARBIO group contributed to panel. Delta Motorsport carried out the initial design, while SHD Composite Materials was responsible for prepegging the Biotex Flax material and

KS Composites carried out the manufacturing.

"The adoption of carbon fibre-epoxy composites to reduce vehicle weight is presenting significant challenges to the volume automotive industry," explained Dr Brendon Weager, technical director of Composite Evolution and project lead for CARBIO.

"Compared to carbon, flax fibres are renewable, lower in cost, CO₂ neutral and have excellent vibration damping properties. In addition, bio-epoxy resins based on cashew nut shell liquid [CNSL] can offer enhanced toughness, damping and sustainability over synthetic epoxies."

Jaguar Land Rover has found components made from CARBIO to be approximately 28 per cent lighter than aluminium and 55 per cent lighter than steel. Because of the flax material's inherent NVH (noise, vibration and harshness) properties it was also found that less sound-deadening material was required than traditional carbon fibre, aluminium or steel, potentially saving more weight.

ELECTRONICS

Ink innovations

New method for printing graphene inks

A high-speed method for printing graphene inks could lead to new ways of manufacturing printed electronics, its UK inventor claims.

Developed by researchers at Cambridge University in collaboration with Novalia, the method allows graphene and other electrically conducting materials to be added to conventional water-based inks and printed using commercial equipment.

The technique works by suspending tiny particles of graphene in a 'carrier' solvent mixture, which is added to conductive water-based ink formulations.

The ratio of the ingredients can be adjusted to control the liquid's properties, allowing the carrier solvent to be easily mixed into a conventional conductive water-based ink to significantly reduce the resistance.

The graphene-based inks have been printed at a rate of more than 100m per minute, which is in line with commercial production rates for graphics printing, and far faster than earlier prototypes. The group tested the method on a typical commercial printing press, which required no modifications in order to print with the graphene ink. **JE**

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DANCING THE SKIES



AMD FirePro graphics has transformed the way Wills Wings designs its hang gliders

Crabbing, rolling, scratching and yawing, a hang glider playing the thermals can attain thrilling heights over numerous landscapes between launch and final glide. The current world distance record, set in 2012, stands at 473 miles after eleven hours in the air. That's for an aircraft that can be carried on the shoulder and assembled in 5 minutes. With super strong materials and light carbon tubing, highly engineered hang gliders have come a long way since the sport first became popular in the 1970s. One company that has been around since that decade is Wills Wing, which has a small team of dedicated enthusiasts producing about 700 hang gliders each year. Steve Pearson has been managing the company since 1977. "We have outlasted many competitors, surviving and growing because we embrace new technology and tools."

Using CAD, CAM and CAE simulation software, Wills Wing controls all design and manufacturing in-house. It employs SolidWorks® for 3D mechanical and electrical design with NEi Nastran for finite element analysis, and has its own CNC machine for producing various free form parts. Despite this level of

sophistication, Wills Wing has a minute infrastructure – Pearson's workstation. He explains how this is achieved. "Graphics play a big part, especially as our products are typically 10 meters wide. We also have crucial components with tolerances of a fraction of a mm. Being able to visualize them all in detail is very important." Pearson uses AMD FirePro professional graphics. "I had an AMD FirePro V5900 that I was very happy with. Then I read the benchmarks for the AMD FirePro W7000 and decided to invest in that. The difference was remarkable, particularly when using RealView for SolidWorks."

According to Pearson the ability of the small team at Wills Wing is growing exponentially. "We use the best materials and produce high quality products at a lower price point because we keep overheads down. The AMD FirePro W7000 helps us with this because it is extraordinarily economical and amazingly quick for such a modest investment."

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The future of fusion

Controlled fusion has the potential to be a long-term energy source. The chief executive of Tokamak Energy explains the next steps

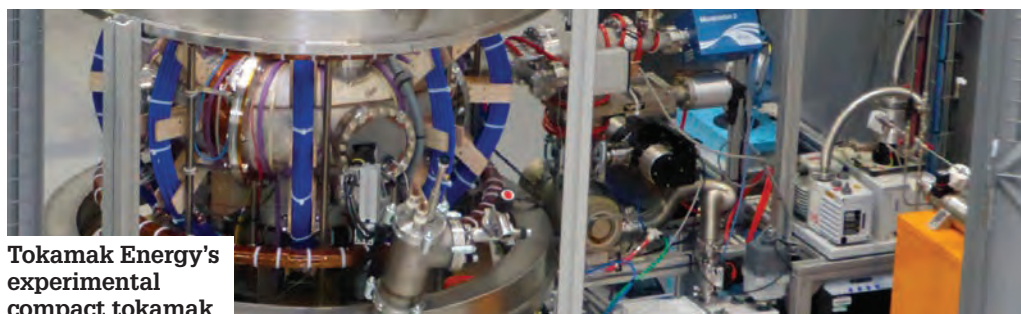
The world needs abundant, clean energy. Fusion – with no CO₂ emissions, no risk of meltdown and no long-lived radioactive waste – is the obvious solution and has been for decades, but it is so hard to achieve. Controlled fusion is the ideal long-term energy source, complimentary to renewables. But why has it proven so difficult?

The challenge is that fusion only happens in stars, where the huge gravitational force creates pressures and temperatures so intense that usually repulsive particles will collide and fuse. On Earth we need to create similar conditions and hold a hot electrically charged plasma at high enough pressure for long enough for fusion reactions to occur. This is understandably tricky and the problem has occupied some of the world's brightest minds for over half a century. Different approaches to fusion energy are being pursued, from cold fusion, which lacks evidence and may never work, to inertial fusion, which could work, to magnetic fusion, which does work.

Two recent papers from MIT and from a group in Durham and Culham in the UK add weight to magnetic fusion methods by throwing the spotlight on the use of high-temperature superconductors (HTS). Both focus on the same novel material – REBCO second-generation HTS tape – and, taken together, add confidence that the engineering of high field HTS magnets is feasible, resulting in more compact and commercially viable tokamak fusion power devices.

These papers reinforce the approach taken by Tokamak Energy, which has recently demonstrated a small tokamak with all its magnets made from REBCO HTS and been recognised as a Technology Pioneer of the World Economic Forum as a result of its progress and bold plans.

Magnetic fusion uses strong magnetic fields to pressurise and trap the hot plasma fuel. There are many configurations of magnets to achieve this, but the best performance has been achieved in ring-shaped tokamak devices, the simplest shape that has no open-ended magnetic field lines. The JET tokamak at Culham Laboratory achieved 16MW of fusion power in 1997 with 24MW of input power.



Tokamak Energy's experimental compact tokamak

“We are now moving forward by increasing the magnetic field in more compact devices

However, progress since then has slowed because the successor device, ITER, reached such gargantuan proportions that it has succumbed to numerous delays. In recent years efforts have focused on a smaller way to fusion. Can this most studied and top-performing device be reduced in scale?

Within the class of tokamaks there are two choices – the conventional doughnut shape such as JET or the apple-shaped spherical tokamak, described recently by Dan Clery in *Science* magazine as “the new kid on the block”. The spherical tokamak has two big advantages: being a squashed-up version of the tokamak it is inherently compact. Additionally, it uses the magnetic field more efficiently. Its limitation has always been the tricky engineering due to lack of space in the centre for magnets and associated temperature controlling and protective elements. But the rapid development of HTS materials is overcoming this. Exceptionally high-field magnets can now be made that allow simpler solutions to the problems of cooling and protection, thanks to their ability to conduct high currents with zero resistance at temperatures well above absolute zero and in a strong magnetic field.

Earlier this year, Tokamak Energy scientists published two ground-breaking papers in

Nuclear Fusion. One showed for the first time that it is feasible to build a low power tokamak with a high power gain. The second tackled one of the toughest engineering challenges of a compact spherical tokamak – the shielding of the centre – with HTS materials.

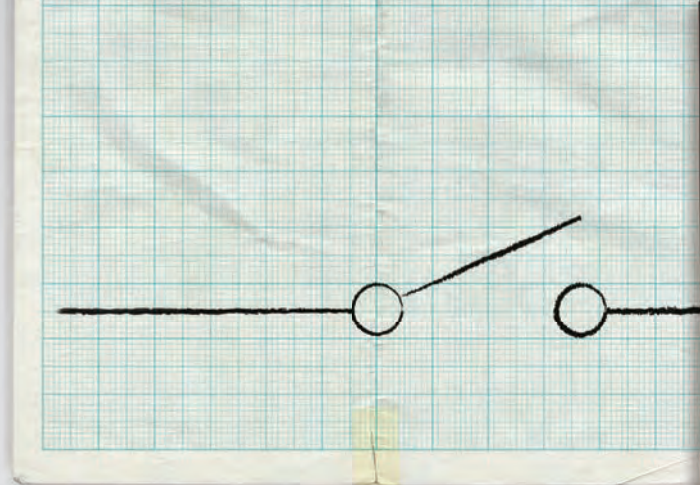
So instead of building ever larger tokamak devices, with huge costs and long timescales, we are now moving forward by increasing the magnetic field in more compact devices. This turns the pursuit of fusion energy from a big moonshot to a series of engineering challenges.

Currently, HTS technology has allowed Tokamak Energy to build and demonstrate a tokamak with all its magnets made from HTS, achieving that first challenge and moving us on to the next: designing a compact tokamak to get to fusion temperatures. When we succeed with one challenge, we can raise the investment to tackle the next. Tokamak Energy is deliberately trying to tackle difficult engineering challenges as rapidly as possible, something HTS materials is helping us do.

Fusion energy projects and start-ups around the world are pursuing fusion in different ways. This concerted effort towards fusion is the best way to reduce greenhouse gas emissions and ensure the supply of safe, clean energy long into the future.

Dr David Kingham is chief executive of Tokamak Energy

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thehottopic

Alternative atomic ambitions

Our article on alternative nuclear reactor technologies that could be developed in the UK prompted a heated debate

My friends in the industry tell me it is possible to build our own designs and a good deal less costly to do so. The expertise is still there, although in some cases now retired or working elsewhere, but were the government only to show some faith in our own engineers, I have it on good authority they would be back like a shot.

Your point about the government's willingness for other governments to own and run our industries is very well made and one I would love to question the prime minister or chancellor on if I ever had the chance. I like the term 'peculiar mental gymnastics' although you, like me, must have been tempted to use somewhat stronger language.

Mike

Thank for you for this excellent summary of a complicated subject. If only someone in the UK government would pick this up and do something strategic and beneficial for the UK.

My personal preference would be for us to develop improved renewables and storage, of course, but in parallel with the following for the base load: energy from thorium (clean and no bomb-making potential); SMRs (for distributed and resilient 'local' power generation); and maybe PRISM. If we could truly convert our historic bomb-making materials into clean energy then it would be a fantastic 'swords into ploughshares' story, as well as getting rid of long-lived and dangerous waste that our great-grandchildren should not have to deal with.

David Hopper

The sensible move for Britain is to court molten salt reactor (MSR) developers/

researchers in the US, Europe and Japan by offering a smooth, quick path to build test and prototype reactors. MSRs are already the safest designs available; many orders of magnitude safer than other fission reactor designs.

Mark Pawelek

At a conference on 7 October, Moltex presented its design for a molten salt fast reactor. This is a safe, fast spectrum reactor with an independently verified cost of less than one quarter (per unit of capacity) of Hinkley C. Other molten salt reactor developers are also looking at the UK, some of which could be producing large-scale power by 2025.

By all means proceed with Generation III builds: they are a known quantity and can provide safe, clean, but expensive electricity. But the main thrust of the UK's clean energy policy should be shifting to small modular reactors, and principally molten salt reactors.

Alex

The molten salt reactor is a relatively good choice, but not the solution to all our troubles as you say. It is possible to extract uranium 233 from the process, which is an excellent material for bomb making, by chemically separating the protactinium 233 and allowing it to decay.

There are also materials and online reprocessing problems to solve, especially the use of graphite as a separator and shielding high-energy gammas from uranium 232. It would certainly be beneficial to develop MSRs, as thorium is many times more abundant than uranium.

Roger B



On point: Artist's impression of the Hinkley Point C reactor

inyouropinion

Educational pace

According to the latest IET skills survey, two-thirds of employers are fearful that education will not keep pace with industry.

■ Engineering employers have every right to fear for the educational output. As far as the majority of engineering teaching goes, it concentrates on creating two per cent of undergraduates who will remain in academia, rather than the 98 per cent who will join the real world.

Mike B

■ As a current engineering student and also part-time

engineering employee I have to say I fully agree with this article. I feel my engineering education, which includes a diploma in engineering and a degree in marine engineering, has given me very little if any help towards any future career in engineering. I have learnt more engineering skills and useful practices from the year I have been working part time for a small engineering company than I have in almost five years of 'education'. I feel ashamed to admit that I've been paying (or rather will have to pay) a total of over £20,000 as repayment for this.

Anonymous

■ Instead of sucking more and more money from overseas, academic institutions should focus more on teaching quality. They are educational institutions not a bank.

Vincenzo

■ As a parent of a female year 12 interested in civil engineering, companies do not offer work experience. She has to be on a degree course before any firms will even offer work experience. Companies need to be working with secondary schools to inspire the next generation of engineers.

Anonymous

Loopscoop

The UK could be a prime candidate for Elon Musk's revolutionary Hyperloop mass transportation concept.

■ Maybe a smaller loop could be built between Heathrow and London City. A 35-mile loop to get you there in a couple of minutes would be welcome, assuming there is no 30-minute security check at the terminus.

Anon

■ This is absolutely achievable from an engineering standpoint, however, I do have to wonder about customer acceptance

thesecretengineer



Our anonymous blogger muses on his new working environment as he settles into Sleepy Hollow (hopefully staying awake and avoiding decapitated equestrians)

I am glad to report that I find myself gainfully employed once more. My new position at Sleepy Hollow Electronics Limited, despite the pseudonym that I have given it (a matter of private amusement and therefore a conceit I hope you will indulge), promises exciting opportunities. It has also highlighted aspects of the design environment that I have found either useful or inconsequential over the years.

First, there is the size of office and the number of people in it. In the past I have worked in large 'cube farms', small offices and all points between. I do not subscribe to the view that everyone being within shouting distance of each other is essential for good communication, especially in the age of e-mail and this communication is even a disadvantage if you're sat trying to work through ideas while those crammed in around chatter and argue. Large offices are also crushingly anonymous so the current situation of two of us sharing a decent-sized office is almost perfect.

Second, is the overall environment. Most places I have worked benefit from regular expenditure on painting the walls and laying new carpet. Not here where there are marks on the wall, coffee stains down the filing cabinets and a lino floor. However, so long as it is serviceable and doesn't let the rain in, I don't mind putting the time in with duster and polish. Equally, although I would prefer to be next to a window with a pleasant view I have found that this does not rate too highly on my scale of professional wants. Of greater importance is not being regularly subjected to vile smells from nearby sewage works and plastics factories. Once again, although not perfect, my new 'home' scores highly.



Then there are the direct environmental influences. It used to be that when working on CAD the ambient lighting would be low with desk lamps illuminating any paperwork. Sadly this seems to be no more and as I'm sharing the office with a non-engineer there is little chance of reverting to such working practices. The most important thing though, by far, is that I now have a decent-sized desk. I remain convinced that until we have A0-sized screens we will still need physical drawings. An ability to see details and context simultaneously is something not only very important but also impossible on the screen. Having struggled with an ever-shrinking surface area over the years I can once more luxuriate in adequate acreage.

By far the best I have experienced was my own office with large windows, two bookcases, a reasonable desk, speakers hooked up to the computer, a layout table and a chaise longue. This may be seen as the 'gold standard', however, I fear I would have to start my own company to guarantee ever experiencing it again.

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

of the compact cabin size with no windows. Have any pods been mocked up for acceptance trials?

OFN

■ To operate in a reduced pressure environment the pod 'cushion' and the 'suck and blow' at front and rear would seem to me to need massive air compression/extraction systems in order to maintain both the low-pressure environment and an adequate air gap between pod and 'rail'. Both elements of this design seem to me to

have a high potential for catastrophic failure.

JohnK

Dronethreat?

The regulation of drones has been debated by our readers.

The regulation of drones is a contentious issue. Registration of small drones of less than 5kg is pretty pointless. Education and vigorous prosecution is the real answer. Perhaps a 'do-and-don't' leaflet as a compulsory inclusion in 'ready-to-fly' boxes. As far as security is concerned

registration is even more pointless. I don't think many terrorists would bother registering.

Brian M

The British Model Flying Association (BMFA) has published guidelines for years, which still apply. Experienced model flyers are concerned this new craze will tarnish an image carefully cultivated at proper flying sites over years, and know that it can take some time with proper supervision to be able to fly safely.

Bob Harris



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WE CREATE MOTION

Becoming image conscious

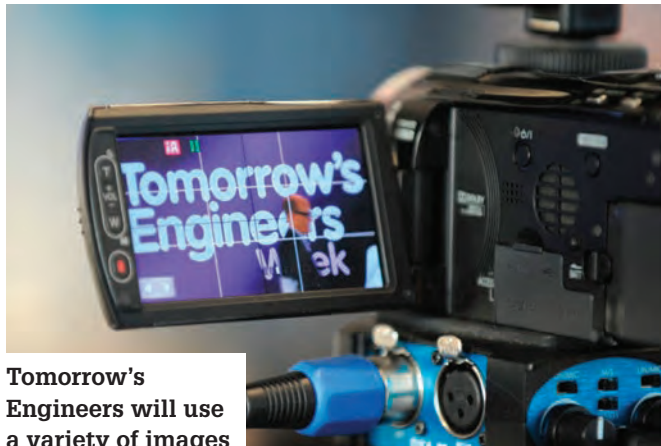
If we are serious about attracting more women, our industry needs to explore its use of images and the messages conveyed



The way engineers are represented online is putting girls off the industry and contributing to the 'leaky talent pipeline'. Within engineering, we do a pretty good job of using a range of images across both genders, but elsewhere, many images reinforce the gender stereotypes that we're trying to overcome.

In analysing engineering-related images from across over 70 popular websites EngineeringUK found that many reflect outdated gender stereotypes. The vast majority of online 'people pictures' related to engineering depict men (as high as 85 per cent for search engines), though only four in 10 include a woman. Stock image sites and search engines are lagging behind other sites on gender balance. Image searches for the term 'engineer' found just 26 per cent

“ If young girls don't see women when they see engineering online we're going to struggle to get them into the industry



Tomorrow's Engineers will use a variety of images

of search engine results featured women and 25 per cent of stock images contained female engineers.

Does it really matter? Yes, particularly when you know that in a survey of 11 to 16 year olds, 28 per cent of girls say the images they see online are too male orientated. If young girls don't see women when they see engineering online we're going to struggle to encourage them into the industry.

If a picture is worth a thousand words, it is extremely worrying that this gender bias (cyber sexism?) is rife when it comes to the depiction of engineers on websites used by young people.

We spend a lot of time explaining how engineers shape the world we live in and are behind many of the amazing everyday things we take for granted. Part of our messaging for young people generally and particularly during Tomorrow's Engineers Week is that engineering is a broad and exciting industry that offers a wide range of career opportunities. Some of those roles will see people in hard hats, but many won't and that's another area where online images can be particularly unhelpful.

One-fifth of images covered in our research feature the stereotypical hard hat – bolstering out-dated opinions that engineering is only about men in hard hats working on building sites as opposed to the full range of careers available to young people today. We need engineers across the board and many of those roles require a hard hat or hi-vis jacket.

