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Fossil future

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Careers feature

Britain's booming automotive sector has a pressing skills shortage

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this**issue**

Volume 297
Issue No.7873
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news

opinion

features

our**opinion**

Beyond burning

The hydrocarbon industry represents possibly the biggest clash of timescales we regularly encounter. Oil and gas form on geological timescales, from the remains of organisms millions of years old; yet they take only a fraction of a second to burn.

As we report in our cover feature this issue (p26), petrochemical major Shell estimates we have just under two-and-a-half centuries of reserves of natural gas remaining in the ground. This is a blink of the eye in comparison to the age of the planet, but way more than a human lifetime and far enough into the future in terms of business to ensure that the activities of the company – and the oil and gas industry in general – doesn't have to make any hasty moves to recast its business models.

And yet the way Shell deals with gas may surprise some readers. It isn't just a fuel to be burned. The company definitely sees it as a more versatile resource than that and is actively looking at ways of upgrading it; approaching it as the chemical industry would a basic feedstock, and turning it into heavier hydrocarbons that form the basis of more valuable products: cleaner liquid fuels, lubricants, ingredients for cosmetics, detergents and food packaging. Attendants at Shell's media event in Amsterdam were even told of plans to use similar processes to turn carbon dioxide in the air back into usable hydrocarbons.

> "Oil and gas are from organisms millions of years old; yet they only take a fraction of a second to burn"

Elsewhere in this issue, we look at how a small British company is building on its success in designing one of the most eye-catching and innovative sports cars in the world (p31), and gain an insight into how the first of the UK's Catapult Centres is developing technologies for high-value manufacturing, seen as key to the future success of our engineering base.

We also bring you a review of an exhibition at the Science Museum London giving an insight into the giant of the 15th century Italian Renaissance, Leonardo da Vinci, best known as an artist but actually one of the first professional engineers in the modern sense.

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AUTOMOTIVE

New hydrogen car set for 2018 launch

Rasa's lightweight materials and simplified powertrain maximise efficiency

JASON FORD REPORTS

Riversimple Movement has unveiled Rasa, a lightweight prototype hydrogen fuel cell car with a range of up to 300 miles on 1.5kg of hydrogen.

The two-seater is set for trials later this year, with production scheduled from 2018. Once on the market, Rasa will be offered through a sale of service model that involves the payment of a fixed monthly fee and mileage allowance in return for repairs, maintenance, insurance and fuel expenses.

Founder Hugo Spowers said the Rasa – developed with the help of a £2m grant from the Welsh government – is designed to maximise efficiency through a combination of lightweight materials and a simplified powertrain that contains 18 moving parts.

The four-wheel drive vehicle's sub-40kg carbon composite chassis is said to absorb more energy per unit weight than steel in impact and its low profile has helped the prototype achieve 0.224cd in wind tunnel tests.

"Making a car a bit sporty is unavoidable if you're trying to make it efficient," said Spowers.

When the car is moving, hydrogen passes through a Proton Exchange Membrane (PEM) inside the 11hp 8.5kW fuel cell, where it combines with oxygen to form water and electricity to drive electric motors mounted in each wheel, which each produce 170Nm of torque at 840rpm.

When braking, the motors act as a kinetic energy recovery system (KERS) that generates electricity and replenishes Rasa's 120 lithium hybrid super-capacitors.

According to Spowers, this allows the delivery of over 80 per cent of the power needed during acceleration, thereby relying on the fuel cell for 20 per cent of the power and allowing it to be sized for constant cruise, which in Rasa's case is 60mph.

Spowers said: "If you do a map of your constants and your acceleration and your hill climbing, for instance, our capability fits like a glove around that profile, but it won't do anything else.

"The only way you can really rely on that is if you can rely on the capacitors for 80 per cent power and the only way you can rely on the capacitors... is if you have really efficient regeneration.

"In a typical braking event we will recover over 50 per cent of the kinetic energy of the car. The Prius talks about regen but it's only about 10 per cent because when you press the brake pedal in a Prius all four friction brakes come on.

"Braking heavily, we can get to about 70 per cent. Now that's not 100 per cent. It's not the 80 per cent we need for acceleration, so there is some top up from the stack. This is why we've got four wheel brakes... if you only had front motors where you do most braking – say 60 per cent – you'd have to have friction for 40 per cent, so by definition you would only be able to rely on capacitors for 50 per cent of the power rather than 80 per cent.

"If you only rely on the caps for 50 per cent you've got to rely on the fuel cell for the other 50 per cent, so you'd have a fuel cell 2.5 times as big, so the benefit of regen to us is not the bit of energy you save and use again but the knock-on effect it has on the sizing on the rest of the powertrain."