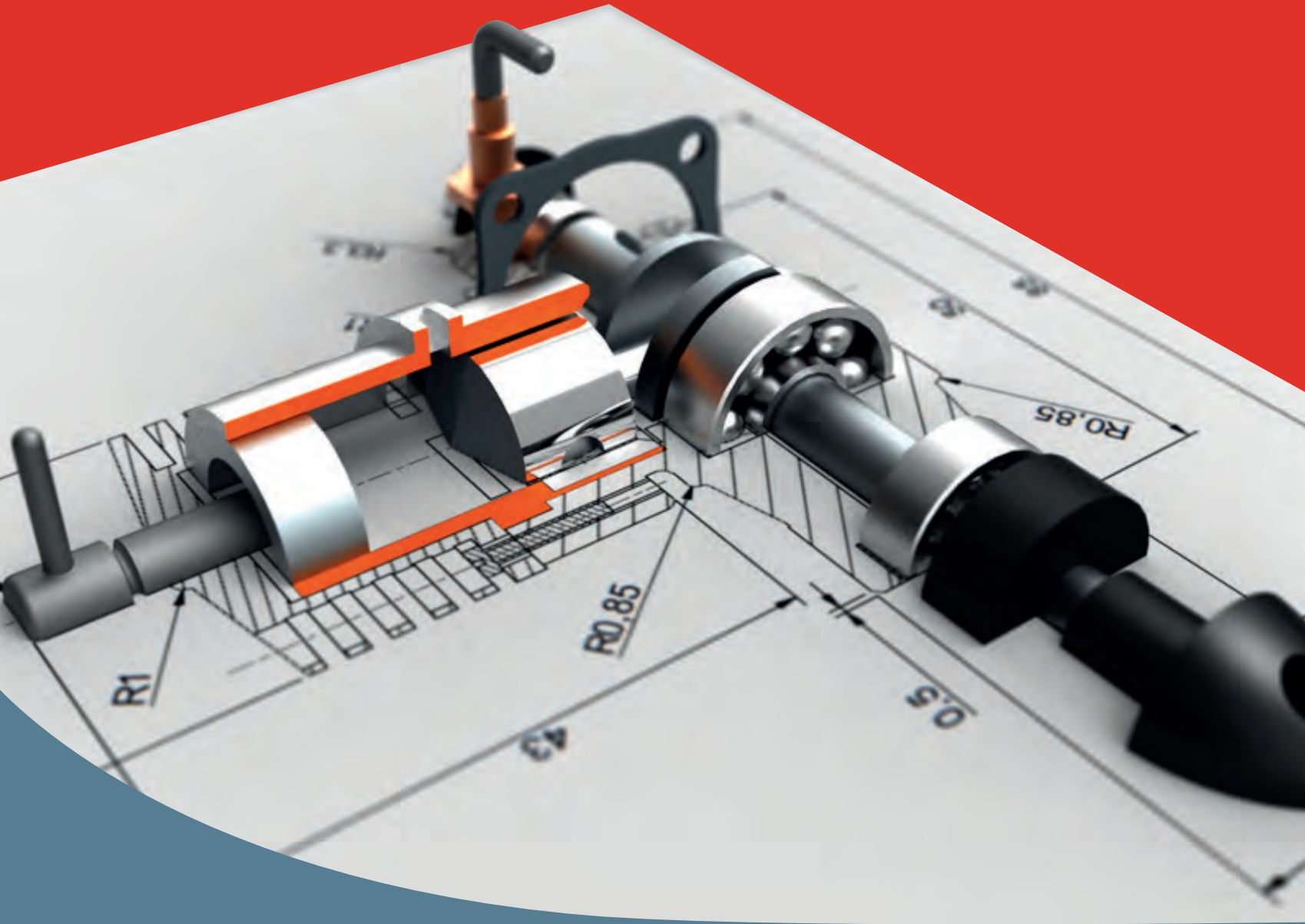
In the next decade, employers will need 1.82 million people with engineering skills, meaning we need to double the number of apprentices and graduates entering the industry.

Almost a third (29 per cent) of all those surveyed believe that the images used to represent engineering are not relevant to them. We cannot afford to lose would-be engineers by carelessly reinforcing stereotypes and not showing the full scope of exciting careers available.

Universities are the best at portraying greater gender balance, with 53 per cent of university images including a woman; and the research also showed that engineering companies and industry bodies are better than average at demonstrating a gender mix in the workplace. But, with almost one in 10 (seven per cent) girls saying that images they've seen online have put them off a career in engineering we need that balance to be much more widespread that it is currently.

We need to inspire, not discourage, young people to consider engineering as their future career. Showing them images of people they can relate to is important if we are to encourage them into the industry. We can't change this overnight but we can work together to boost the variety of engineering images we all use online. ☺

Paul Jackson is chief executive of EngineeringUK



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Electric impact

What do innovations in electric drivetrains mean for cars and drivers?
Stuart Nathan reports



The shift to electrification is one of the biggest changes the automotive sector has seen during its century-long history. In its earliest years, there was little indication as to what would provide the motive force for the new-fangled 'horseless carriages' and electric motors, petrol and even steam engines were developed in parallel. But after the petrol engine achieved dominance in the early decades of the 20th century, the automotive industry spent many decades refining what was essentially the same technology those early cars had possessed.

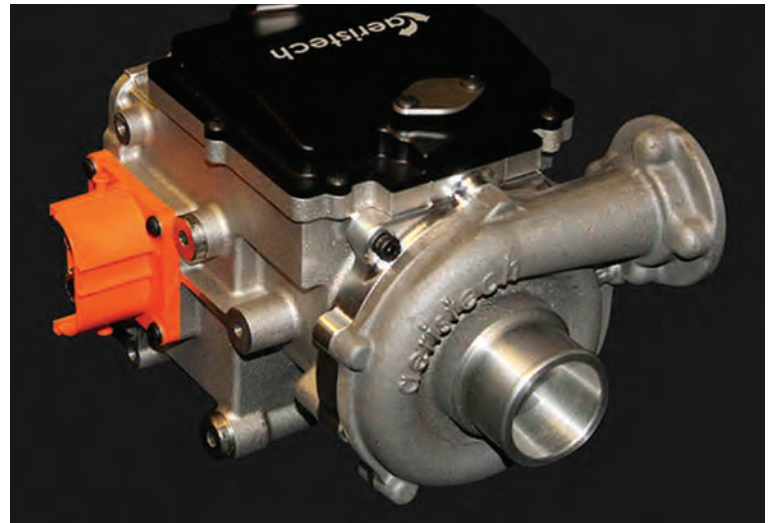
That's not to say there was no innovation; but in the years since the introduction of the first truly successful commercial hybrid vehicle, the Toyota Prius, have seen the pace of development in the sector take off in a way it has never seen before.

The primacy of the internal combustion engine (ICE), whether in its petrol- or diesel-burning form, is now seeing what is probably its first real challenge.

But while much coverage has focused on specific aspects of this change — in particular the issue of range and how battery technology and charge management can help to increase it, and more recently the developments towards autonomous vehicles — the issue of how using an electric motor to propel the car changes the way the vehicle functions and how its driver perceives a difference in it has been relatively ignored. Electric vehicles aren't ICE vehicles; the change in motive force isn't just a drop-in replacement. So what do innovations in electric drivetrains mean for cars and drivers?

It's fair to say that the main drivers for the switch to electric propulsion have been environmental. It was probably concern about climate change that first triggered the automotive sector's interest in looking at electricity again: ICE systems are among the largest emitters of carbon dioxide. Alongside this and now becoming increasingly important is the other aspect of emissions: air quality. Burning petrol generates carbon monoxide and nitrogen oxides, while diesel also produces particulates; all of these can and have been reduced by fine-tuning engine technology, but as cities grow and their residents demand mobility, the detrimental health effects have become more pressing; and doing away with ICEs is the obvious (although challenging) solution. In the case of climate change, electrification of transport doesn't eliminate the problem; it shifts it, making it an issue for the electricity-generation sector rather than automotive.

Bosch is one of the most important 'tier one' companies involved in electrification (this refers to companies who supply whole systems to car manufacturers, rather than making entire vehicles or just individual components), working on electric and hybrid power trains for a very wide range of major mass-manufacturers, including Volkswagen, Audi, BMW, Porsche and Fiat. According to Michael Budde, executive vice-president of Robert Bosch Battery Systems, "user experience is the main driver for the market success of electromobility. By integrating electric with automated and connected driving, the user can enjoy driving while contributing to environmental protection. In addition, we know that



Left: Porsche 918 Spyder **Above:** An electric supercharger **Below:** GKN's eAxle

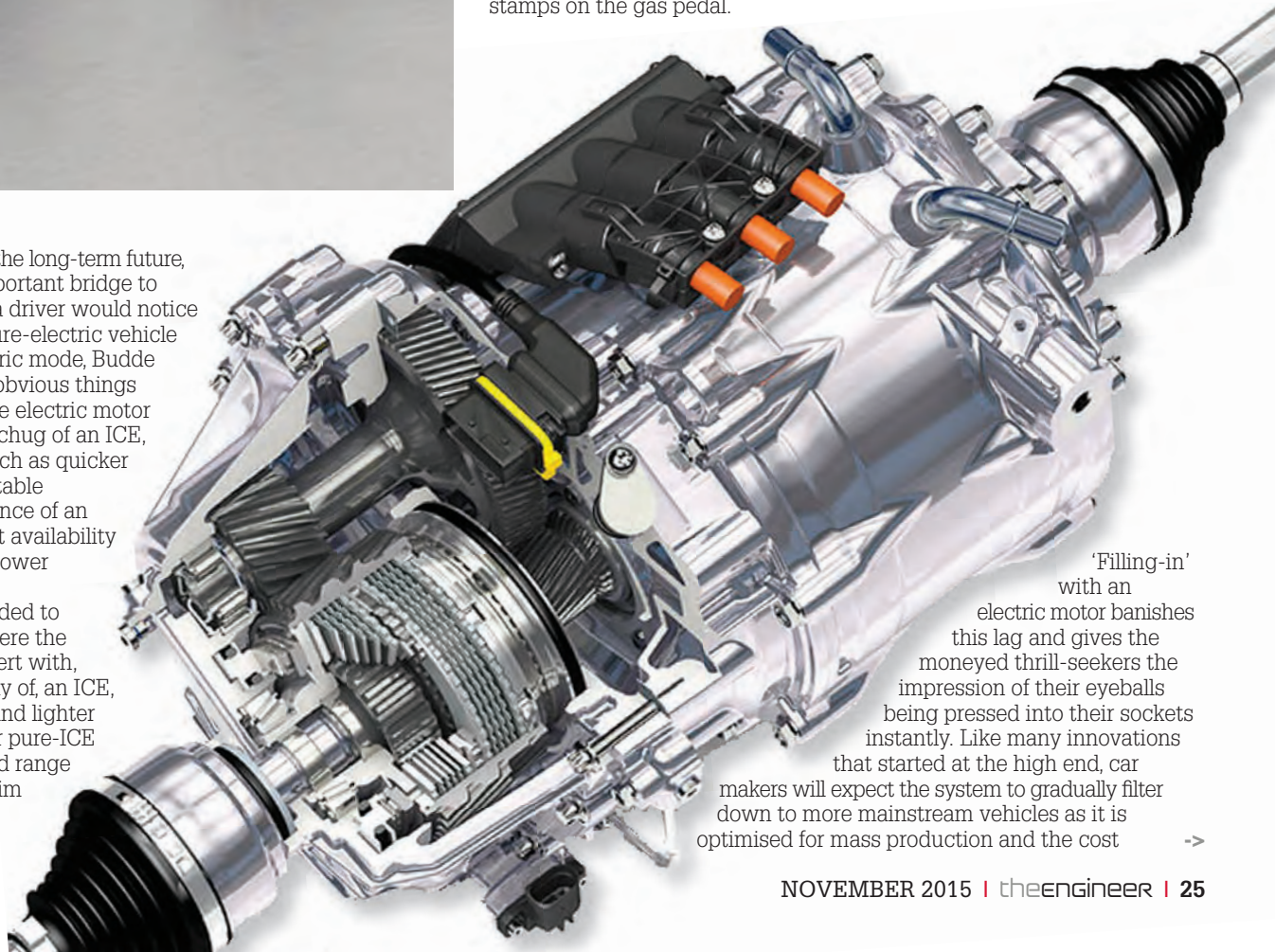
“ The instant-torque ability of electric drivetrains is one currently enjoyed by a few drivers of high-end hybrid hypercars

Budde said. The full switch is dependent on improvements in battery systems and power electronics, he added, with post-lithium ion technologies potentially capable of doubling the energy density of current systems by 2020 while also reducing cost.

The instant-torque ability of electric drivetrains is one that is currently being enjoyed by the lucky few drivers of the highest-end hybrid hypercars in the automotive stable. McLaren's P3, the LaFerrari and Porsche 918 all use electric motors to boost the performance of their turbocharged engines; these suffer from a characteristic 'turbo-lag' which means that acceleration only kicks in a little after the driver stamps on the gas pedal.

fossil fuels will be scarce in the long-term future, so electromobility is an important bridge to sustainability." In general, a driver would notice a definite difference to a pure-electric vehicle or a 'strong hybrid' in electric mode, Budde said. These might include obvious things such as the quietness of the electric motor compared with the roar or chug of an ICE, and less obvious factors such as quicker acceleration; one of the notable differences in the performance of an electric motor is the instant availability of torque, rather than the slower build-up typical of ICEs.

Bosch's efforts have tended to concentrate on hybrids where the electric motor acts in concert with, but can work independently of, an ICE, which is typically smaller and lighter weight than one in a similar pure-ICE vehicle. "Strong hybrids and range extenders are only an interim solution with pure electric vehicles a future solution,"



'Filling-in' with an electric motor banishes this lag and gives the moneyed thrill-seekers the impression of their eyeballs being pressed into their sockets instantly. Like many innovations that started at the high end, car makers will expect the system to gradually filter down to more mainstream vehicles as it is optimised for mass production and the cost

->

indepth**Charging infrastructure is a vital prerequisite for electric vehicles to flourish**

Electric vehicles may change the way we drive but another thing they will have to change is the streets themselves.

Charging infrastructure is a vital prerequisite for electric vehicles to flourish, whether they're pure electric or one of the wide variety of hybrids. While there is uncertainty about who should provide charging infrastructure and where it should be located, one of the automotive industry's largest players has taken it upon itself to put a metaphorical toe into the water. BMW, whose i-series vehicles are seeing it take a leading position in the electric vehicle sector, earlier this year revealed another hybrid: an LED street light that incorporates a car charger.

Given the self-explanatory name Light and Charge, the system is an attempt to simplify street furniture requirements of a road by making the necessary lighting multifunctional, thereby not cluttering up the roadside space with more items. Use of LEDs, which consume much less electricity than incandescent lighting systems used for street

lighting, means that the lamps could dramatically reduce the electricity usage (and bill) for lighting. Moreover, the units are equipped with a smart lighting system that detects motion around them and only brightens when there are people or vehicles moving in their vicinity; this results in further saving of electricity and cuts light pollution, without risking safety.

"It uses so little electricity we could virtually give the power for charging away," claimed BMW board member for sales and marketing Ian Robertson, at a recent summit organised by the Society of Motor Manufacturers and Traders in London. It also makes the system modular and flexible: "Up to four LED modules can be used to provide night-time lighting on main roads, while one or two modules are sufficient to provide lighting on side streets and in residential areas," BMW said in a launch statement for the system.

Each Light and Charge unit is equipped with a socket that allows a standard charging cable to be plugged in, and charging is initiated by swiping a card.

Light and Charge: BMW's LED street lamp incorporates a car charger



reduces. Diesel engines are typically turbocharged to improve fuel combustion (which also improves their power output) so are likely to become the beneficiary of this technology.

That torque can be used in a variety of ways. One of these is torque vectoring; which put simply is varying the amount of torque that's delivered to the wheels on either side of the car as it turns. Used in concert with the conventional steering system, it changes the way the car feels as it goes into turns; either to make the driving experience more exciting, or to sharpen the car's turning characteristics if it has to change lanes rapidly or swerve to avoid an obstruction. It's among the technologies that have come down to conventional cars from motorsport, having its origin in rally cars.

BMW i8 hybrid sports car



This is one of the systems that Bosch is working on, as is GKN, another 'tier one' supplier. While torque vectoring is possible with conventional ICE vehicles, using an electronic differential on the driven axle to vary the amount of torque delivered to each half of the axle and therefore to the wheels, it's a natural fit to electric vehicles, the company argues, because it already depends partly on electric power, making it a matter for systems integration; something GKN prides itself on.

The company has recently unveiled a torque vectoring system designed specifically for hybrid vehicles. It's based on its 'eAxle' technology, which as the name implies is an electrically driven axle system for hybrid cars; GKN developed it for the Porsche 918 Spyder and BMW i8 hybrid sports cars. "The success of our eAxle systems in sports cars demonstrated how the right kind of hybridisation creates new value propositions for the driver. We are now preparing mass-production versions of the technology that can also deliver torque vectoring," said GKN Automotive president of technology Peter Moelgg at the launch of the system. GKN believes that by 2025, 40 to 50 per cent of cars will have some degree of electrification in their drivetrain, and that as time goes on,

“We are preparing mass-production versions of the hybrid technology that can also deliver torque vectoring

Peter Moelgg

vehicles will derive more of their power from electricity. Currently, most mass-production hybrids get no more than 30 per cent of their power from batteries, but Moelgg expects this to rise to 60 to 70 per cent for future vehicles, even relatively small and low-cost ones. "GKN's research and development is focused on developing technologies that can achieve this crucial tipping point for electric drives in mass production. More powerful, dynamic electric drives from GKN will help put batteries in the driving seat and create new electric driving experiences for customers," he said.

The eAxle system uses a 60kW, 240Nm motor with a 1:10 transmission connected to a dual clutch that distributes 2,400Nm of torque between the wheels. GKN expects it to be available for mass-market cars within three years. The eAxle system can also give a front-wheel drive vehicle the driving characteristics of rear-wheel drive, or vice-versa, or more commonly, allow drivers the option of all-wheel drive, with its advantages in handling and grip.

The idea of using electric technology to improve the performance of conventional cars is one that's gaining traction. Audi, for example, is to use an electric supercharger in production vehicles to tackle the problem of lag mentioned earlier in the article. Lag occurs because turbochargers are driven by the car's exhaust gases; they operate a compressor that forces air into the engine, improving combustion efficiency and boosting the amount of energy the burning fuel generates. Simple physics state that the pressure of the exhaust gases puts a hard limit on how effective this can be. But using an electric motor to drive the compressor gets around this limit, as the turbo effect is now independent of the engine. Switching it on provides an instant boost of power; it also allows the engine to be run at lower revolutions without compromising power. ©

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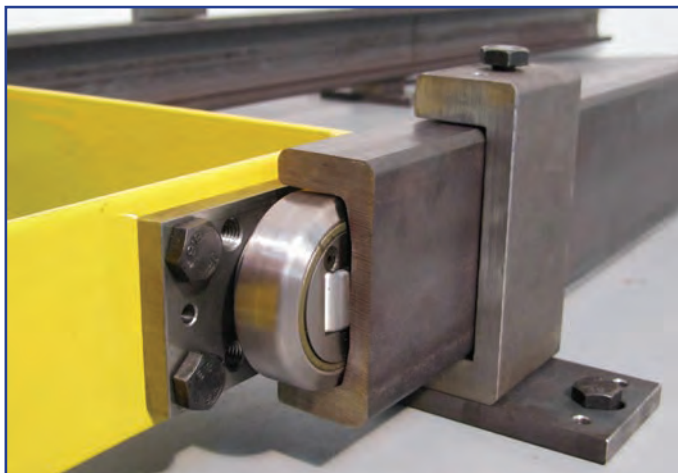


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Danish engineers are poised to begin construction of the world's longest immersed tunnel. **Jon Excell reports**



Denmark is no stranger to challenging infrastructure projects. Over the years – primarily in an effort to improve the transport links between the country's mainland and its largest islands – it has built a host of record-breaking bridges and tunnels that have cemented its reputation as a global centre of structural engineering excellence.

But now, its civil engineers are poised to begin a construction project that could be the country's most challenging yet: an 18km-long sub-sea tunnel that will link the German island of Fehmarn with the Danish island of Lolland. Its proponents claim that it will fundamentally transform transport in the region, replacing around two million ferry journeys annually, and slashing rail travel time between Copenhagen and Hamburg by more than 25 per cent.

Dubbed the Fehmarn Belt Fixed Link (after the Baltic strait separating the two islands), the new link will be the longest immersed tunnel ever built and will be five times longer than the current record-holder, the Øresund tunnel, which is also in Denmark. Constructed from vast pre-fabricated concrete sections that will be installed in a trench on the seabed up to 35m beneath the surface, the tunnel will comprise twin railway lines, four motorway lanes and a separate emergency tube.

Kim Smedegaard Andersen is the technical director for Femern A/S, the Danish government-owned organisation responsible for building the tunnel.

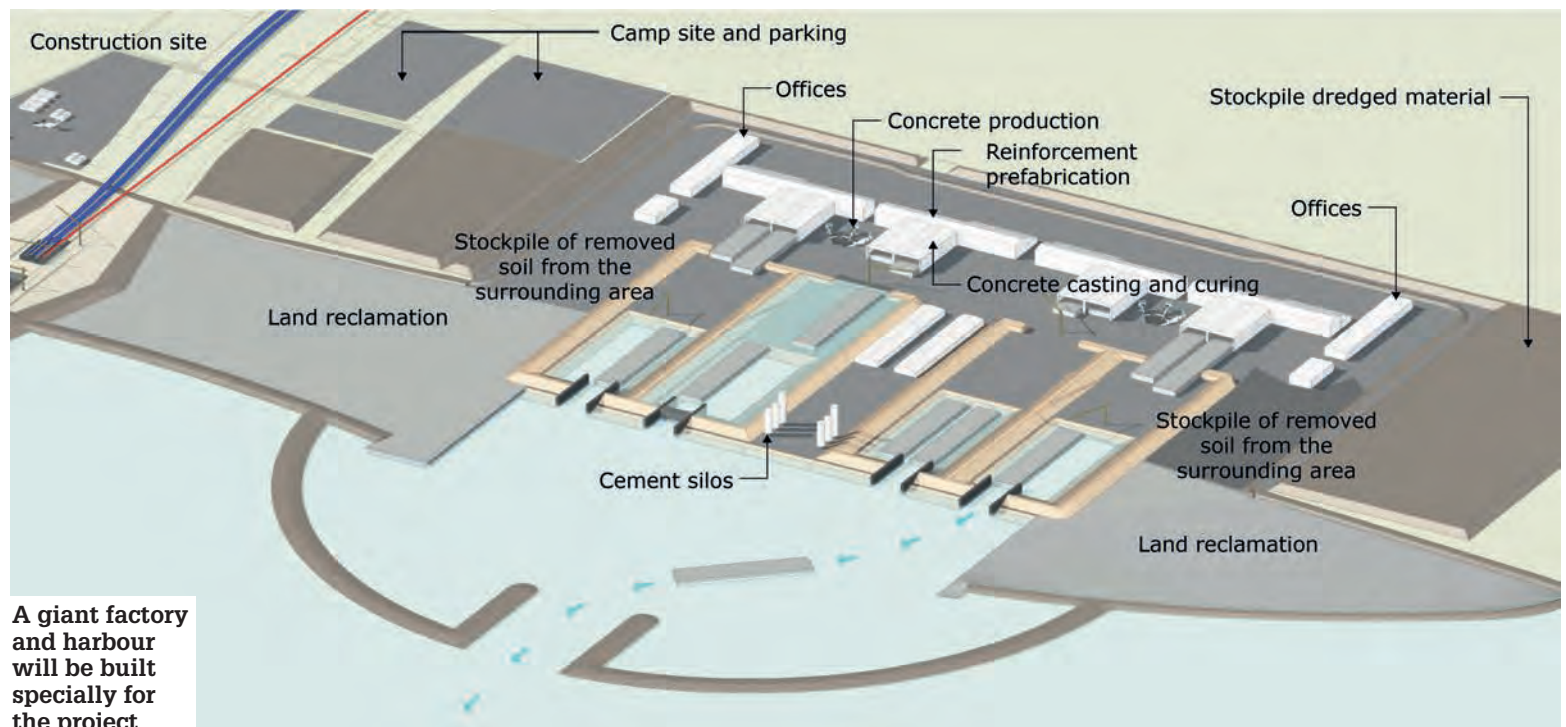
He explained to *The Engineer* that a direct link across the Fehmarn Belt has been under discussion for a number of years, but that a tunnel was chosen as the preferred solution primarily because of the distance of the link, the water depth in the Fehmarn belt and a host of environmental factors. "A tunnel below the seabed will cause some environmental disruption during construction," he said, "but once in place it will be neutral, while a bridge, which would have giant pillars would constantly impact on the environment."

The decision to build an immersed tunnel rather than a bored tunnel such as those recently excavated for London's Crossrail project was, he added, driven by both the desired size of the tunnel (it would require the largest tunnel-boring machine ever built) and the complex geology of the region. "We don't have a uniform soil type, there are some very plastic clays and some very hard marine clays with a lot of flint and it can be a very complicated to construct machinery which can cope with material changing from sand and silt to clay and so forth."

The project has been formally approved in Denmark, and the team is now waiting for it to be signed off by the German government. ->



The tunnel will comprise twin railway lines and four motorway lines



A giant factory and harbour will be built specially for the project

Once this happens, a mammoth manufacturing and engineering operation will begin.

The first step will be the construction of a giant purpose-built manufacturing facility and harbour near Rødbyhavn, on the south coast of the Danish island of Lolland.

Here, eight identical production lines will be set up for the continuous casting of the huge reinforced concrete elements that will form the structure of tunnel.

Made from a series of nine identical segments that are joined together during the manufacturing process, each element will weigh approximately 73,000 tonnes and will be 217m long, 9m high and 42m wide. A total of 89 separate elements will be produced for the tunnel. Ten of these will feature a special additional deck beneath the traffic tube that will be used to carry out maintenance work once the tunnel is operational. This, said Andersen, is a completely new innovation in immersed tunnel design that has been necessitated by the distance of the crossing. "Most tunnels are so short you are only operating from the poles," he added.

Connecting separate elements on the seabed is an elegant process likened to a 'great big kiss'

Once an element has been cast, watertight steel bulkheads will be added to each end of element to ensure that it floats and it will be pushed into a basin and towed to a holding area near the trench.

The element will then be connected to advanced pontoons that will be used to carefully guide it to the immersion site.

Once positioned directly above the trench, cables anchored to the seabed will hold the element in position, and its ballast tanks will be filled with water to enable it to sink to the seabed. Its descent to the immersion site will be carefully controlled by cables attached to the immersion pontoon while a combination of GPS and sonar will help guide the giant structure to its final resting place.

The next challenge is connecting the separate elements together on the seabed in order to form the tunnel, and this is achieved using an elegant process that Andersen likens to "a great big kiss". When the tunnel element has been placed in the tunnel trench and lined up with the previous one, a hydraulic arm will be used to haul the new element right up to the existing one.

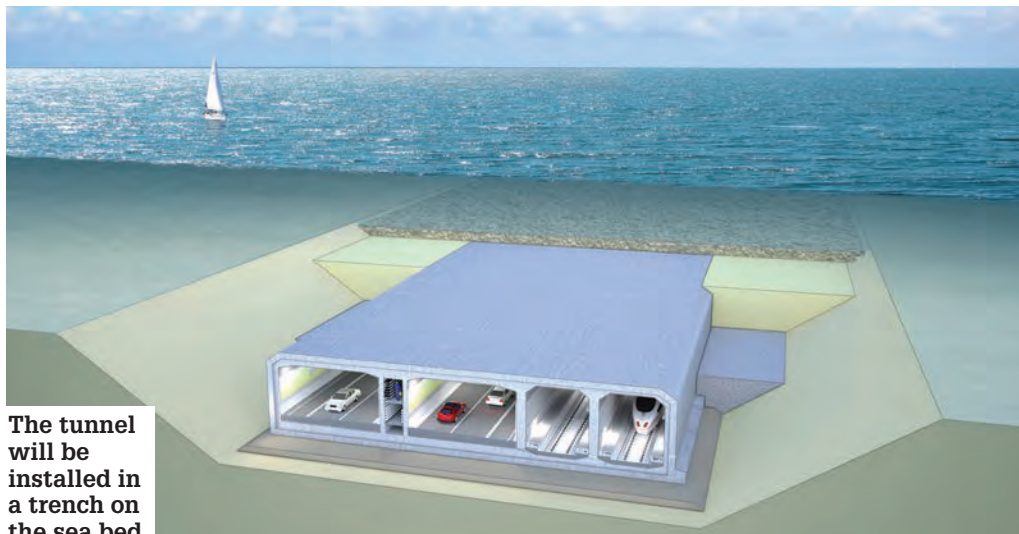
As the elements are brought together, huge rubber gaskets mounted on their ends will form a watertight chamber between the steel bulkheads. Water is then pumped out of this chamber, until it's at normal atmospheric pressure, and the considerably higher water pressure on the free end will force the elements close together creating a watertight seal.

This will continue until all the elements are in place. They'll then be secured in the tunnel trench with gravel and sand, and covered with a protective layer of stone. The top layer of stone will be level with the existing seabed and the tunnel itself will be safely below the seabed, protected against ship anchors and other collisions.

Once that process is complete, the engineering team can then set about installing the road and rail infrastructure that will, says Andersen, make the Fehmarn tunnel one of the most advanced links of its kind in the world.

Much of the technology that will be deployed in the tunnel is, he said, still to be decided. Safety and traffic management systems are evolving rapidly and with the project expected to take around eight years to complete, he and his team are watching developments around the world with interest.

In the meantime, with the Danish parliament giving the scheme the go-ahead earlier this summer, Andersen and his team are anxiously awaiting a similar vote of confidence from the German federal government. ©



The tunnel will be installed in a trench on the sea bed

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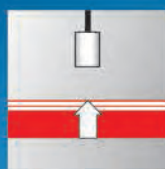


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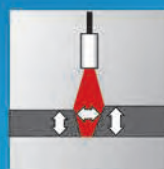
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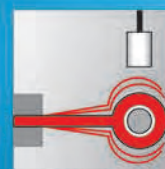
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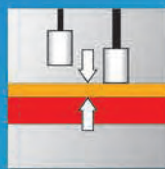
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in our opinion

Redcar shows a lack of steel

The steelworks closure illustrates a shortfall
in strategic thinking around UK industry



The closure of the Redcar steelworks is a huge blow to the UK's steelmaking ability and potentially to the manufacturing sector in general.

The plant has been in the hands of receivers since its owner SSI UK went into liquidation last month, and with no last-minute buyer stepping forward, the hard-to-reverse process of closing down the plant's furnaces is now complete.

It is, of course, terrible news for the local economy. Around 1,700 steelworkers and many other local workers in related businesses have lost their jobs. And the government's pledge to provide £80m to support affected workers will, in all likelihood, do little to alleviate the impact of one of the region's biggest employers disappearing.

But the closure is also bad news for the wider manufacturing economy. And, while there's no denying the challenging climate faced by the UK steel industry, the government's failure to step in to find a way of rescuing the plant is a short-sighted mistake that may return to haunt us.

A successful manufacturing economy requires a long-term strategic view. And any administration serious about supporting the transition to a more balanced economy – as the current government claims to be – needs to recognise that business is cyclical.

Worryingly, there's little expectation that steel prices will recover

in the short term, which could spell more bad news for the UK's remaining steel producers. But, if we fail to protect this key strategic industry, when steel prices do recover – as they surely will at some point – the cost to the UK could be punishing. At a hastily convened 'Steel Summit', which will be held later this week, steel companies, MPs, and trade unions will meet to consider solutions to the challenges faced by the sector.

And while any effort to solve the industry's crisis will come too late for the Redcar plant, there are still measures that can be taken to protect the UK's remaining steel producers, not least finding a way to protect industry from the cripplingly high energy costs it faces.

There is also another glimmer of optimism. While restarting a blast furnace is a tricky and expensive process, it's not, as some reports seem to imply, impossible.

Indeed, it's worth remembering that the very plant that is currently being shutdown, was itself relit three years ago, when SSI acquired the site from Tata Steel.

It's a faint hope. But maybe the dismal scenes currently unfolding on Teesside won't mark the end of the region's century-long relationship with steel.

Jon Excell Editor
jon.excell@centaur.co.uk

“Worryingly, there's little expectation that steel prices will recover in the short term

See p34 for reader comments on this emotive issue



your comments

I totally agree. This is so short sighted, and the sort of decision that is only be taken by a government that knows nothing about manufacturing. I can't imagine the French or German governments allowing a large plant such as this to close.

We all know that to build a facility such as Redcar from scratch would simply not happen now. So once it's gone, it's gone. The alternative employment such as supermarkets and DIY shops are no longer an alternative either as they are shedding thousands of jobs. So it is even more important to get this rebalancing of the economy that is talked about but never gets any help.

Why not invest a small amount of taxpayers' money into keeping a skeleton staff employed to keep the facility serviceable for, say, 10 years? The price of steel will definitely have risen then and the plant would be viable again.

Surely it can't be right to allow just China and a few others to produce everything? They will hold the world to ransom once we get to that point.

Spencer Deakin

The plant on Teesside has nothing to do with the UK car industry, or indeed any part of the manufacturing sector. It is a producer of crude semi-finished steel slabs, originally bought by SSI as a feedstock for their own rolling mills in Thailand.

It was not intended to be a merchant slab supplier to the world market, as now seems to be the impression and stated by SSI UK as a reason for closure. The UK is not the place to try to produce merchant slabs. There are only two such plants in the world;

one in Brazil and one in Mexico (which was not originally intended as such). Other suppliers enter the market from time to time when their own rolling mills are shut down for upgrading/maintenance. This allows them to continue to operate their blast furnaces and steel-making units until the mills are ready to roll again.

Anonymous

So what should the government do? Buy up the steel and sell it on at a loss? Keeping the facility serviceable for 10 years could be an option, but is it likely that a buyer will be found?

Alex

So saying, it is a national industrial asset, albeit a 40-year-old one. As such is worth 'hot' mothballing for a few years to see if it can be brought back into profitable operation again when iron prices rise. But, the problem then will be, where are all the skilled personnel and will they be willing to return?

Alex Morris

This is terrible news for the community but starkly focuses attention on the need for the UK to move up the intellectual ladder.

Unless we want to compete with countries such as China and India, and pay equivalent wages, while resurrecting coal-fired power stations to provide dirty, cheap energy, we must improve our education system.

Third World countries build their economies on cheap labour, cheap land, cheap energy and cheap natural resources. It's about time people realised that we have run out of all these things in the UK and if we are to maintain our collective high

standard of living, we must continue to move into a creative, intellectual culture with high-value, advanced services.

It is, in fact, nothing more than exploiting what the UK was always famous for, innovation, organisation and invention; we just didn't outsource our labour.

David Redfern

To prop up SSI was to simply give money to the Thai banks and creditors outside the UK. Not a great use of our taxpayers' money.

The other option was to re-nationalise a loss-making industry. The calls of 'typical of a Tory government' forget that Anglesey's aluminium smelting works was shut under a Labour government for precisely the same reasons that the current lot are not intervening here. I accept we need to support manufacturing but energy-intensive industries are not particularly viable at the best of times.

Nick Brook

There's a huge UK and worldwide excess of steel production. Something has to give. Be realistic. Throwing taxpayers' money at the problem has never been a satisfactory answer. If it was the last steelworks in the country there might be more of a case but steel still rolls off production lines in Sheffield and other places.

Roger

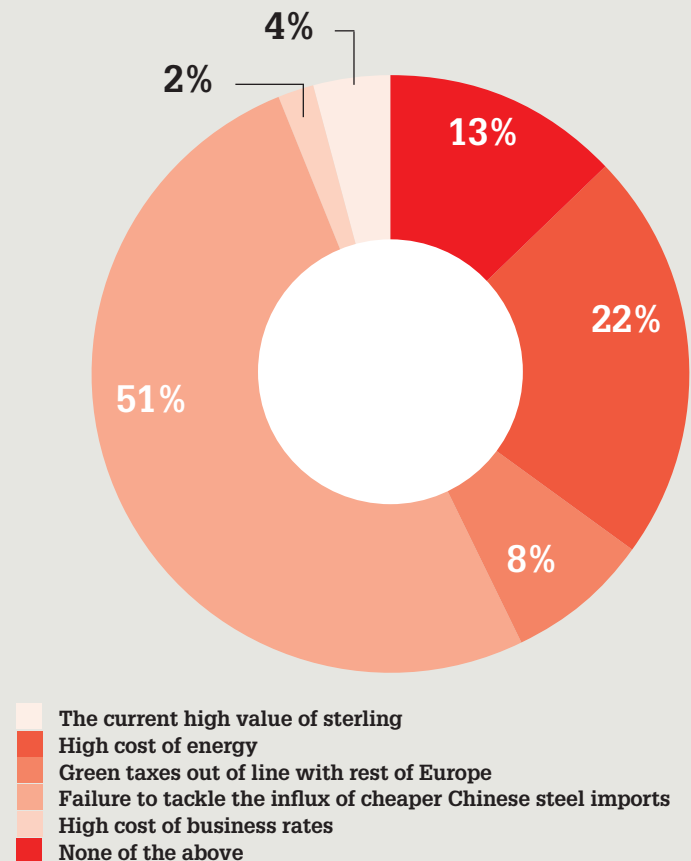
Roger, there's not a huge UK and worldwide excess of quality steel production. In fact, there are many qualities and grades that the UK and many other countries such as China, India and Russia simply cannot produce. These products are at the higher end of the market and it is the inability of the UK to supply this market that is the main reason for their troubles. It is useless trying to compete on price at the clog iron end. We should be building hot strip rolling mills to produce gauges down to 1mm and cold tolling down to 0.1mm.

Herbert Jones

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Which of these do you believe is the greatest problem facing UK steel?



theengineerpoll

We asked readers what they believed is the biggest problem facing the UK steel industry

There seems to be little doubt among the 575 respondents to our poll: the biggest threat to the UK steel sector is cheap Chinese imports. A small majority, 51 per cent, of respondents said that failure to tackle these imports was the biggest problem facing the beleaguered sector, with the next biggest group being less than half the size: 22 per cent thought the cost of energy was a bigger factor. Green taxes attracted the attention of eight per cent, while the value of sterling was the favoured choice of four per cent. Just two per cent thought business rates were the biggest factor, and 13 per cent declined to pick an option. Some commentaries thought that domestic demand was a concern, while others identified IP issues as the root cause of the sector's problems.



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Catch the tide

david shemmans
chief executive
Ricardo



Education

1987 BEng, electrical and electronic engineering, University of Manchester
1998 Harvard Business School

Carer

1990-93 Marconi Instruments, senior engineer; also consultant engineer with the Technology Partnership
1993-99 Waverider, managing director
1999-present CEO at Ricardo

“Ford introduced an electric bicycle; who would have thought you would see that?”

The chief executive of Ricardo has watched the automotive sector come up from the doldrums in the last decade. **Stuart Nathan reports**

In some ways, the automotive engineering consultancy Ricardo could be seen as emblematic of the UK automotive sector, or even of UK engineering as a whole. It's widely known and respected in the industry at home and abroad, is active in a large variety of areas, particularly at the higher-value end of the product range, but it's little known by the general public, perhaps because its customers are industrial rather than consumer facing and its name doesn't appear on any particular products.

David Shemmans, Ricardo's long-serving chief executive, has had a ringside seat for the UK automotive sector's changing fortunes for over a decade; one of the most eventful periods in the sector's long and chequered history, which has seen it rise from the doldrums, mainly with the help of overseas investment. The last year has been a good one for the company, he told *The Engineer*; it's also been busy, marked by several acquisitions, which underline some of the new factors affecting industry.

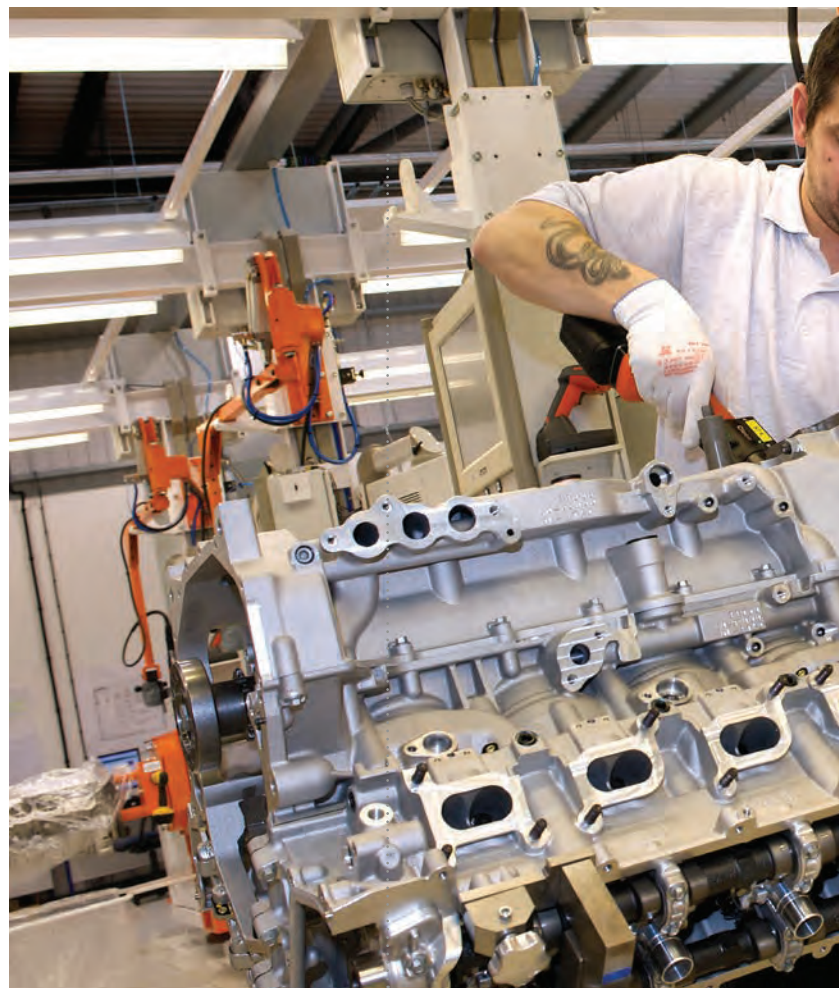
Towards the end of the financial year, in late spring, Ricardo made two relatively small acquisitions: V-Pro, a consultancy specialising in motorbike engineering; and PPA, an electricity consulting business. These were followed swiftly after year-end by two larger purchases: Lloyds Register Rail and a water consultancy called Cascade. In business terms these add to both Ricardo's headcount and its bottom line, Shemmans said: "The story for next year is about 40 more people, and about £0.4m of operating profit and £3m in revenue from V-Pro and PPA. Lloyds is 440 people; it's a £350m turnover business and a £4m profit. Cascade is about 30 people and £400,000 profit. So, in all

you can add £4.8m in extra profit for 2016."