Riversimple will conduct a public 12-month trial of 20 Rasa prototype cars for the first full production model, which is expected to come to market in 2018.

When braking, Rasa's motors act as a kinetic energy recovery system that replenishes the 120 lithium hybrid super-capacitors

Readmoreonline

Automotive
Aston Martin goes electric with the RapidE

Aerospace
Solid-state hydrogen reservoir powers UAV flight

Energy
Jobs boost for East Anglia following £2.5bn investment into offshore wind farm

Electronics
Magnetic spin waves brought under control to enable nanocircuits

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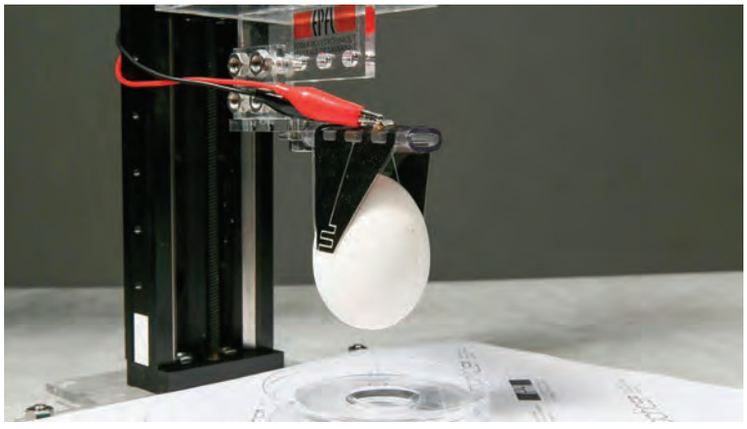
AUTOMATION

Electrostatic forces give gentle touch

Soft robotic grippers can conform to any shape or size to handle delicate objects

STUART NATHAN REPORTS



The robot's fingers can pick up eggs, water-filled balloons and pieces of paper

Researchers in Switzerland have developed a soft robotic gripper that uses electrostatic forces to pick up objects of arbitrary shape and stiffness.

The gripper from the Ecole Polytechnique Fédérale de Lausanne (EPFL) could be used, for example, in the food and drink industries, where fruit and vegetables have unique and unpredictable shapes and sizes, and must not be damaged as they are moved around. This makes packing and handling difficult to automate, and necessitates human involvement, which pushes up costs.

Soft robotics – making robotic manipulators out of plastics and gels – is a potential solution for the development of automated equipment that can handle this problem. Soft robots mimic some aspect of human physiology to gently grip and move items while conforming to their shape, exerting enough force to take the item's weight without damaging it.

EPFL's robot's fingers – which can pick up eggs, water-filled balloons and pieces of paper – are flaplike and consist of five layers: a pre-stretched elastomer sandwiched between two layers of a flexible electrode, which is then sandwiched between two layers of silicone of differing thicknesses.

With no current running through the electrode layers, the differing thicknesses of the silicone make the flaps bend outwards. When switched on, the electrodes first straighten and then bend inwards, mimicking the action of muscles.

The tips of the electrodes have an interdigitated pattern resembling interlaced fingers, which is designed to maximise electrostatic attraction. The force this generates can lift 80 times the weight of the electrodes, the team claims in a paper in *Nature Materials*.

Other soft grippers use pneumatics to exert a grasping force, which can be too strong for fragile items. Others need to be programmed for the specific object they hold. However, the EPFL grippers conform to any shape with no need for customisation and can handle deformable and flat items.

"This is the first time that electroadhesion and soft robotics have been combined to grasp objects," said Jun Shintake, doctoral student at EPFL and first author of the paper.

"The novelty of our soft gripper is the ideal combination of two technologies: artificial muscles and electroadhesion," said PhD co-supervisor Dario Floreano of EPFL.

"Our unique configuration of electrodes and silicone membranes is what allows us to control the bending of the flaps and the electrostatic grip," added PhD co-supervisor Herbert Shea of EPFL.

As well as food, the team said the system could grasp debris in space or be used in prosthetic hands.

AUTOMOTIVE

New drivetrain tech speeds up hybrid vehicles

GKN's dual-clutch system offers superior handling

JON EXCELL REPORTS

New drivetrain technology that uses electronically controlled clutches to vary torque across an axle could help hybrid vehicles be more efficient and dynamic, claims its developer, GKN.

Recently demonstrated to *The Engineer* at GKN's Wintertest proving ground in Sweden, the 'e-Twinster' system is a plug-in hybrid module claimed to make it simpler for vehicle platforms to offer electric all-wheel drive and torque vectoring.