V-Pro has chassis engineering expertise that Ricardo did not previously possess, enabling it to deliver a capability to design, engineer and build complete two-wheeled vehicles. This is a response to the world trend for people to move to cities, Shemmans explained; motorbikes, scooters and even electric bicycles are options that he believes will become increasingly important to move people around these new or larger urban areas. "Ford

introduced an electric bicycle this year; who would have thought you'd see a major car producer do that?" he asked. "They're not the only ones, and we're supporting several clients in their efforts in this direction, including tier ones working on the enabling technologies and systems."

Ricardo divvies most of its activities into two broad areas: consultancy and performance products. "The first is when we engineer for other people; performance products is when we actually make things, such as the



McLaren engines or Bugatti transmission." Both areas have seen good performance in the last year, in particular, in the second half and then in the opening months of the next financial year, when order books grew markedly after being slightly down for the financial year as a whole. "We've had a great eight months, and all the deficit was caught up over the summer," Shemmans said. "Our order book is at over £200m; that's including the rail business; at the end of June it was £140m. So our business is now substantially bigger."

The Lloyds Register Rail business will also help Ricardo address issues arising from urbanisation. "We're seeing more activity in public transport, and we're talking about getting involved with monorails and maglevs. We're involved with a monorail scheme at Orlando Airport; and we're also looking at a maglev project in Beijing. The idea of how you ship people around cities is getting important, and one big advantage of monorails and maglevs is that they're elevated; it's like a bridge, it takes up less real estate and you can still have roads. Plus it's safer; there's no problem with people having to

cross tracks and complications like that. They're going to be very interesting in the future."

PPA and Cascade fit into Ricardo's consultancy side. "Air quality and climate change are big areas for us in our environmental business, we work with governments worldwide to help set their legislation," Shemmans added. "While our engineering business helps clients develop and build products to meet that legislation."

One factor that Shemmans said was becoming increasingly important to Ricardo's environmental consultancy is resource scarcity, with water now coming under much more scrutiny. "This is particularly because of the drought in California," he said. "The developed world has money to invest in technologies to help resolve that problem. We're seeing the world waking up to how scarce a resource water is."

An intergovernmental environmental summit in Paris in December could be enormously significant for Ricardo. "It's anticipated that China and the US will sign up to emissions targets for the first time. Those two nations signing up will increase

“If we were selling products into China, maybe we'd be feeling the heat a bit more

the focus on CO₂ reduction technologies, which will have a huge effect on transport, energy and industrial policies around the world."

China is becoming more important to Ricardo. "It's one of our important stories," Shemmans said. "It's been very busy, going from £14m to £20m in turnover and over £25m in order intake. China is trying to get modern technology to address its emissions problems in connection with climate change and air quality. Our work with Chinese clients continues to grow."

This does add concerns to the business though. "People are very concerned about China's economy, but as a lot of the work we do is legislation development and engineering development on products that are scheduled to come out in the next two years or so, we're a bit more sheltered. If we were selling products into China, maybe we'd be feeling the heat a bit more; if I were GKN, Jaguar Land Rover or Borg-Warner, say, I'd be more worried."

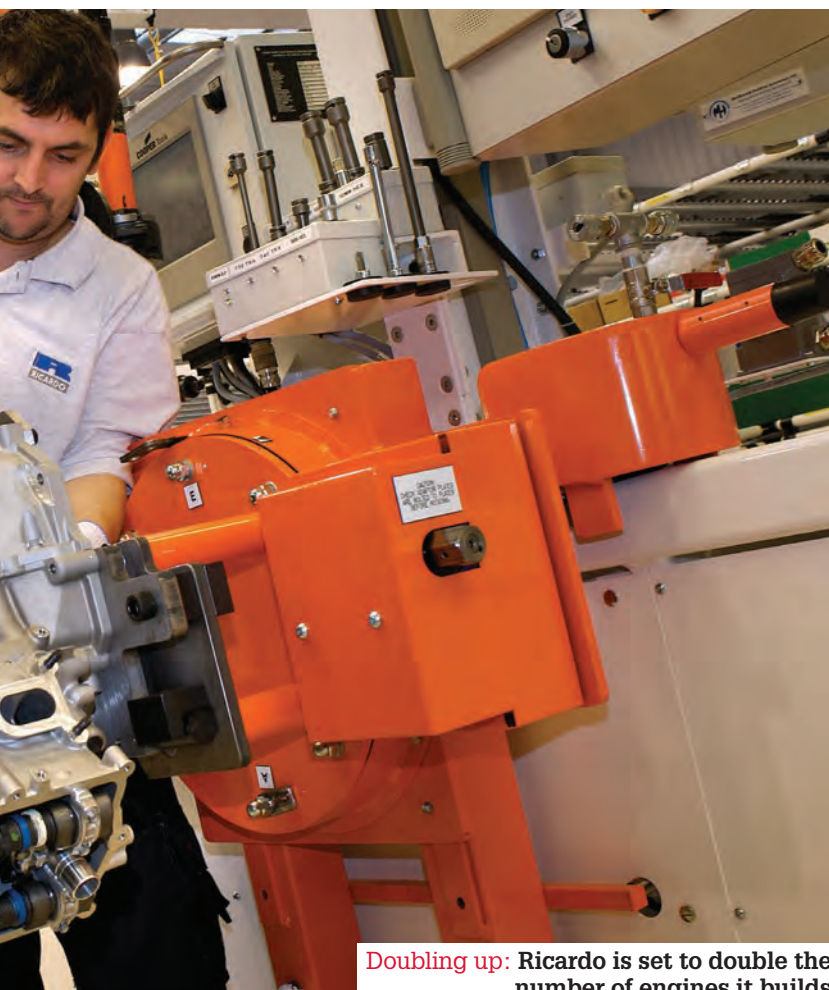
Other trends Ricardo is responding to include the development of electric vehicles and autonomous cars. "With autonomous vehicles we do a lot of work on control systems and safety analysis," Shemmans said. "You have to check all the failure modes and make sure it's always in a safe mode; for example, if someone walks out in front, someone pulls out, or if the some of the sensors are not delivering the right information. We delivered a complete drive-by-wire vehicle for Volvo a number of years ago, so we can do whole vehicles; this one was a road train so it was locked onto the vehicle in front."

The upcoming year will be an important transitional period for Ricardo, because of a change in the work it does for one of its most important clients, McLaren Automotive, for whose sports cars it makes engines. McLaren will next year launch a new model, the 570 series, lower priced than its MP4-12C supercar and the hybrid P3 hypercar, and aimed to compete with cars in the Porsche 911 price bracket. This new contract will see Ricardo double

the number of engines it builds to 49,000 per year, and has entailed the expansion of its production facilities. "Our new facility has been commissioned in the last couple of months and we should be seeing test units on it in the next month or so," he said. "The back wall [of the factory] was always intended to be knocked down, and the production space now goes back twice as far as it did before. The production line itself is the same and we're just going to double-shift it, but we have to build another end-of-line test dynamometer, plus in the extension there's lots of storage space, because we'll have twice as much stuff coming in as well as going out."

This is significant in more ways than just in terms of concrete output. "Our McLaren work has shown that we can provide good quality control and good product even at low volumes," Shemmans said. "That's very useful. A lot of electric vehicles are niche products, and the big car companies might not be set up to do runs of thousands or tens of thousands per year; they're set up for hundreds of thousands or millions. That means there's a role for us on the production side." The electric vehicles business is likely to benefit from this success, he thinks. "It's quite possible that we'll supply components such as electric motors or even whole electric scooters. We might well be looking for suppliers who can help us with niche volumes, which could be a few thousand units to start with."

With the UK economy, there are mixed indications. "We've obviously had good results, McLaren has plans to launch this new vehicle, so from that you'd say there's evidence that the UK economy continues to improve," he said. But the situation concerning Europe worries him. "About 30 per cent of our business comes from Germany but that tends to be long-term relationships with Porsche, Bugatti and BMW Motorcycles. Our competitors are based in Germany, which makes it difficult to win new work there. I don't think it helps to be seen as a country that doesn't want to be part of Europe, which is the impression I get from questions I'm asked; that we're happy to take the work but don't want to be part of Europe." ■



Doubling up: Ricardo is set to double the number of engines it builds

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Hardy help-mates

Experts answer your questions on developing robots for extreme environments. **Stuart Nathan reports**

In the last few decades, robots have advanced from the realm of science fiction to become an essential technology for a host of applications. In particular, robots are often designed for tasks that would be too tedious, too precise, or too dangerous for humans to be expected to do for long periods. In the last of these categories are the hazardous areas robots, which work under conditions that humans can either not handle at all, would require too much protective equipment for the task to be worthwhile, or simply cannot reach: in the heart of nuclear reactors, in space, under the sea, or in environments where the atmosphere is too dangerous for people to stay.

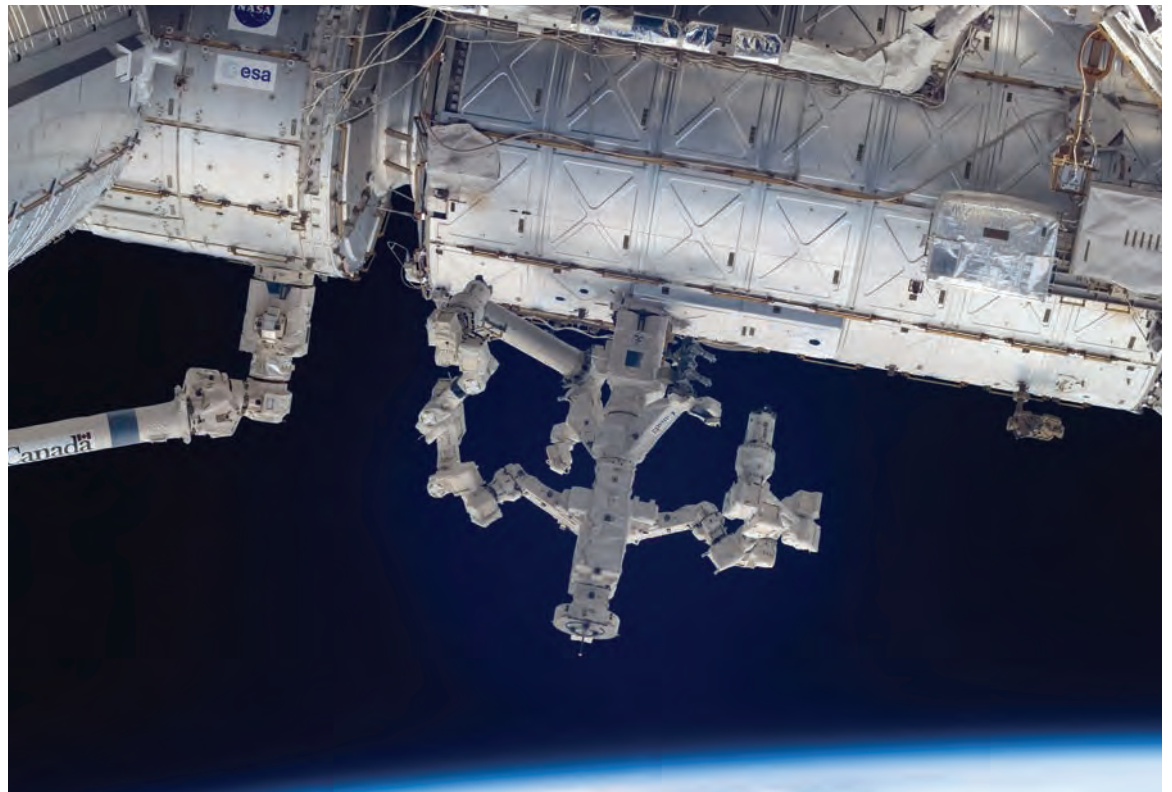
We put your questions on hazardous area robots to experts in the field, including:

■ **Prof Robin Murphy (RM)** of the department of Computer Science and engineering at Texas A&M University. One of the leading experts in the field, Prof Murphy is the director of the Centre for Robot-Assisted Search and Rescue, and specialises in artificial intelligence for mobile robotics.

■ **Shaun Whitehead (SW)**, founder and director of Scoutek, who develops terrestrial and space exploration robots. Previously, a systems engineer at space technology specialist Magna Parva, Whitehead has worked on projects including the ExoMars European robotic rover mission to Mars; snake robots for archaeology in the Great Pyramid at Giza; tunnelling machines; and the Indian robotic lunar rover Chandrayaan 2.

Realistically, when would these types of devices be cleared for use in Britain's nuclear industry? What standards are being defined for operators and site licence holders?

RM: Unmanned systems are essentially 'good enough' for use now. They are not perfect but they won't improve until there



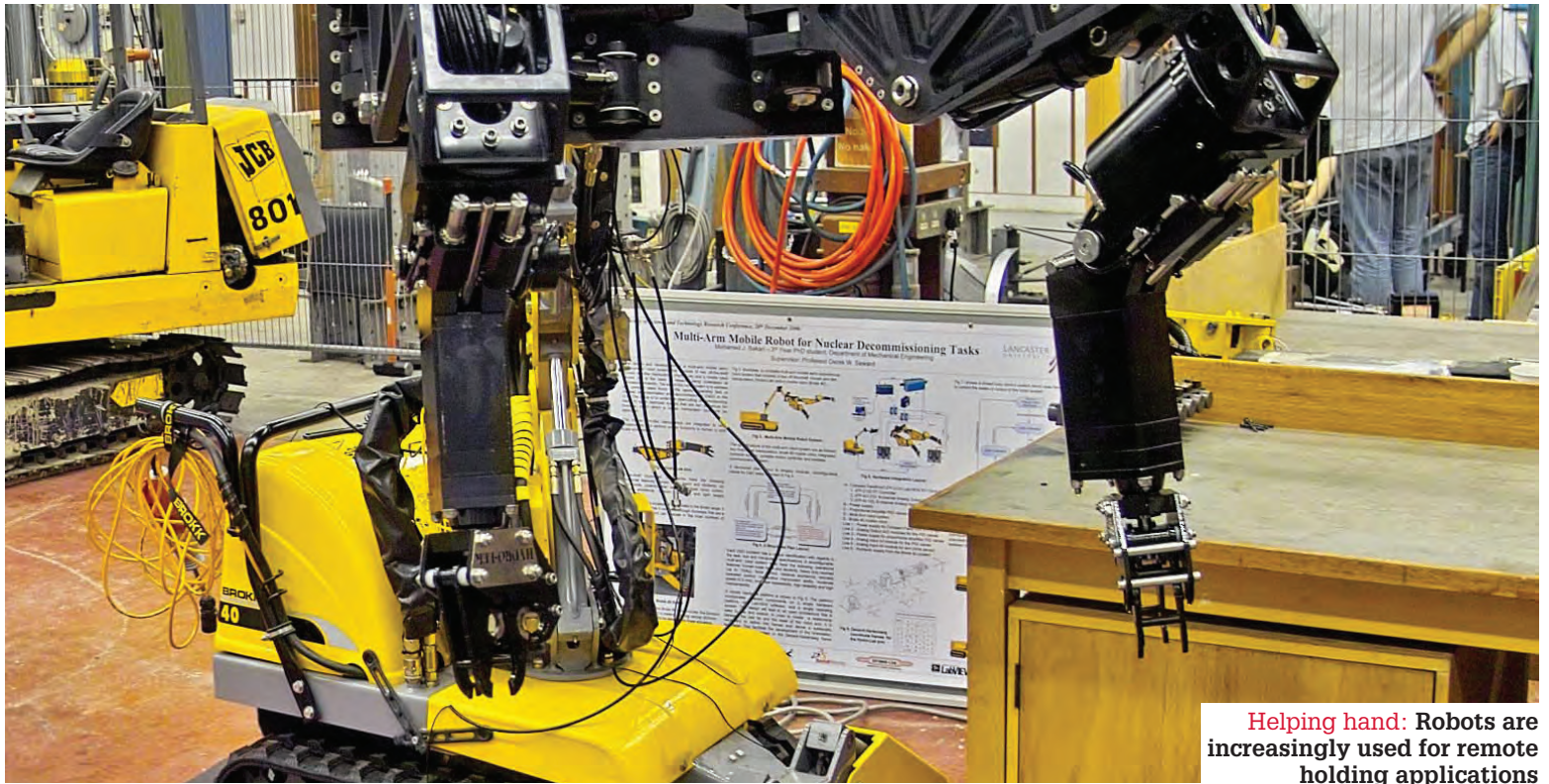
is significant use, leading to meaningful feedback to the manufacturers, who will be incentivised by the market.

What markets are we looking at here for the use of these machines in nuclear reactors? Does the panel think that they will play a part in the decommissioning of the UK fleet, or are they looking more toward similar work with foreign fleets? Also, where does the UK stand – if we were to rank these things – in developing these machines, compared to the rest of the world?

RM: I can't imagine how decommissioning can be done cost-effectively without robots. I do not know where the UK stands in development.

To what degree do developments made in the defence sector filter through to robots that are designed for use in other extreme environments?

->



Helping hand: Robots are increasingly used for remote holding applications

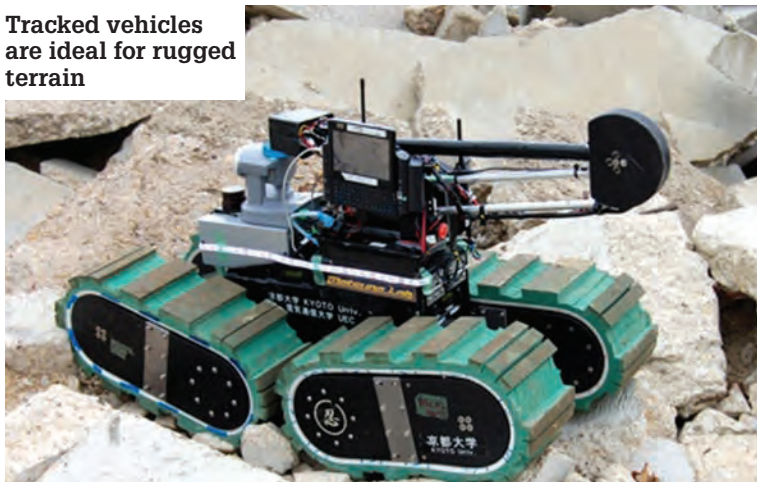
“ If the robot is performing dexterous manipulation, a human is generally involved in the fine motion

Robin Murphy

RM: The defence sector has been critical in developing unmanned ground and aerial systems. For example, the QinetiQTalon and iRobot Packbot, which were used in the immediate response and mitigation phase of the Fukushima nuclear accident and are heavily used in the decommissioning, were developed as part of the US Defense Advanced Research Projects Agency's Tactical Mobile Robots programme. The Honeywell T-Hawk used at Fukushima was also developed by DARPA. The military is a medium-volume, high-profit technology market. The nuclear industry is a very low-volume, medium-profit technology market – there is no market incentive for companies to invest in R&D, only to adapt what they have built for the military.

SW: There are some examples of complete robots from the defence sector that can be used for other extreme environments, but probably the biggest transfer is not of complete robots but

Tracked vehicles are ideal for rugged terrain



rather individual components – i.e. the parts, or enabling technology, such as radiation hard electronics.

Most 'extreme environment' robots tend to be remotely operated. Do autonomous robots (for example, with no outside control and onboard decision making) have any potential in this area? And can the panel identify any specific examples?

RM: The role of autonomous capabilities depends on the mission, the environment and robot. Manufacturers have tended to be either-or in terms of terms of teleoperation/navigational autonomy, in part because the US military has not been able to create test and evaluation methods for complex human-machine interaction and thus hasn't pushed for it. If the robot is being used for exploration, then having an operator drive and look opportunistically as interesting features come up, but have the robot autonomously avoid obstacles and build a map, is useful. If you want the robot to come back home at the end of the day, that is another set of capabilities. If the robot is performing dexterous manipulation, a human is generally involved in the fine motion because the computer vision systems aren't good enough.

SW: Autonomous or semi-autonomous robots not only have potential, but are already absolutely necessary in some cases. For space robots, the communication delay caused by huge distances between operator and robot mean that it is not practical to directly remote control the spacecraft. Practically every planetary spacecraft and lander is a great example of this autonomy. As we push the boundaries in other extreme environments on Earth, we will reach the limit of communication or tether distances, and so autonomy is going to be essential.

Hazardous areas describes a wide variety of conditions, but are there any common features or systems that might be used ->

“ As we push the boundaries in other extreme environments on Earth, we will reach the limit of communication

Shaun Whitehead



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“ Over 50 per cent of the terminal failures of robots in 29 disasters were attributed to human error

Robin Murphy

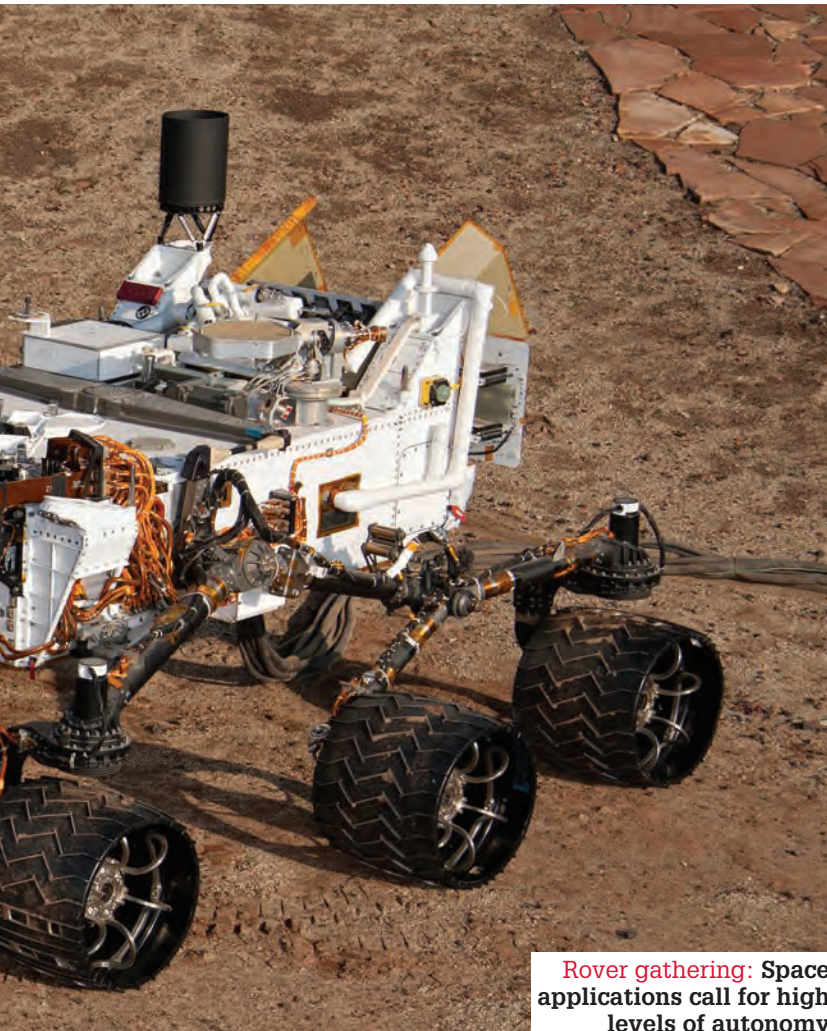


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Rover gathering: Space applications call for high levels of autonomy

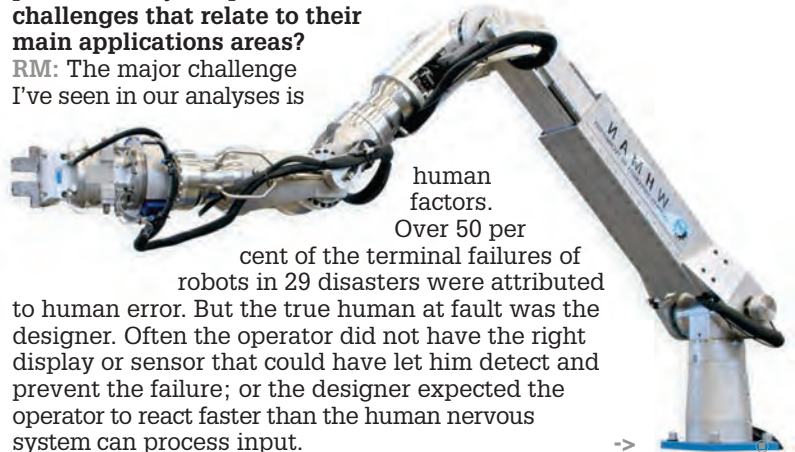
for all 'danger zone' robots, or in robots for particular areas? For example, what might an undersea robot have in common with a space robot?

RM: Robots of all types can be thought of as consisting of the following subsystems: control system, effectors (skids, wheels, arm), sensors, power, and communications.

SW: There aren't necessarily features that are common to all 'danger zone' robots, but there are certainly common challenges between different fields. Ionising radiation is a challenge for space and nuclear (civil and military) robotics. Nuclear decommissioning robots often have to survive in a much more harsh radiation environment than space robots. The development of radiation-hard electronics has been accelerated by space missions, and so designs and processes for rad-hard space hardware are transferable to nuclear. Increasingly, autonomy of robots for hazardous areas is going to become important, and that is what several have in common.

Obviously, there are many different types of extreme environment, each with its own set of challenges. Could the panel identify the particular challenges that relate to their main applications areas?

RM: The major challenge I've seen in our analyses is



human factors.

Over 50 per

cent of the terminal failures of

robots in 29 disasters were attributed to human error. But the true human at fault was the designer. Often the operator did not have the right display or sensor that could have let him detect and prevent the failure; or the designer expected the operator to react faster than the human nervous system can process input.

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Inset Bomb disposal: The defence sector is a major driver of technology

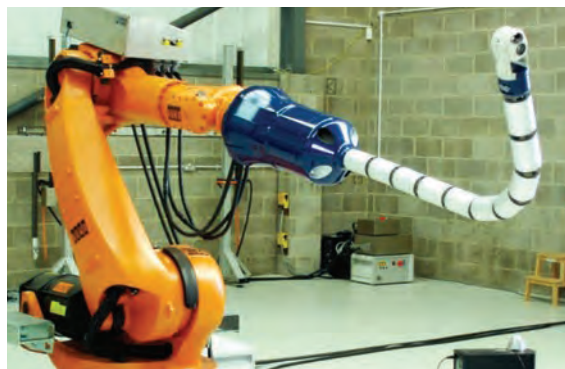
Below: Snake arm robots are ideal for accessing hard to reach environments

SW: The main application area of Scoutek is space exploration, and space is an awfully big place with every extreme. We've worked on missions to Mercury, where the surface temperature is 174°C, and missions to Mars, where the surface temperature can easily reach -120°C. Ultraviolet radiation and ionising radiation from the sun, the cosmos and trapped within the Van Allen radiation belts cause components to weaken and fail. Operation in vacuum and partial vacuum bring their own sets of challenges, especially for tribology and material degradation and contamination by outgassing. Dust is a huge issue; lunar dust is a great abrasive. As if all of that is not enough, we add our own extreme environment by placing sensitive instruments into huge rockets that vibrate all the way up to orbit. And when we visit another planet to look for signs of life, we don't want to take our own microbial hitch-hikers, and the process to sterilise the spacecraft can be just as tough as any environment that space can throw at us.

We've seen iRobot's Packbot used for bomb disposal in the Middle East and even in the hunt for the Boston bombers. What role does the panel think robots might play in future anti-terror operations?

RM: Unmanned systems are generally thought of as responding to an event, but these same technologies can be used to prevent events. For example, unmanned marine vehicles can routinely patrol ports and inspect the hulls of ships for contraband or detect

radiation that would be otherwise shielded. Aerial and marine vehicles can monitor and survey bridges and critical infrastructure. Ground vehicles can autonomously build up-to-date maps of key buildings at night.



SW: For anti-terrorism, I think that data-based security will have more of an impact, but there is always a need for smaller and less easily observed 'spy' robotics.

Does the potential market for hazardous robots not pale in comparison to that of more everyday types of automation? Will that restrict innovation in either sector as a result?

RM: The market for hazardous robots pales in comparison to industrial, agricultural, and consumer-based applications. Robots working in hazardous environments have constraints on platforms, for example, radiation hardening, intrinsically safe, etc., that drive the cost upwards. Also they have to be more reliable because they cannot make the situation worse.

SW: The value of the market or robots for hazardous environments is potentially huge, even if not as widespread as 'everyday' automation. A couple of examples: eventually mankind is going to want to mine the moon and asteroids, and you can't get a more hazardous environment than those places. Nuclear decommissioning is always going to be needed, even if facilities have decommissioning designed into them from the beginning. Even though it's not really related to this whole topic, I believe that we are almost at the tipping point of robotics for everyday use, and there will be plenty of innovation there. Right now, the mentality is that we will build a few expensive machines for specialist tasks, but soon the market will wake up to successes that would normally have remained in the lab or just for specialist use. The development cost has already sunk, and some companies have realised that their technology can be mass produced, creating a need that some may not have realised was there. ©

Unmanned marine vehicles can routinely patrol ports and inspect the hulls of ships for contraband

Robin Murphy

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Looking out of this world

Active optics will help convert light from billions of miles away into a focused telescope image. **Will Stirling reports**

The words of Genesis – “And the Lord said let there be light” – may have passed the lips of engineers, scientists and businessmen in December 2014, when the Council of the European Southern Observatory ESO approved the construction of the European Extremely Large Telescope, or E-ELT. The green light on the two-phase build opened up the market for thousands of components required to build this enormous, pan-European project, valued at €1.083bn (£772m) at 2012 prices.

Located in Cerro Armazones, deep in Chile's Atacama Desert, the telescope's main scientific goals include the search for exoplanets – planets outside our solar system – and studies of the stellar composition of nearby galaxies.

An extremely large telescope needs extremely accurate moving parts. E-ELT's five mirrors must align precisely to steer the beam toward the final focal surface, where the final visible (or infrared) image is produced. The E-ELT will gather more light than all of the existing 8-10m-class telescopes in the world combined, and 100 million times more light than the human eye.

The engineering required to convert light millions, or billions, of miles away to a focused image is out of this world. The optical structures are mounted on an altitude-azimuth telescope main structure that uses the 'rocking-chair' concept, with two massive cradles for the elevation motions and two major azimuth tracks, which operate the vertical and horizontal axes. The structure

weighs approximately 3,000 tonnes.

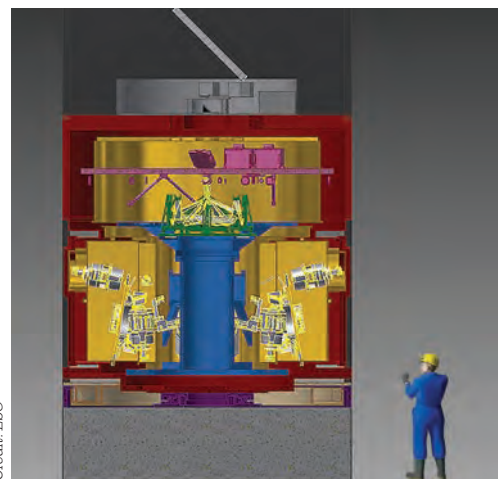
One of the great challenges of the E-ELT is to co-ordinate the engineering of its tremendous size with the demands of both active optics and adaptive optics.

Big primary mirrors allow astronomers to capture more light and a perfectly shaped mirror surface is needed to avoid distortions; the effective combination of the two makes it possible to observe fainter objects. But with mirrors over 5m in diameter, the image quality decreases enormously as gravity pulled the mirrors out of shape – maintaining a perfect shape becomes harder as telescope mirrors become larger.

ESO engineer Raymond Wilson came up with a clever and “simple” idea called active optics. A thin and deformable primary mirror would be controlled by an active support system that applies the necessary force to correct for gravitationally induced deformations as the telescope changes its orientation.

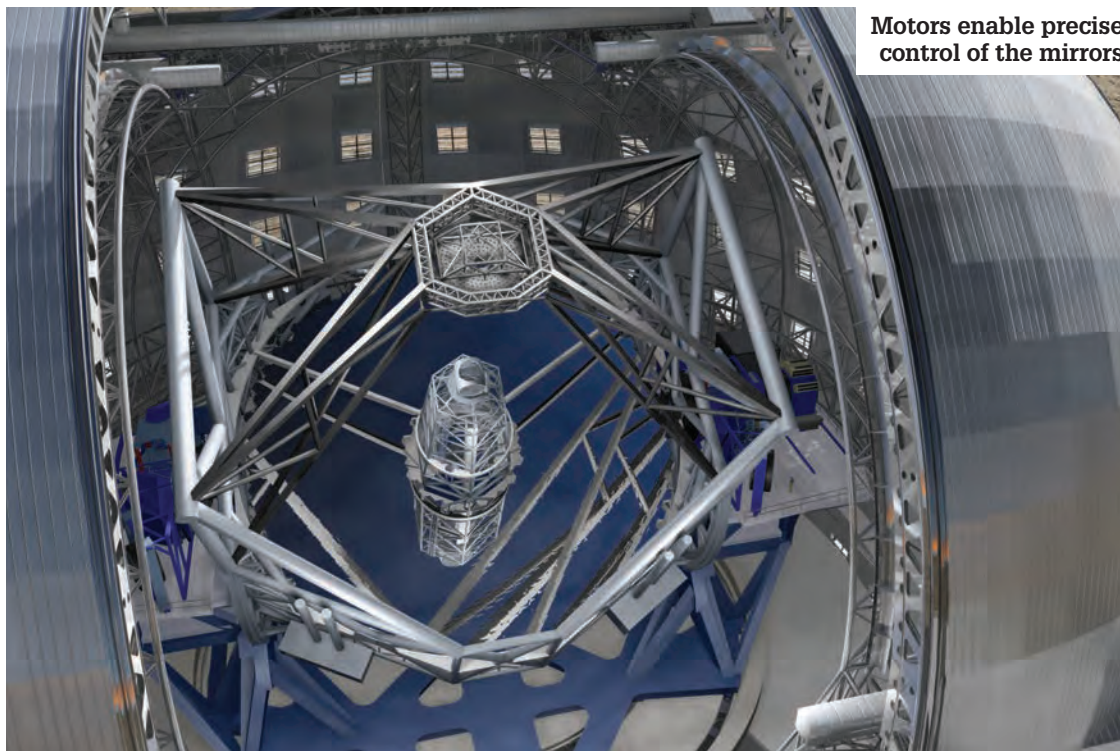
Active optics require actuators, motors that move very accurately and can be controlled precisely: by pushing the mirror, they correct its shape and compensate for the distortion produced by gravity. As the telescope moves, this active system can maintain the correct shape of the mirror. The corrections applied by the actuators are calculated in real time thanks to a computer with an image analyser that detects even the smallest deviations from the ideal mirror shape.

The discipline of active optics faces its biggest challenge yet ->



Credit: ESO

Motors enable precise control of the mirrors



Credit: ESO

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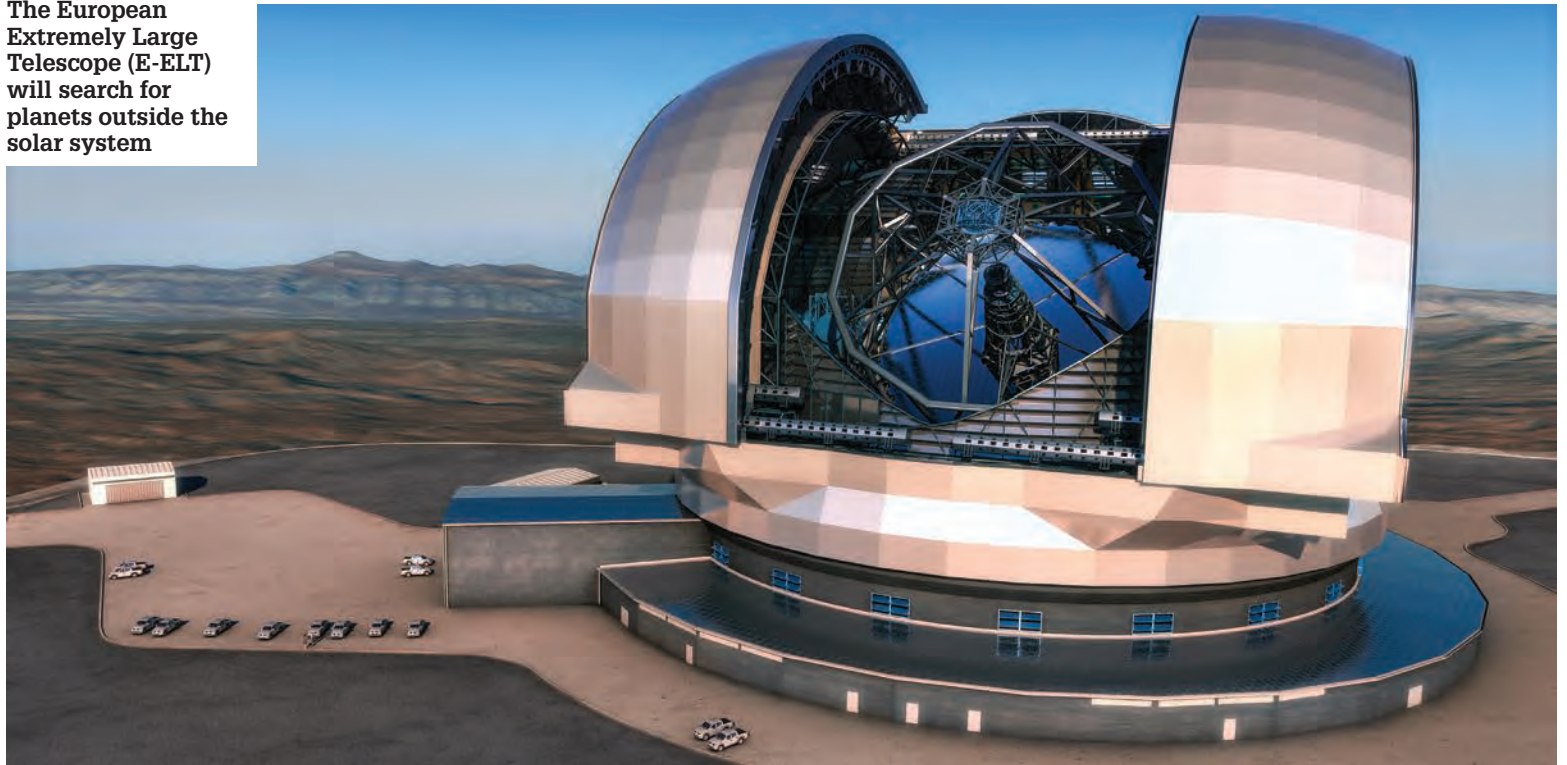
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The European Extremely Large Telescope (E-ELT) will search for planets outside the solar system



with the 39m primary mirror of the E-ELT and its 798 individual segments. Each segment can be moved by a piston and tip-tilt mechanism, making this mosaic work as a single giant mirror by compensating for the effects of temperature fluctuations and gravity.

The E-ELT also has to deal with the distortion caused by the Earth's atmosphere. ESO scientists use adaptive optics here. Precisely engineered, deformable mirrors controlled by computers can correct in real-time for the atmospheric distortion, making the images obtained almost as sharp as those taken in space. Adaptive optics allows the corrected optical system to observe finer details of much fainter astronomical objects than is otherwise possible from the ground.

The engineering challenge for ESO is to synchronise the whole arrangement, blending adaptive optics with the primary active optics, simultaneously. The design of the business end of the telescope, the primary mirror control strategy, takes into account wind disturbances, sensor and actuator noise – both edge sensors and the embedded position actuator sensors – changing gravity, thermal expansion and vibrations. Several control strategies were evaluated at ESO and by an external study with the University of Liege.

Engineers made a trade-off analysis between global, modal, local and the LTSI (linear time and space invariant) time baselines and decided that modal control forms the baseline. Within this baseline the segments are commanded in piston tip-tilt to reduce cross-coupling at the segment level.

The E-ELT primary mirror (M1) is a 39m diameter concave mirror, with a 69m radius of curvature. The M1 mirror is made of discrete optical elements: the primary mirror segments.

There is a wonderful understatement in the E-ELT Construction Proposal. “Any strategy that addresses 798 mirrors with almost 2,500 actuators and 5,000 pairs of edge sensors needs to be investigated for robustness.” Stability and wind strength are key variables.

The mirror segments are axially supported on 27-point identical whiffletrees, structures that spread load equally via linkages. A lateral restraint is located in the centre of the segment using

a membrane to allow limited motion in the direction orthogonal to the back surface.