The technology combines the firm's existing eAxle technology – already used on plug-in hybrids, including the Volvo XC90 T8 and BMW i8 – with the twin-clutch torque vectoring technology featured in the Ford Focus RS and Range Rover Evoque.

The technology was demonstrated on a prototype version of the Volvo XC90 T8 chosen partly because GKN already supplies the vehicle's electric motor module. In the vehicle, a 60kW 240Nm electric motor drives an electric axle with a transmission ratio of 1:10. A dual-clutch Twinster system then vectors the resulting 2,400Nm of torque between the rear wheels. The prototype demonstrated significantly superior dynamic response and handling on a frozen lake at Wintertest.

GKN Automotive technology chief Peter Moelgg said: "Our system represents the next step forward for the industry: a production-ready way to create higher performance hybrids that are more rewarding to drive."

GKN predicts that by 2025, up to 50 per cent of all vehicles will have some level of electrification, with a greater proportion of hybrids' power delivered from the electric motor.

Newsinbrief

New plant, new jobs

Around 1,000 new jobs will be created at Aston Martin following confirmation of a new manufacturing plant in Wales for the DBX crossover and production of the DB11 and RapidE in Gaydon. The jobs will be created across the new facility at St Athan and Gaydon between 2016 and 2020, with an additional 3,000 jobs likely to be created through the supply chain and local businesses.

Critical shortage

Up to 5,000 job vacancies in Britain's automotive industry could be vacant due to the skills shortage affecting the sector, claims a new report published by the Automotive Council. Just under a fifth of unfilled vacancies cited in the report are identified as 'critical' and having a significant impact on company operations. Design and production engineer roles are particularly difficult to fill.

Scope for gas limited

The UK will only be able to use gas as a 'bridge' to a lower-carbon future to a very limited extent, and even this depends on government action, warned the UK Energy Research Centre, which has published new research showing that without carbon capture and storage, the scope for gas use in 2050 is only 10 per cent higher than consumption in 2010.

Ready for battle

Formula E chief executive Alejandro Agag revealed vehicle designer Daniel Simon, whose portfolio includes lightcycles for the movie *Tron: Legacy*, will work on the RoboRace series. Speaking at Oxford University, Agag said Simon would contribute to the race series that will see fully autonomous electric cars battle it out in the 2016-17 season.

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AEROSPACE

‘Bat wings’ respond to a gust of wind

Thin-rubber membranes’ ability to mimic bat wings increases efficiency

HELEN KNIGHT REPORTS

Bat wing-like membranes that change their shape in response to prevailing wind conditions have been tested in-flight, taking them a step closer to use in micro air vehicles (MAVs).

The membranes have no mechanical parts and alter their shape in response to the forces acting on them, making them more efficient and easier to maintain than traditional rigid wings.

The membrane wings are being developed through a combination of experimental research at Southampton University and computational modelling at Imperial College, with funding from EPSRC and the United States Air Force European Office of Aerospace Research and Development.

The team has used the findings from the computer models to build a 0.5m-wide test vehicle, said Prof Bharath Ganapathisubramani of Southampton University’s Aerodynamics and Flight Mechanics Group, who led the overall project.

“Since the wing is a flexible, thin rubber membrane, it can change shape depending on what the wind hitting it comprises of,” said Ganapathisubramani. “So if it is in a gusty environment then it would continuously change shape, but if it was in a steady wind it would form a single shape and then maintain it.”

The researchers are also working on a future version of the bat wing, which will incorporate electro-active polymers that allow the membrane to stiffen and relax in response to an applied voltage.

Bats use muscles to stiffen and relax their wings as needed, he said. “We can sag the membrane a little bit or stiffen it up a little bit, depending on the voltage we apply, which mimics the bat’s behaviour,” he said.

> “If it is in a gusty environment it would change shape”
>
> Prof Bharath Ganapathisubramani

This way, the shape of the wing can be changed irrespective of the wind conditions. “You can also use it as a sensor to sense oncoming wind conditions, because when you apply a voltage and the membrane changes shape, it will also change the voltage that you have applied,” he said.

The researchers have developed a prototype of the electro-active wing, which they have tested in the laboratory, but have yet to attach to a vehicle.

In-flight tests are taking the wings a step closer to use in micro air vehicles

DATA

Billion-year data storage

Southampton University creates 5D storage solution that can be kept in space for generations

Scientists at Southampton University have created a method to store hundreds of terabytes of data in small discs of nanostructured glass that could last billions of years.

Developed by researchers at the university’s Optoelectronics Research Centre (ORC), the technique uses femtosecond lasers to deliver ultrashort pulses of light, writing data files in three layers of nanostructured dots separated by five micrometres. Size and orientation provide an additional two dimensions, making the storage 5D.

When the technology was first demonstrated in 2013, a 300kb digital file was successfully recorded in 5D. The process has now been refined to the point where 360TB can be stored on a single disc.

“It is thrilling to think we have created the technology to preserve documents and information and store it in space for future generations,” said Prof Peter Kazansky from the ORC. **AW**

Small discs of glass can store 360TB

AUTOMATION

Sensors provide real-time tool monitoring

Temperature, force and vibration to be tracked

HELEN KNIGHT REPORTS

Faster and more reliable manufacturing processes, with less human intervention, should be possible thanks to a UK collaboration to develop printable sensors for real-time monitoring of machined metal parts.

Dubbed Intelligent Tooling, the two-year Innovate UK-funded project will develop sensors and electronic components that can be embedded close to the cutting surface of the tooling inserts in machining systems.

The sensors will be designed to monitor parameters including temperature, force, acoustic emission and vibration.

This should improve processing times and tool usage, according to Steven Bagshaw, at the Centre for Process Innovation (CPI), one of the partners in the Intelligent Tooling project.

“This allows you to identify early stage deterioration of tool insert performance,” he said.

A lack of real-time monitoring in existing machining means variations in material or tooling properties, for example, are often detected only in the final product inspection.

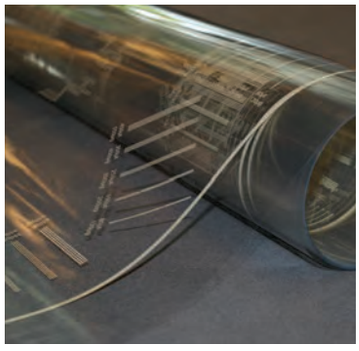
“The metals that these tools are working on are very expensive, so you don’t want to be cutting them with a tool that is underperforming,” he said.

This often forces manufacturers to be overly conservative in the machining parameters they set, and in predicting the life of their tools.

The project, which includes AMRC and BAE Systems, is aiming to develop a prototype tooling insert printed with embedded sensing, designed to withstand the harsh conditions found in metal machining.

Conventional electronics will be integrated with the sensors in order to transfer the data they produce to control systems.

The flexible nature of printed sensors means they can be incorporated into curved structures or other bespoke designs, and at a low cost, said Bagshaw. “We will be using our own ink formulations and a variety of printing techniques, including inkjet,” he said.



Printable sensors provide early warnings

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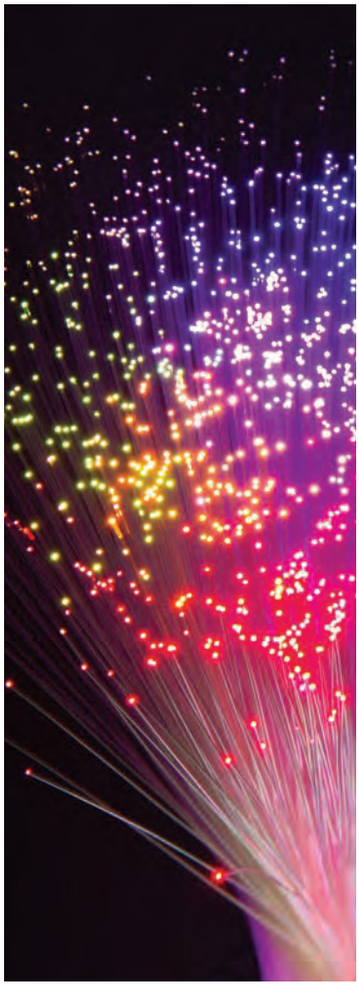
MEDICAL

Optical ultrasound to guide surgeons

Real-time imaging technique wins Healthcare Technologies Challenge Award

HELEN KNIGHT REPORTS



The probes can be placed in devices

Minimally invasive surgical procedures could be guided more precisely and efficiently by using a new real-time imaging technique known as optical ultrasound.

The optical ultrasound probes are being developed by Dr Adrien Desjardins at University College London, who was recently named as one of the first nine recipients of the EPSRC Healthcare Technologies Challenge Awards.

The awards, designed to encourage research that will improve healthcare diagnosis and treatment, will allow the successful researchers to work with clinicians, companies and charities to help speed up the clinical adoption of their technologies.

The nine researchers, each of whom will receive a share of a £9m fund, are developing technologies ranging from smart wound dressings and new ways to examine sperm, to tools to improve diagnosis and cancer treatment.

The new optical ultrasound probes are designed to be integrated into devices including needles and catheters, to provide detailed imaging from inside the body and help guide the surgical tools, said Desjardins.