Actuators, edge sensors and whiffletrees work together to manoeuvre the mirror segments precisely at the correct speed, within the physical constraints of the environment. A total of seven sectors, 931 segments, are procured. Coating strategies have dictated the design; having seven segments per family allows for a realistic operation scheme in relation to coating, where it is estimated that up to two segments will be recoated per day. Three position actuators move the whiffletree, and consequently the segment, in piston and tip-tilt. The actuators are required to have sufficient stroke to reposition the segment to its nominal position compensating for the deflections of the underlying telescope structure.

In addition, the actuators need to provide the resolution and accuracy necessary for phasing the primary mirror in the presence of disturbances. These are dominated by the wind across the front surface of the primary mirror and possible vibrations arising from machinery either directly under the segments or transmitted through the structure to the primary segments.

The position actuator is based on a high-bandwidth voice-coil actuator in series with a gravity off-loading electromechanical stage. An encoder is used to close the local loop. The layout of the actuator is shown in the two figures below that identify the key components of the design.

While the contract for the dome and main structure will have been awarded by the first quarter of 2016, no contracts have yet been awarded the main mirror assemblies where the majority of actuators, drives and sensors are fitted. The final design contract for the main mirror segment support is running and will complete by Q3 2018. Tenders for position actuators for the M1 unit will be received in 2017.

“We are encouraging all UK companies that qualify to manufacture these mechanical components to bid,” said Sandi Wilson, UK Industry Liaison Officer for ESO at the Science & Technology Facilities Council in Edinburgh. “We believe that defence especially, and aerospace, companies will have the necessary capabilities to bid for these contracts and because E-ELT is a European member organisation, the UK has a very fair shout.” The E-ELT said the programme will invest some €820m (£585m) in industry. In line with ESO's procurement policy, the bulk of investment will be made in the member states and Chile. As for the UK's likely share, the ESO said there is no hard percentage per member state.©

Any strategy that addresses 798 mirrors with 2,500 actuators needs to be looked at for robustness



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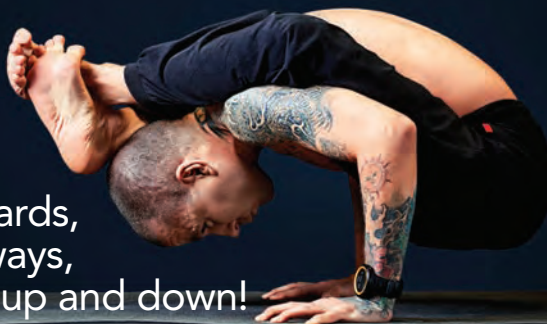


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productnews

A lock with no key

Fenner Drives has launched three new problem-solving products for speed, precision and defence.

B-Loc Speed is a new series of keyless locking devices engineered to reduce installation time by up to 60 per cent while maintaining the same physical performance as a standard keyless locking device. Trantorque Micro is a patent pending keyless locking solution for small shaft applications that require precision positioning.

RotoShield Gearbox Torque Limiters provide defence against torque overloads. Easily mounted between the motor and gearbox, RotoShield instantly disengages when a torque overload occurs, preventing costly damage and unscheduled downtime. These products are designed to bring cost savings to variety of industrial power transmission applications.

It's all in hand

Maxon Motor has developed a robust brushless DC motor for hand-held surgical tools: the EC-4pole 30. Featuring two pole pairs, this DC motor provides a nominal torque of 106mNm and an output of 150W. It has a hermetically sealed rotor, meaning that it can withstand over 1,000 autoclave cycles.

The EC-4pole 30 is equipped with special ironless Maxon winding, which makes it highly efficient.

Another key feature is that the torque and current behave linearly and the drive can be overloaded.

It is available with an optional Hall sensor, as well as with a hollow shaft with a diameter of up to 4.1mm.

Ensemble performance

Aerotech's Ensemble QLe panel-mount nanopositioning piezo drive has been designed for use with the Ensemble range of drives and controllers.

The QLe connects to any Ensemble controller network enabling coordinated motion between piezo stages and servo axes at much higher rates than other controller or drive products. It is suitable for applications ranging from demanding scientific research to advanced OEM machine systems.

Small steps and spaces

Motion Control Products has recently introduced the smallest Lexium MDrive integrated motor, which is a 1.7in/42mm NEMA size 17 stepper motor with built-in electronics, delivering a large range of features to small spaces.

Features now include an IP65-rated version with industrial M12 connectors. M12 Lexium MDrive products provide a robust interface, with IP65 certification for protection against water and dust in harsher environments.

For more on this story visit
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Air of intelligence

Library utilises drives and motors

France's biggest library has chosen drive and motor products from Emerson to maximise the reliability of its air-conditioning units. The National Library of France (BnF) in Paris contains a unique collection of books, periodicals, manuscripts, prints, and much more – and the facility's air-conditioning system is key to preserving and maintaining this world-leading resource.

Recently, the BnF turned to automation specialist Leroy Somer to replacing an asynchronous variable speed drive assembly with a new drive system that would be used to power an air-conditioning pump, itself responsible for half of the library's reading rooms.

To handle the variable torque load (also referred to as the quadratic torque) of the pump and ventilation applications, Emerson implemented a solution comprising a Leroy-Somer Dyneo LSRPM 250 (85kW) motor and a Control Techniques Unidrive M600 variable-speed drive unit.

According to the company, the permanent magnet synchronous motor is perfectly suited to applications of this kind, offering enhanced efficiency of up to 96 per cent over the whole operating speed range. Another advantage, in terms of cost, comes from the sensorless control.

This function, integrated into the Unidrive M drive unit, simulates an encoder input with a high degree of precision.

"With this solution, not only do we eliminate the cost of the encoder, but we also reduce the number of components and thus the probability of a breakdown", said Jérôme Hardy, from GED ADREM, a partner company of the Leroy-Somer service network.

The original motors, also from Leroy-Somer, were overhauled and kept as back-up. The assembly is connected to the building management system, an automated, centralised supervision system that gives the speed setpoint. The next phase will involve conducting an energy-efficiency study on the central air-treatment systems and replacing the drive solution.



Cool location: The National Library of France relies upon its air conditioning

Aquatic automation

Linear motors reduce use of antibiotics in fish farms

Linear motors, widely used in packing and handling machines have been given an unusual new application in a machine that vaccinates up to 20,000 fish per hour, eliminating the need for preventive medications.

These medications, especially antibiotics, are widely used in fish farms but attract criticism due to side effects such as pollution of the world's oceans with medication residues and the development of antibiotic resistance.

One solution to this is fish vaccination which, in Norway, for instance, has eradicated exposure of farmed salmon to antibiotics. However, this procedure is difficult, because up to now each fish has had to be manually injected with the vaccine using a syringe. Considering the number of fish that are raised annually – 1.4 million tons of salmon in aquaculture worldwide in 2010 – this procedure has reached its limits.

Automation of the vaccination process has been made possible by the machine builder

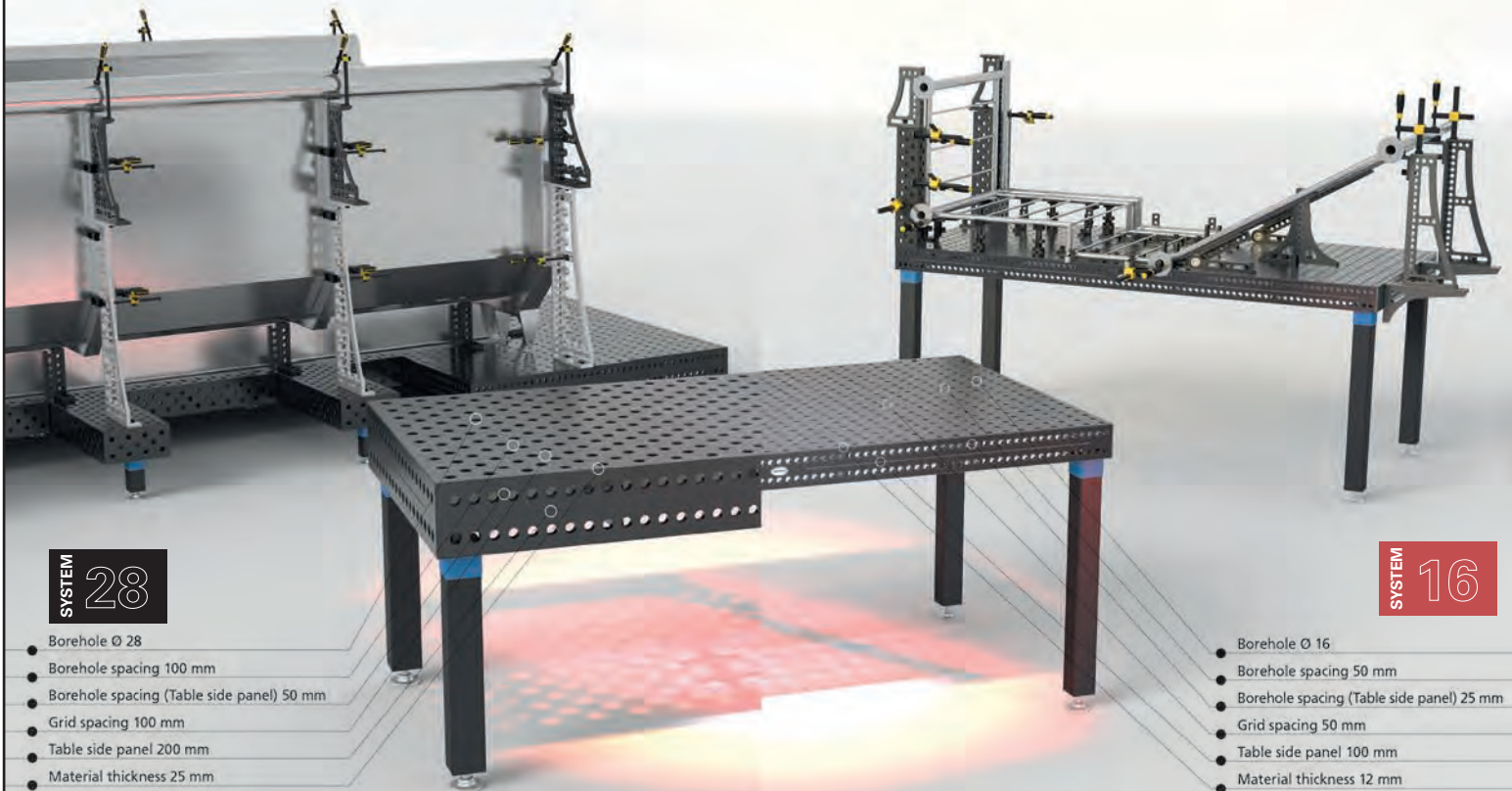
Maskon. This system allows a single operator to automatically anaesthetise, sort, singulate, and vaccinate up to 20,000 fish per hour.

The machine consists of one or two vaccination modules each equipped with four vaccination stations. An image-processing system first measures each fish and provides information used to calculate the individual point of injection.

The entire vaccination station is then positioned accordingly by stainless steel linear motors developed by Swiss firm LinMot. This makes it possible to hit the optimal injection site for each fish with a precision of over 98 per cent.

The length of the fish, as determined by the image processing system, is also used to calculate the depth of the injection for each individual fish. A sensor on the needle then monitors the injection process and the vaccine dosage for each fish. As a result, the mortality rate is less than 0.02 per cent.

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Gathering intelligence

How manufacturers handle big data is key to boosting productivity. *Helen Knight reports*



Big data can be used to drive simulation

Manufacturers have always had to sift through large quantities of data from their production lines in order to understand how their businesses are performing.

But with the increasing use of sensors and instrumentation to monitor, measure and automate the production process, the sheer quantity of information that manufacturers are now faced with has risen dramatically in recent years.

That is set to increase exponentially with the adoption of Industry 4.0, a German government initiative to promote the greater use of sensors and automation within the manufacturing industry, with the aim of developing so-called smart factories.

But it is not enough to simply gather more data, companies need to be able to analyse it, in order to find previously hidden connections that can be used to improve their production

processes and, ultimately, the performance of their business.

The term 'big data' is often used to describe both the sheer volume of information many companies are now generating, and the analytical tools used to manage and interpret it.

Many of the technologies being introduced to the production line as part of the Industry 4.0 initiative are designed specifically to extract more data, according to Dr Lina Huertas, technology manager for manufacturing informatics at the Manufacturing Technology Centre (MTC) in Coventry.

As the power of decision-support tools become more sophisticated, companies will want to get even more data out of their shop floor, so they will start bringing in more sensors and measurement technologies to provide that data, she said.

"Machines have evolved to be equipped with more sensors ->



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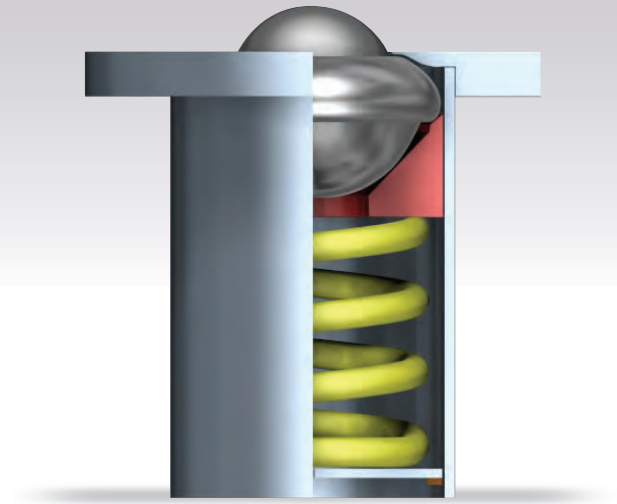
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feature: automation

and to generate large volumes of data, but as Industry 4.0 evolves, companies are needing to extract even more information in order to inform their decision-making," Huertas said.

But how do companies determine what information is most important from within this flood of incoming data?

Research by the MTC suggests there are three essential areas that companies should be prioritising, if they are to get the most out of the rise of Industry 4.0. These are data on product quality, including faults or components not meeting their required specifications; information on the health of production equipment, such as maintenance and repair data; and any data that allows them to be more flexible, by allowing them to more easily meet customer demands for increased customisation of their products.

In addition to these, information on the power consumption of each machine, and therefore the energy efficiency of the production line as a whole, is also an important area that companies may wish to analyse, she said.

The main idea behind the trend towards big data is to collect any and all information, no matter what form it takes, according to Dr Daniel Peavoy, technology manager for process modelling at MTC. "The idea with big data is to keep everything, no matter how it is structured, and then integrate these different types of data into one analytics platform," said Peavoy.

Big data is about integrating any and all data, whether that be information from sensors, data on product quality, or resource planning data, into a single framework, he said. That could mean collecting not just data from production equipment, but also information from the internet, weather reports, images, video or audio files, emails from customers, or even a twitter feed, Peavoy added.

"So whereas previously you might have held data on business performance within a database, no one would have considered integrating that with their sensor data, supply chain data, or customer feedback data," he said.

Once all of this data is collected, companies need to determine what specific information they want to analyse further, added Peavoy. "So you may have a specific issue with quality, and you want to understand if there is any relation to equipment performance, or equipment life, or any manufacturing parameters such as throughput, or the number of rejects," he said.

Combining data from various sources into the same framework allows you to spot connections between different areas of the production process that may have been difficult, if not impossible, to identify previously.

"So you might have some properties measured from your machine tools, such as the temperature within the coolant, and you can relate that to quality data that may not be gathered until a few hours, days or even weeks later," added Peavoy. "As soon

as you can carry out data mining on these integrated data sets then you can start to discover previously unknown relationships," he said.

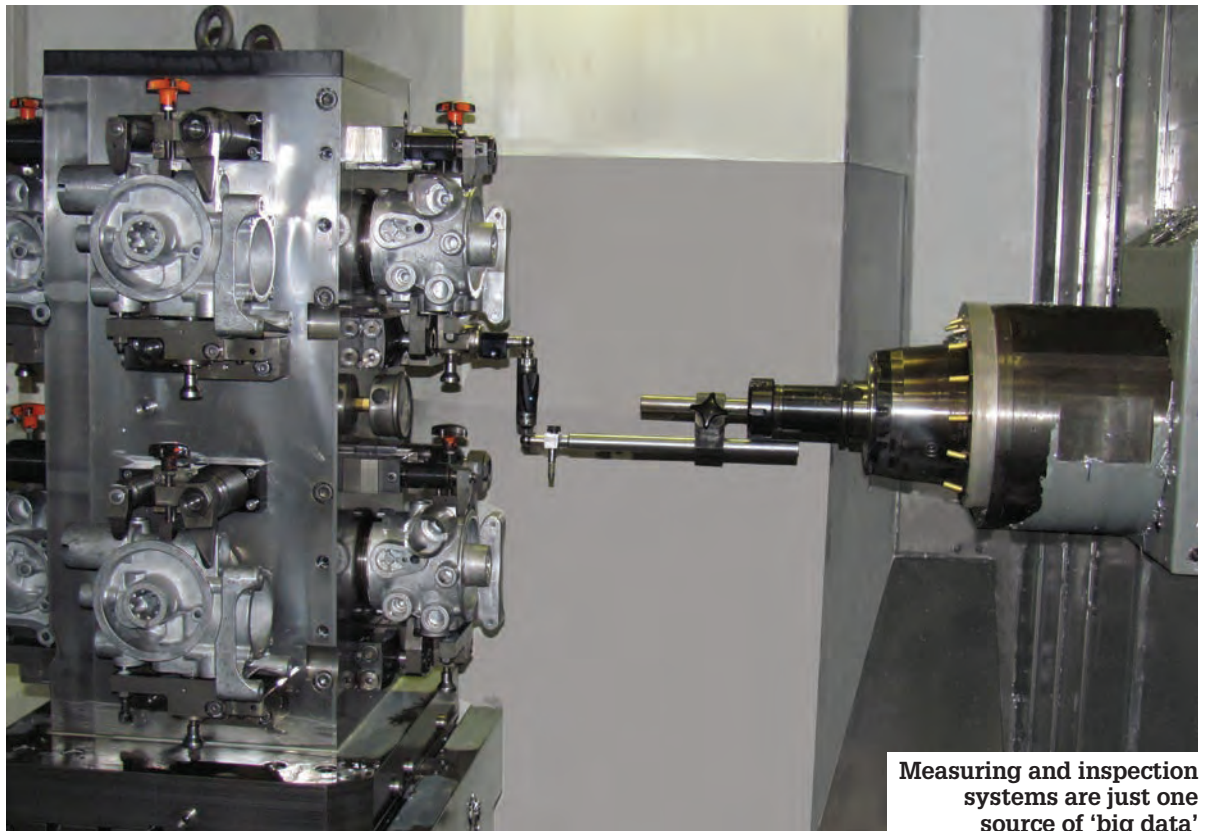
This is not a task that is easily performed manually, however, as it involves trawling through and comparing huge amounts of information, all held in different file formats.

So companies may need to seek help from tools such as business intelligence software, according to Andy Graham, senior systems architect for Wonderware UK and Ireland. This type of software has previously been used in areas such as enterprise resource management, but it is now being increasingly deployed on the shop floor to help manufacturers keep track of their production lines as well, he said. "These tools allow you to

“ These tools allow you to analyse multiple data sources and reveal more information about the process

analyse multiple data sources and reveal more information about the process," added Graham.

So rather than just reviewing data on a particular machine to monitor the amount of time in which it is productive on a given



Measuring and inspection systems are just one source of 'big data'

“ Combining data from various sources into the same framework allows you to spot connections between different process areas

day, for example, companies can use business intelligence tools to compare this with shift data, or information from the internet on the weather at that time, say, to try to understand the reasons behind this performance.

"That is key, to be able to analyse the data in the best way possible and I think the only way to do that to real effect is through an enterprise software product, as it isn't something that people can do manually, or if they could it would take them a very long time to do," said Graham.

Visualisation tools can also be used to help companies to better understand what the information is telling them about how they could improve their production process and the bottom line.

But ultimately though, software tools will only be useful once a company has given careful thought to what they hope to get out of all of the data they are collecting and analysing. In that way companies can begin to understand what all of the data is telling them about what is happening on their production line. ©

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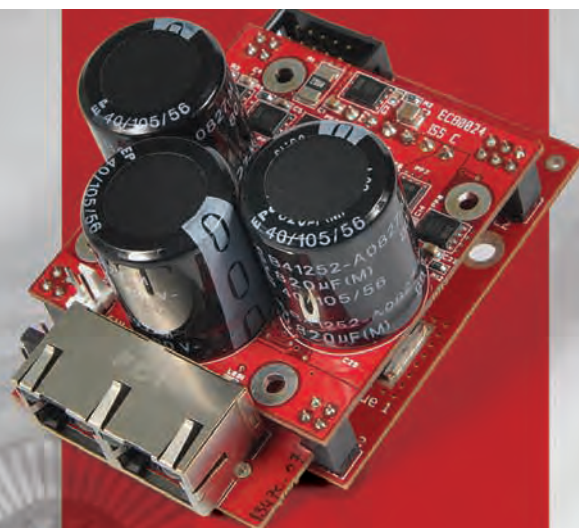


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NECR offers engineering professionals an unrivalled opportunity to meet face to face with leading engineering firms

Demand for engineers is at an all-time high, so the National Engineering & Construction Recruitment Exhibition (NECR), in association with the *Daily Telegraph*, has come at an ideal time.

Running on 27 and 28 November at the NEC, Birmingham, the event will offer engineering professionals and those at the start of their career a forum to meet face to face with leading engineering firms. Visitors will be able to explore the range of career opportunities available and equip themselves with job-seeking tools at a range of seminars and informative features.

Free to attend for registered visitors, the two-day event will showcase a variety of sectors, including automotive, mechanical, civil, design and electrical. Each sector will be represented by industry leaders, including General Electric, Highways England, Lear, Network Rail and Anglian Water @one Alliance, all looking to recruit the industry's best talent.

The exhibition will provide a one-stop shop for job seekers to discover thousands of vacancies and gain valuable advice. Visitors can expect a full seminar programme, a careers advice lounge, CV and interview clinics, a Professional Development Hub and an engineering challenge for current students.

John Hancock, managing director of Venture Marketing Group, which organises the event, said: "With the demand for engineers dominating headlines, it is clear there has never been a greater need for the NECR exhibition. Engineering and construction are ever-growing markets which offer a wealth of career opportunities. Now in its 17th year, this event is the perfect platform for skilled professionals seeking a new challenge, as well as those looking to forge a career within the industry, to explore their options.

With everyone brought together under one roof, the networking opportunities are endless and it gives job-seeking engineers a valuable face-to-face experience with leading recruiters, which is not readily available anywhere else."

Alongside the main exhibition, visitors will also have access to a wide range of features designed to aid career progression. Across both days of the event, a packed programme of free presentations will offer an insight into key developments within the industry and their impact on the recruitment process. Attendees can drop in to the careers advice lounge for a free one-to-one consultation with careers counsellors from Inspiring Talented Minds, or call in to the CV clinic where The Write Stuff will be available to give individual feedback on visitors' CVs.



Meet and greet: All the major sectors will be represented at the NEC

“ Visitors will also have access to a wide range of features that are designed to aid career progression

Facilitated by Chris Morrall from leading consultancy Talent Transitions, the Interview Clinic will be on hand to offer support and advice on interviewing in today's competitive job market.

Whether an experienced professional considering a new challenge, or a recent graduate confused about where to start, experienced careers coaches will be able to offer guidance to help visitors fast track their route through the recruitment process.

Major engineering institutions will take centre stage in this year's Professional Development Hub; a central attraction for engineers looking for ways to enhance their career progression. Representatives from professional institutions will share their knowledge of the industry, as well as the range of benefits professional registration offers.

Sponsored by Comau UK and supported by the Women's Engineering Society, the highly popular Women in Engineering Forum will focus on the topical issue of female

representation within the industry. Taking place on Friday 27 November, the forum is open to all female engineers and looks as if it will provide an excellent networking opportunity for professionals at all stages of their career.

This season, inspirational female engineers will deliver two keynote presentations entitled: 'Engineering: the good, the bad, and the female' and 'Civil Engineering – high vis to high heels'. They will be looking into the future of women in industry and sharing their personal experiences to give first-hand advice to those developing their career as an engineer within an often male-dominated industry.

Speakers include Kuksy Akande, estimating engineer, Katie Pavey, sales specialist from Comau UK and Helen Randall, senior engineer at Buckingham Group Contracting.

The Engineering Challenge, which is being sponsored by General Electric, aims to put passionate university students to the test with a live task on the exhibition floor.

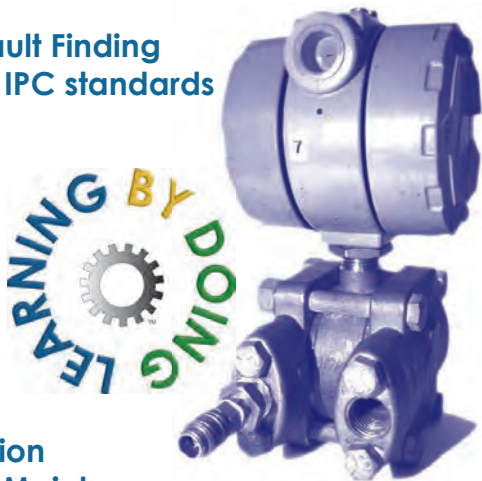
Groups of students from across the UK will be invited to compete against one another to design, build and test their inventions to solve a real-life problem to be in with a chance of winning £500.

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The sense of achievement

Female engineers should be far less modest about their accomplishments argues **Dr Sue Ion**

New research by the Queen Elizabeth Prize for Engineering has revealed that 71 per cent of people around the world think engineers' contribution to society is undervalued. The *Create the Future* report also shows that interest in engineering remains higher among men (66 per cent, compared with 43 per cent of women) but the gap is closing faster in emerging economies such as India and Brazil. In the UK only around 14 per cent of STEM professionals and seven per cent of engineers are women.

Engineering is all too often considered to be a messy, mechanical or physically demanding career. But this is a narrow view of a sector that encompasses far more than just construction and civil engineering, including areas as diverse as biomedicine and renewable energy. The Institute of Engineering and Technology's *Engineer a Better World* research recently highlighted that a staggering 93 per cent of parents would not support their daughter in pursuing an engineering career. More needs to be done to dispel outdated perceptions that put off both parents and children.

As an industry, we could learn a lot from successes in medicine. Only half a century ago, female doctors were few and far between but now women account for around 60 per cent of medical students. Medicine requires many of the same skills as engineering, so why do the sectors have such a different demographic? It may be because medicine is overwhelmingly perceived to be a career about helping people

and improving their quality of life. Yet engineers also enable the provision of clean water and power, we are responsible for the transport systems that get us to work, and we are behind many of the medical technology developments of the last 100 years. If we could do a better job of communicating the vital role that engineering plays in our everyday lives, we might find it easier to attract young people, particularly women, into the profession.

There can be reluctance among engineers to stand up and shout about accomplishments, and this is especially true of women. This so-called 'confidence gap' is not unique to engineering – a frequently quoted statistic is that men apply for a job when they meet 60 per cent of the qualifications, but women apply only if they meet 100 per cent of them. I have frequently noted that female engineers, scientists and technologists are more modest at celebrating their achievements, and often put successes down to team effort.

If young women don't see successful engineers like themselves, they will be less likely to think that engineering is a career that is well suited to them.

The talent is out there and women are increasingly represented in some high-profile STEM roles. The Royal Academy of Engineering, the IET and the Institute of Physics all have female presidents: Prof Dame Ann Dowling DBE FREng FRS, Naomi Climer FREng and Prof Dame Julia Higgins DBE FREng FRS respectively.

Through my role at the Royal Academy of Engineering I have had the privilege to work with a huge number of incredible women who work in engineering. Elspeth Finch, now director of innovation at Atkins, designed the X crossing on London's Oxford Street, and continues to strive to make our cities more user friendly. A transport planner by background, Finch has been awarded a prestigious Royal Academy of Engineering Silver medal for her work in business and technical leadership in over 100 transport planning projects in the UK and internationally. The Silver medal's most recent female recipient is Dr Susannah Clarke, inventor of 3D-printed customisable surgical instruments.

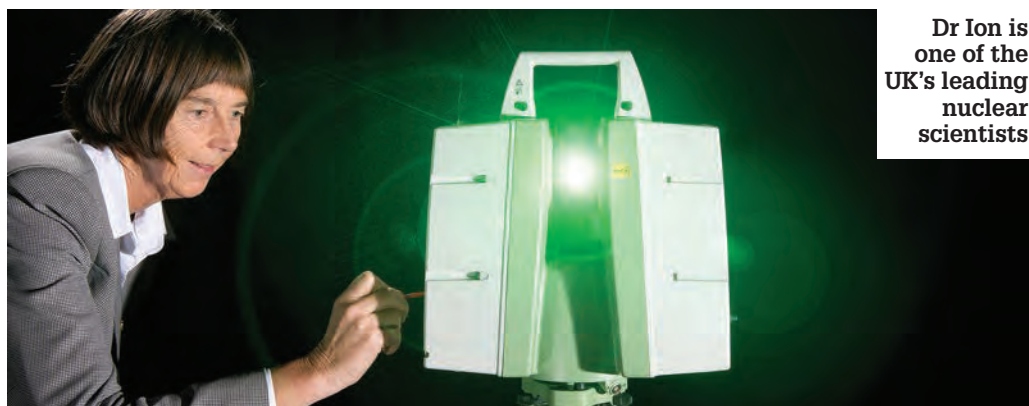
I also lead the judging panel for the UK's premier prize for engineering innovation, the Royal Academy of Engineering MacRobert Award. Through this I have been privileged to meet some brilliant innovators, but very few have been women.

I would urge my female colleagues to put themselves forward for this and other high-profile awards, as well as actively seek out outreach opportunities through organisations such as STEMNET.

Progress is being made, and recent efforts such as Ada Lovelace day and social media campaigns such as #looklikeanengineer have helped to capture the public's imagination around women in STEM. I would like to see even more active and positive promotion of achievers in our field to improve the public perception of engineering. Strong engineering skills are integral to the growth of our society and economy. The more female role models we present in a diverse range of engineering careers, the better chance we have of recruiting more women and bolstering the UK's strength in these sectors.

The 2016 Royal Academy of Engineering MacRobert Award is now open for entries, closing date 31 January 2016. ©

Dr Dame Sue Ion DBE FREng, Royal Academy of Engineering



Dr Ion is one of the UK's leading nuclear scientists

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Ref: 2012

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**naomi
climer**

President, Institution of Engineering and Technology (IET)

Education

1986 BSc Chemistry, Imperial College London

Career

1996-2000 Controller technology, BBC News
2000-2002 Director, ITV Digital
2002-2006 Sony, director, professional services
2002-2012 Sony, vice-president, Professional Solutions Europe
2010 Joins IET Board of Trustees
2012 Becomes deputy president of the IET
2012-2015 Sony, president, Media Cloud Services
2013 awarded Fellowship of the Royal Academy of Engineering
2014 named International Association of Broadcast Manufacturers Woman of the Year
2015 begins term as IET president

A matter of perception

IET president wants to show engineering has more to offer. **Stuart Nathan reports**

Naomi Climer has been president of the Institution of Engineering and Technology (IET) – the international, trans-disciplinary professional body, headquartered in London, that represents and promotes engineering interests – for barely a month. As the IET's first female president, she has spent a significant part of her brief time in the post – not to mention a while before taking it up – talking about gender issues. While she accepts this is hardly surprising, when I met her in her office, currently tucked into a small corner of the IMechE's building in Westminster while the IET's own offices off the Strand are refurbished, and told her I wanted to start by speaking about other matters as well, she let out a small cheer.

Climer's route into engineering has been an unusual one. "I can't say I had much of a specific engineering interest when I was a child, or at school," she said. Her degree is, in fact, in chemistry, which she studied at Imperial

College London; but, after graduating, she was accepted onto a graduate scheme run by the BBC that combined hands-on experience with further academic study to train her as a broadcast engineer. "It was a conscious effort by the BBC to broaden their employee profile, both in terms of the gender balance and just in the type of people they had and looking back, I realised that I actually have always been interested in how things work and had had a phase of taking things apart and putting them back together again – or at least trying to – so maybe I had that germ of engineering after all. Certainly adjusting to engineering after studying science for three years wasn't difficult for me."

“I was very taken with the Californian can-do start-up attitude... I went out there as a typical Brit

services to the broadcast industry and audiovisual systems for other sectors; and eventually running Sony's start-up Media Cloud business in Los Angeles until earlier this year. The operation offers cloud-hosted production and post-production software that broadcasting clients can download. "I was very taken with the Californian can-do start-up attitude," she said. "I went out there as a typical Brit, slightly cynical, but by the end of my time talking to people in the organisation had embedded the positivity. I'm still having to adjust back to being able to complain about things without people giving me funny looks."

Climer mentions several times that she'd hoped that her generation

starting out in engineering would be the one to open the doors to more women taking up the discipline, and that by the time she achieved a senior position, the gender balance would be much more equal. This hasn't happened, however; it has remained steady at the low figure of five to seven per cent female. "I really thought it'd be a non-issue, but we haven't moved on from where we were 30 years ago."

But Climer said that her first priority for her presidency is to work towards changing the perception of engineering. This is, of course, something that has been much discussed in the UK; but different countries have different issues. "India, for example, sees engineering very differently from the way that we do in Europe; but the perception of the sector there can also cause problems, particularly with gender," she said. "For example, they don't have the problems that we have with attracting girls into engineering university courses, but very few of them go on to work in engineering when they graduate."

For Climer, there are several goals in this perception challenge: to show how pervasive and fundamental engineering is to so much of everyday life; to spread the word about how it's a creative, problem-solving profession that's ultimately about people rather

The BBC remained Climer's employer for 14 years, then after a two-year spell as director of ITV Digital she joined Sony, initially in a role managing systems integration, then running the company's professional solutions operation, which provides



Trailblazer:
Climer is the IET's first female president

interview: **women in engineering**

than nuts, bolts, engines and girders; and to demonstrate that it has much to offer all sorts of people.

This, she said, is connected to the very language we use, especially in Britain, to talk about engineering. “Changing the perception of engineering in this country is important to me; I’d like to work on that or at least kick it off. We need a societal shift in the perception of how cool engineers are; the incredible, life-changing things they’re doing. It’s an appreciation you do see in California, with conversations about Elon Musk, for example, being commonplace. In terms of language it’s subtle; connected to a typical British negativity, and the fact that anyone can call themselves an engineer in Britain.” Climer admits that she has changed her thinking; while she has thought that maybe a new term was needed to get rid of the ambiguity of the word “engineer” in Britain, she now thinks “maybe we should call ourselves professional or chartered engineers; people appreciate there’s a difference between accountants and chartered accountants even if they don’t know what it is”.

Part of the change needed might be “in terms of finding some positivity in the way we discuss projects; people talk about architecture on buildings and bridges, but we need to make sure the engineering is discussed as well, in terms of the problems that were encountered and how they were overcome”.

Climer said that there has been an encouraging change in the three years she was in the US. “I thought that in the media generally there could be huge, detailed discussions about the arts or sport but when engineering or science and tech came up it would switch to ‘let’s see what those funny people have done’ and it was almost a badge of honour to not understand it. But now, it’s almost like saying you’re illiterate, and people accept you need to have at least a bit of tech awareness to function, and that is connected to science and engineering. There’s more of an appreciation that science is an interesting and important topic that we should all strive to understand more about, as individuals and a society. That has definitely started to shift, so more of the same please.”

Climer is aware of the view that somehow trying to persuade girls into engineering is a wasted effort; that girls just aren’t interested. But she rejects this viewpoint. “We have research where we interviewed parents teachers and children, and it seems that about age nine girls seem to get the idea or the message that engineering isn’t for them. I’ve also seen a very large, statistically rigorous academic study that showed that boys are interested in ‘things’ and girls are interested in ‘people’. The way I’ve been reflecting on that is to stress the ‘people’ stuff in engineering, but it is definitely perceived to be at the ‘things’ end of the spectrum, so it’s not surprising that most girls are put off it.” This is clearly an education issue, she said. “If I thought they didn’t want to do it, then fine, why force them. But we’re not using the right way to describe it; they aren’t interested in it because they’re hearing about it as being to do with things not people. In my early experience, once I understood how it fitted with my interests I was all over it. Do I think boys and girls are different and interested in different things? Yes I do. But that doesn’t mean girls aren’t interested in engineering.”

In general, Climer said, she would rather be inclusive; if a female role model were brought in to address students — which she is very much in favour of, and would like a wider range of ages and expertise in such speakers — then they should address mixed-gender groups. She also appreciates that some of the IET’s single-gender activities, such as Young Woman Engineer of the Year, have been controversial among both men and women. “My take is that I look forward to this not being an issue and not having to do anything about it, but it’s a fact that women are grossly underrepresented and we need to change it. Not because it would be fairer to women, but because I think there would be business and societal benefits to have more diverse teams.” In her experience, diverse teams are more creative and feel more natural to work in, although she concedes that they can be more difficult to manage. “But once they are all working together, these teams are superproductive.”

Climer would also like to use her experience in rising to a senior management position to help dispel the idea that engineers are best kept in hands-on roles within their organisations; the demands of engineering roles are valuable skills for management. “Sometimes people do need

a nudge; if you haven’t considered it it’s quite common to not realise that you have the potential,” she said. “Mentors can be really useful here, just to encourage people to take that step. Admittedly, I did find management to be very different from a hands-on engineering role; but it was just as rewarding and I was using many of the same analytical skills, just applying them to the business rather than technological systems.”

In some ways this is a matter for companies to tackle, she said. “I do think there are some people who want to be subject-matter experts; and some people definitely think there’s a glass ceiling on salaries and so on if they don’t want to go into management. You need people who want to follow that track and stay in hands-on subject matter roles, so that needs to be addressed.” And taking on a management role can be difficult, she said; new managers feel like they’re abandoning the skills that got them to that point in their career and have to learn a whole new set. “But it’s an engineering attribute to want to understand what’s going on, and in management you do need to sort of raise yourself up and see the big picture. Things such as planning and an ability to extrapolate are engineering skills that are very useful in management. Even as a manager, my engineering skills showed in the way I analysed options and so on.” Although Climer thinks that this outlook could have benefits across all of industry, she added: “From personal experience I think that engineers would be more valuable to technology companies.”

Climer stressed the importance of ensuring workplaces are friendly and welcoming to a diverse workforce. “From my experience it can be very lonely and isolating to be the only woman in a big event or meeting. A women’s group, for example, can help tremendously with that; to know you’re not alone is a powerful thing.” ☉

Role play:
Female role models have an important role to play when addressing groups of students



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Balancing

act

Evelyn Adams examines a number of efforts to promote engineering to young girls

Jared Mauldin, an engineering student at Eastern Washington University, caused a stir earlier this month when he declared that men and women in STEM are definitely not equal. "I did not grow up in the world that discouraged me from focusing on hard science," he explained in a letter to the editor of his student paper. "Nor did I live in a society that told me not to get dirty, or said I was bossy for exhibiting leadership skills."

Mauldin's comments struck a chord with many women who believe their path into engineering has been a bigger struggle than their male colleagues. "A boy tells someone that he wants to be an engineer and the reaction is 'that's fantastic, what type?'" said Hannah Pearlman, a finalist in the 2014 IET Young Woman Engineer of the Year awards. "When I told people I wanted to be an engineer the reaction was: 'Really? Wow, isn't that a very male industry?'"

It's a view that industry has recognised in recent years. Various initiatives have been launched specifically to encourage women to follow careers in engineering. For instance the Women's Engineering Society (WES), has recently introduced a new project dubbed Sparxx, which targets girls between the ages of 11 and 18 who express an interest in STEM. But there's also been a backlash against this type of positive discrimination. One of the most common comments is that 'society shouldn't force girls and women into roles they obviously don't want to do'.

Research, however, has shown that girls are just as interested as boys in STEM and engineering up to a certain age, then they get discouraged. In a recent study of nine and 10 year-olds by the National Science Foundation, 66 per cent of girls and 68 per cent of boys reported liking science. But something else starts happening a few years earlier. At the age of seven, when students were asked to draw a scientist, most portrayed a white male in a lab coat. If they did draw a female scientist, she often looked severe and unhappy. By the age of 13, boys are twice as interested in STEM careers as girls.

Today, only seven per cent of engineering professionals in the UK are female, and the proportion is even lower for engineering apprentices at just over four per cent. The dearth of female engineers is a problem across the world, however, the UK has the lowest representation of women in engineering across Europe. With the sector battling a skills gap, addressing this imbalance has become more crucial than ever.

But what puts young girls off engineering at such a young age? A lack of encouragement from parents and teachers is at the heart of the issue.

"One thing that always disappoints me is when I hear young girls come out with statements such as 'I'm just not good at maths', which is a crazy thing to be saying at the age of 10," said Naomi Mitchison, IET Young Woman Engineer of the Year. "I think part of the problem is that this attitude in girls is acknowledged and accepted by parents and teachers, in a way that just doesn't happen to young boys."

Mitchison also thinks a major problem is that parents, teachers and career advisors don't really understand what engineering is themselves. As a result, their outdated and inaccurate views of these jobs are passed onto young girls. "I don't think it's a coincidence that so many female engineers had a family member in engineering who inspired them growing up, because these women are the ones who had the most realistic idea of what engineering actually involves," said Mitchison.

And the problem is more serious than many believe. "At a recent outreach activity run by the Women's Engineering Society one young girl

commented to me that she didn't even know that women were allowed to become engineers," recalls Dawn Bonfeld, former president of the Women's Engineering Society. "As a society we have held these stereotypes for so long that they become difficult to shift, and our unconscious and conscious biases are passed on to the next generation all too easily."

In an effort to encourage more women into the sector, various initiatives are promoting what some people believe are more female-centric aspects of engineering. The stereotype suggests that this is in careers that make a positive impact to society, such as environmental engineering. Lina Nelsson, a biomedical engineering lecturer from the University of California, Berkeley, claimed that if the

content of work is made more societally meaningful, women will enrol on her course in droves. But she says that also applies to more traditional, male-dominated fields such as mechanical and chemical engineering.

"There is anecdotal evidence that suggests girls may be more interested in the social aspects of engineering and its potential to help people," said Jenny Young, head of diversity at the Royal Academy of Engineering. "However I think this is a dangerous generalisation. There is no single typical girl and to pigeon-hole them into particular disciplines risks ignoring the myriad reasons that girls can be attracted to the profession." ©



Diversity drive: A girl's engineering group in the US



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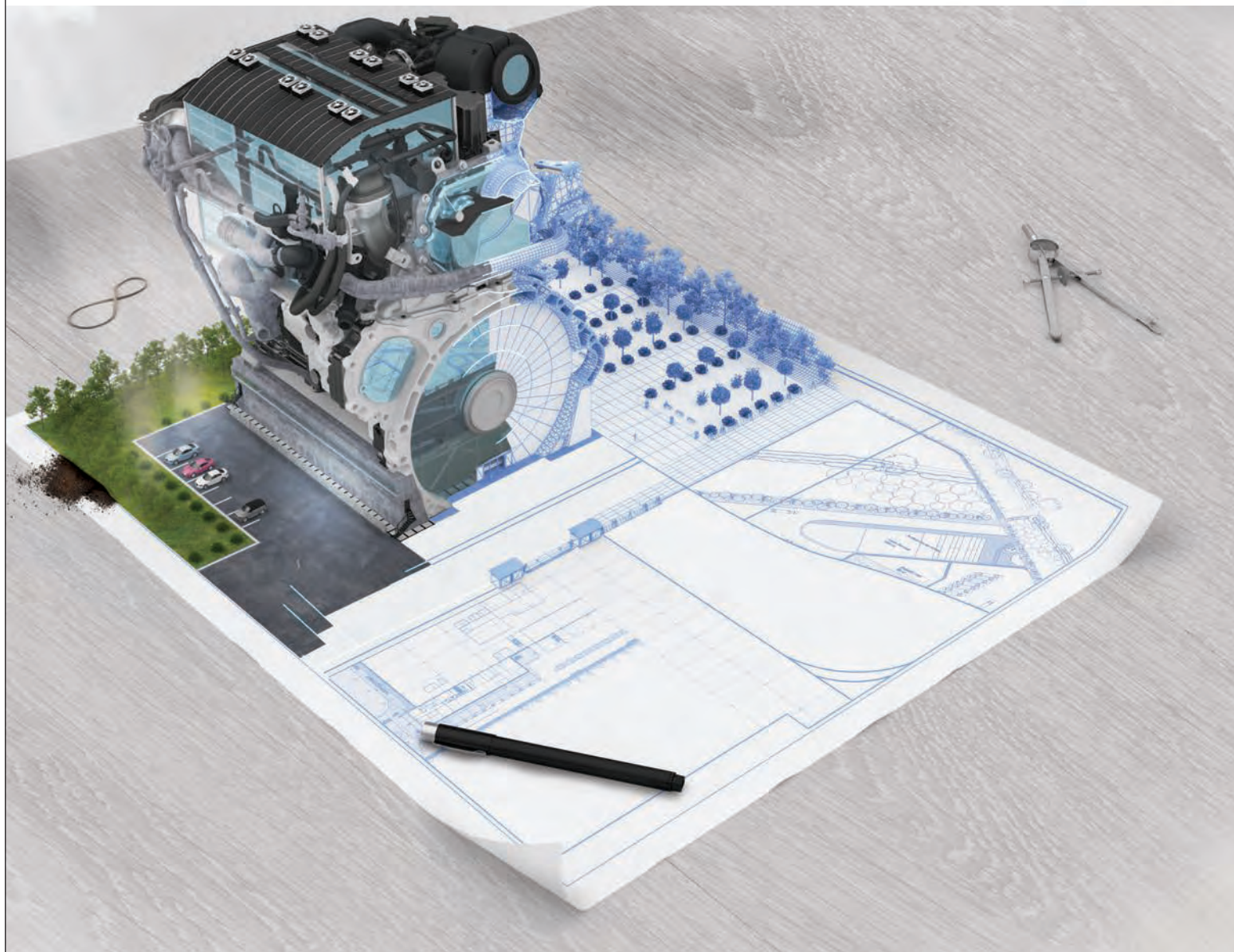
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Expert opinions

Women engineers from a range of sectors talk about their key projects and areas of expertise. **Andrew Wade reports**



Prof Paola Lettieri

– vice-dean (strategic projects) in the Faculty of Engineering Sciences and professor of chemical engineering at UCL

As well as being a professor of chemical engineering at UCL, Paola Lettieri is also the vice-dean of strategic projects in the engineering faculty. Right now that role is keeping

her very busy, as the university develops its UCL East campus in the Queen Elizabeth Olympic Park.

She is also the first female engineer to be awarded a RAEng Fellowship, and is a fellow of the Institution of Chemical Engineers (IChemE). Energy systems are a particular area of expertise, and she is currently involved in research on energy from waste gasification, as well as the life cycle of nuclear waste management.

“During my fellowship, which was entitled ‘Fluidisation for Sustainable Development’, I had a vision of working on fluidised processes that would have applications related to the incineration or gasification of waste,” she told *The Engineer*.

After honing her skills with BP for a number of years across a range of projects, Lettieri got a chance to build on her initial fellowship and explore the commercial possibilities of waste gasification. Working in collaboration with energy company Advanced Plasma Power (APP), she helped develop a process that combines gasification with plasma conversion, using waste to produce a synthetic gas (syngas) that is highly versatile.

“The Gasplasma cycle, which is what the process is called by APP, starts off basically with waste collection. This can be domestic waste, or industrial commercial waste. It is basically sorted so that the metal, the plastic and the glass is separated. The rest of the waste goes to what is called the ‘fuel preparation’, where it is shredded and dried, until it becomes a fluffy RDF [Refuse-Derived Fuel] that goes into the fluid-bed gasifier.”

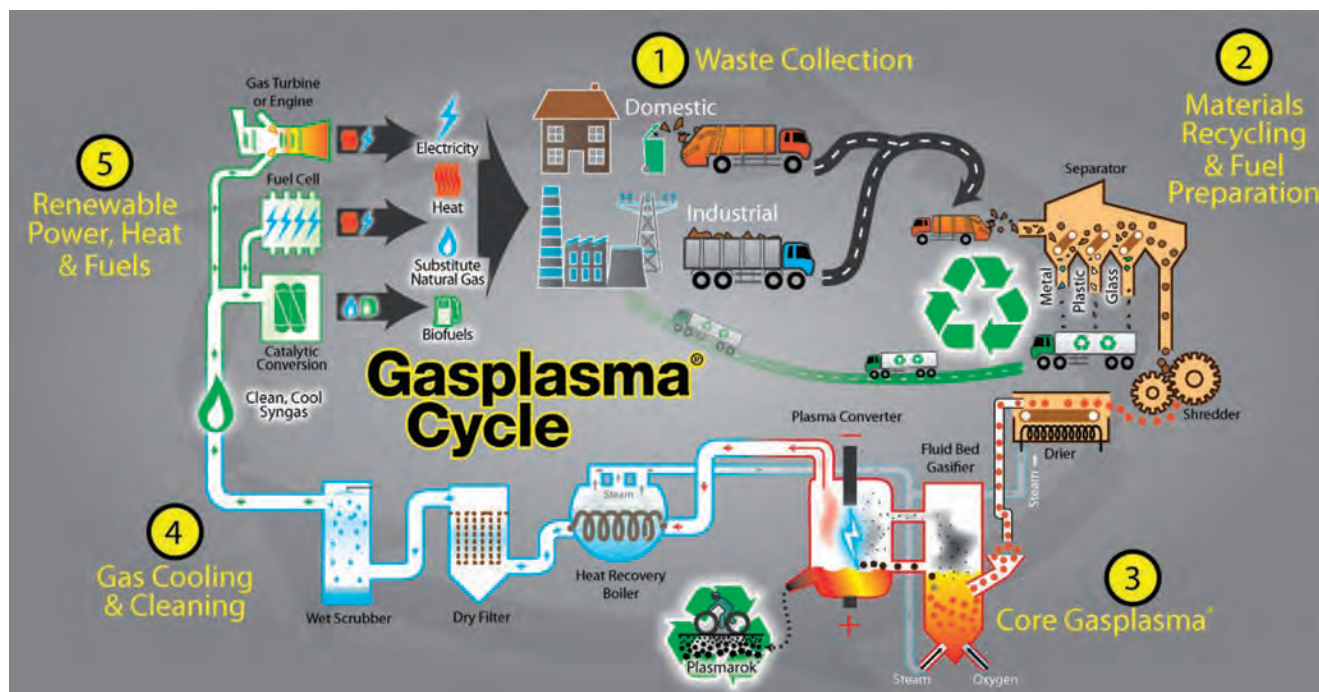
The gasifier is a metal vessel filled with extremely hot sand, suspended using steam and oxygen. RDF is pumped into this vessel, setting off a series of reactions that produces a syngas made up of hydrogen, carbon monoxide, carbon dioxide, steam and tar. The gas then passes through a plasma converter, which operates in excess of 8,000°C. Here, the tars are broken down and separated from the syngas, which is purified and cooled before entering the power system. The gas can be used for heating, electricity generation, Bio-SNG production, and even in fuel cells.

“The beauty of the Gasplasma cycle is that basically you crack down the tars,” said Lettieri. “The presence of the tars in the syngas are the very reason why today, gasification of waste is not such a well-

established technology. It’s also got the flexibility at the end of giving you energy from waste, where energy can be electricity, can be heat, can be biofuel, can be a substitute for natural gas.”

“There are 60 million tonnes of waste produced annually in the UK, and the

Lettieri has helped develop a new waste-to-energy process



role models: **women in engineering**

equivalent energy content of that is 510 million gigajoules (about 85 million barrels of oil). So waste can really contribute by a large amount to the energy mix."

While waste has the potential to play a major role in the UK's energy future, nuclear is virtually guaranteed to do so. Projected to make up 40-50 per cent of the energy mix by 2050, the recent announcements on Hinkley are a major step in this direction. Prof Lettieri's second and current fellowship with the RAEng involves weighing the pros and cons of both closed and open nuclear cycles, and assessing the entire nuclear waste management life cycle.

An aspect of this includes investigating the viability of a geological repository for the long-term storage of high-level waste in the UK. The current policy is for a voluntary approach to siting the facility, but there are some who view this as unrealistic.

"I think it's about educating the public, because I don't think there is a risk in terms of the solid emissions from the waste that will be stored in the geological repository," said Lettieri. "There are already studies that have actually quantified and predicted the emissions from solid waste, and it is shown that these emissions will be very, very low."

"Nuclear may sound like a scary business for people who are not engineers, and do not necessarily have the background to understand what it involves. I think going through that process of looking for a community that voluntarily is happy to host a repository, is part of educating the community that this can be done."

Jackie Anderson – engineering manager working for Carrier, an air-management systems organisation at United Technologies Building & Industrial Systems



After working for her father's bridge construction company from the age of 14, engineering was the obvious career choice for Jackie Anderson. She obtained her master's degree from Rochester Institute of Technology and her PhD from Syracuse University.

In both instances, her thesis was based on fluid dynamics, and this expertise would serve her well on a unique project she worked on for Carrier, part of United Technologies.

"The Sistine Chapel project was just beginning when I was hired at Carrier," Anderson says. "My background for my PhD was indoor air quality where I used CFD [Computational Fluid Dynamics] to model different nozzles and diffusers to deliver air into interior spaces. This project was a natural extension of that work, but on a more challenging level."

Anderson was in charge of modelling the indoor air quality of the

Sistine Chapel and ensuring the velocity of the air being delivered to the chapel was minimised to protect the frescoes. She also designed the air diffuser that was installed below the chapel's windows, reducing air velocities and allowing more visitors through the chapel.

"There were several factors that were critical when implementing the new HVAC solution: low velocity to limit scrubbing effects on the frescoes; reduced levels of CO₂ to limit the formation of calcium bicarbonate, which creates a whitish film on the surface of the frescoes; and controlled air temperature and relative humidity to limit fluctuations across the fresco surfaces."

"In addition, because every part of the Sistine Chapel is covered with priceless artwork, we didn't have the luxury of making structural changes to accommodate our design. These restrictions created the opportunity to develop a custom diffuser, which allowed us to supply more air to reduce CO₂ concentration levels, remove particulates, and control the temperature and humidity, without increasing velocities within the space."

Melanie Windridge – plasma physicist with a PhD in fusion energy from Imperial College London. Consultant for start-up business Tokamak Energy



Although physics was the least popular subject in the girls grammar school that Melanie Windridge attended, it was always her favourite.

She would go on to get a PhD in plasma physics from Imperial College London, as well as become a lecturer for the Institute of Physics Schools.

Her first book, *Star Chambers*, is a collection of her experiences teaching school children about nuclear fusion. Windridge also works as a consultant for Oxford company Tokamak Energy.

The Engineer asked her to set out the pros and cons of two competing fusion technologies, namely tokamak and inertial confinement.

"The thing to remember is that there are several cross-overs between the two, and areas for collaborative research," she said. "For fusion reactions to happen, the fuel plasma must be kept hot enough for long enough for fusion to occur. The tokamak and the lasers are different ways of heating and confining the fusion fuel."

"Outside of that – e.g. extracting energy to make electricity, breeding tritium fuel, protecting sensitive components – there are commonalities. Both tokamak and laser communities are getting close to achieving energy break-even, but arguably tokamaks have a slightly more developed path to commercialisation. The lasers themselves require quite a big jump in technological capability if they are to fire frequently enough for power generation."®

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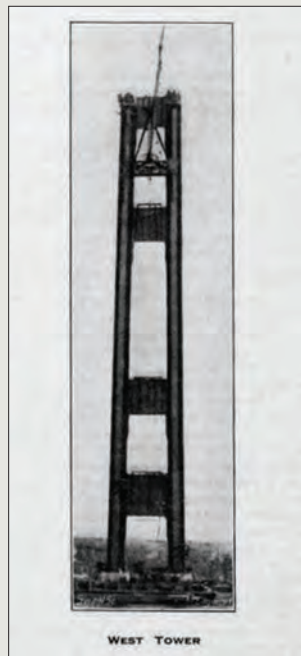


The Engineer Jobs

november 1940

The Engineer was more than a bit interested in a spectacular engineering failure that occurred on a bridge in the US state of Washington

This month marks the 75th anniversary of one of engineering's most infamous failures. The Tacoma Narrows Bridge, which (very briefly) spanned the Puget Sound in the US state of



Washington, was opened in July 1940. Just five months later, the bridge was to suffer a catastrophic collapse, the iconic video footage becoming synonymous with engineering disasters.

Christened the 'Galloping Gertie' by construction workers due to its vertical movement in high winds, the 1,800m-long structure had a main span of 853m, the third longest in the world at the time behind the Golden Gate Bridge in San Francisco and George Washington Bridge in New York City. Although several measures were introduced to correct the flaws in the bridge's design, on 7 November Gertie went for her final gallop. In winds of just 40mph – relatively mild for the Pacific North West – the bridge began to sway and buckle dangerously. Aerostatic fluttering caused the central span to twist and contort, with the amplitude ultimately causing the suspension cables to fail.

“ A reporter only escaped by crawling 500 yards while the road bed was tipping

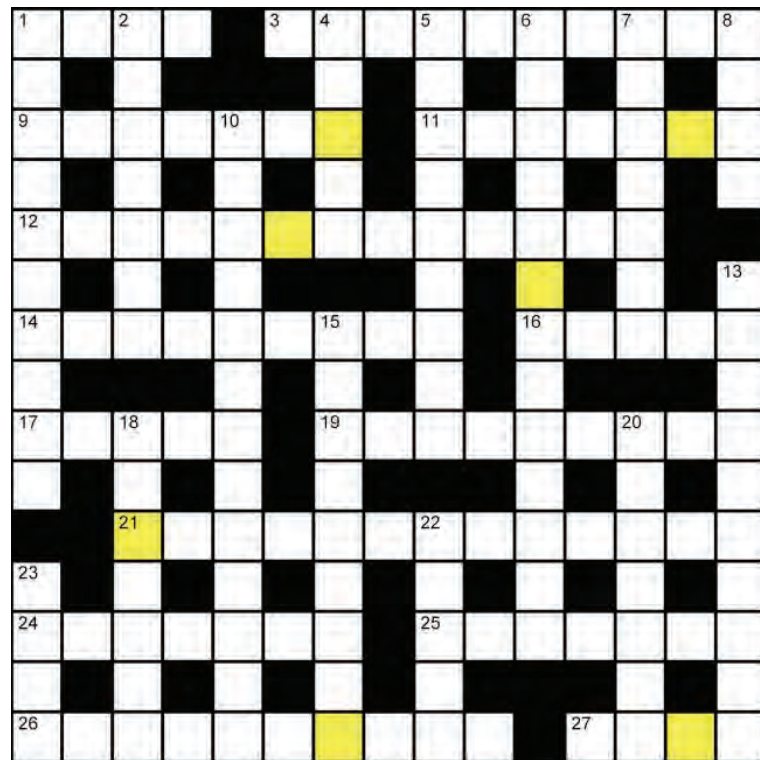
while the road bed was tipping to an angle of 45 degrees”.

In the 1940 article, our predecessors at *Engineer Towers* quote from their US contemporary *Civil Engineering*, published by the American Society of Civil Engineers. One part of the report gives some insight into one of the underlying causes of the collapse: “The span-to-width ratio of the Tacoma Bridge at 72 may be contrasted with the comparable figure of 42 for the Golden Gate Bridge at San Francisco, itself at the time of its design considerably higher than that of any earlier bridge.” **AW**

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

prize crossword

When completed rearrange the highlighted squares to spell out a temporary passageway of planks. The first correct answer received will win a **£20 Amazon voucher**. Email your answer to jon.excell@centaur.co.uk



ACROSS

- 1 Inclined surface connecting two levels (4)
- 3 Large tall chimney (10)
- 9 Former division of a German Mark (7)
- 11 Situated at or extending to the side (7)
- 12 Stopping working temporarily (6,4,3)
- 14 An equivalent given in return (3,3,3)
- 16 On and on for a long time (2,3)
- 17 Selected as an alternative (5)
- 19 Conductor in a circuit (9)
- 21 Something added to embellish or make perfect (13)
- 24 Having a common axis (7)
- 25 Temporary constructions (7)
- 26 English mistress of Charles II (4,6)
- 27 Act of putting something in working order again (4)

DOWN

- 1 Act of doing or performing again (10)
- 2 Mongoose-like animal of South Africa (7)
- 4 Physical strength (5)
- 5 0.621371 miles (9)
- 6 Event organised by unhappy workers (3-4,6)
- 7 To a small degree (1,6)
- 8 A furnace for firing or drying (4)
- 10 Not able to transmit heat or electricity (3-10)
- 13 Called to public attention (10)
- 15 By means of heat (9)
- 18 Work hard (7)
- 20 Handle and cause to function (7)
- 22 Poplar tree (5)
- 23 Obtain data from magnetic tapes (4)

October's highlighted solution was Promenade. Congratulations to Graham Oxendale who provided the first correct answer.

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

First used in the mechanical sense in 1791, 'bearing' is word borrowed from its use as a synonym for 'deportment', to carry oneself. Both are ultimately from the verb 'bear', from Old English beran or 'to bring forth, produce, sustain' and just as is still used when relating to childbirth. The Old English word can be traced to other European root languages, such as Old Frisian bera, Old Norse bera, Gothic bairan, and others all used to mean 'give birth' and all from

Proto-Indo-European bher with the same meaning. Many will also have wondered about the use of 'bear' in the mechanical and wondered about the large omnivorous mammal known by the same word, still found in Europe but long extinct in Britain. The two words have quite different meanings and origins but, fascinatingly, have mirrored one another in both spelling and pronunciation throughout the centuries.

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