"Ultrasound imaging can provide exquisite visualisation of tissue from within the body to guide minimally invasive medical procedures," he said. "Currently, though, ultrasound imaging is performed with electronic transducers, which have costs that are often prohibitive for single-use medical devices and are too bulky for many procedures."

The new imaging probes, in contrast, generate and receive ultrasound waves using light. To generate ultrasound, optical fibres are coated in a micron-scale thick layer of an optically-absorbing material, such as carbon-polymer nanocomposites.

Pulsed laser light is targeted at this coating, causing it to heat up and generate an ultrasound wave, which propagates into the body and is reflected from interfaces within tissue.

The reflected ultrasound waves are received by extremely sensitive optical elements such as Fabry-Pérot cavities, in which light is reflected between two opposing mirrored surfaces.

> "Ultrasound imaging can provide exquisite visualisation of tissue from within the body to guide minimally invasive procedures"
>
> Dr Adrien Desjardins, UCL

"By varying the location in the tissue in which the ultrasound wave is generated, signals can be acquired and processed to produce high-resolution pulse-echo ultrasound images in real-time from within the body," said Desjardins.

Optical ultrasound could also have widespread applications outside medicine. The technology could be used in non-destructive imaging of materials, for example, particularly in environments with high levels of electromagnetic interference.

COMMUNICATIONS

Low-cost fibre-optic broadband

UCL develops simplified optical receiver capable of being mass-produced

Researchers at UCL have developed and tested new hardware that promises to cut the cost of delivering fibre-to-the-home broadband technology.

The team believes the technology will help address the challenges presented by providing homes with high bandwidths while future-proofing infrastructure against growing demand for data.

Core optical fibre networks often terminate in cabinets far from end users. The so-called 'last mile' that connects households to the Internet via the cabinet is still often built with copper cables as the optical receiver needed to read fibre-optic signals is too expensive to have in every home.

Dr Erkilinc, from UCL's Department of Electronic & Electrical Engineering, said: "We have designed a simplified optical receiver that could be mass-produced cheaply while maintaining the quality of the optical signal. The average data transmission rates of copper cables connecting homes today are about 300Mb/s… Our technology can support speeds up to 10Gb/s." **JF**

ELECTRONICS

Putting the right spin on power for nanocircuits

A possible alternative to electronic charge carriers

HELEN KNIGHT REPORTS

Researchers in Germany are working on magnetic spin waves as an alternative to power-hungry electronic charge carriers.

In a paper published in *Nature Nanotechnology*, researchers at the Helmholtz-Zentrum Dresden-Rossendorf (HZDR) and TU Dresden in Germany describe a method they have developed for controlling these spin waves, making them suitable for use in nanocircuits.

As electrons spin around their own axis they behave like magnets and altering the direction of one spin impacts those neighbouring it. In this way a spin wave can be created that travels through a solid body.

This wave can be used to transport and process information in the same way as charge carriers, according to Dr Helmut Schultheiß from HZDR's Institute of Ion Beam Physics and Materials Research.

Spinning electrons generate little heat and spin waves can reach frequencies into the terahertz range, with nanometre-sized wavelengths, said Schultheiß. "The wavelength of electromagnetic waves is about three orders of magnitude larger, so it is much more complicated to squeeze conventional electromagnetic waves into nanocircuits," he added.

To control spin-wave propagation, the researchers have taken advantage of domain walls, which represent the interface of differently aligned magnetic regions. They created a domain wall within a nickel-iron alloy nanostructure and used microwaves to trigger a spin wave.

They found spin waves of a certain frequency became trapped in the domain wall, with different magnetic regions ensuring the waves travelled along a controlled path.

Previous methods for controlling spin waves have tended to be power hungry, said Schultheiß. "We can move these nano-sized channels using very small magnetic fields, of just fractions of the Earth's magnetic field. So our method works without [the need for] external energy supplies."

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NATIONAL INSTRUMENTS

AUTOMOTIVE

Virtual city built for driverless pod test

Simulated version of Coventry will provide safe environment for vital checks

HELEN KNIGHT REPORTS

Driverless pods are to be put through their paces in a simulated version of Coventry, as part of efforts to introduce autonomous vehicles to the UK.

Researchers in the Warwick Manufacturing Group (WMG) at Warwick University will use Lidar to scan 30 miles of Coventry's roads to test the driverless pods.

The project, dubbed INnovative Testing of Autonomous Control Techniques (Intact), will trial vehicles developed by RDM Group, the only manufacturer of driverless pods in the UK.

The project, funded by Innovate UK, will allow the research team to analyse how driverless vehicles react to real world conditions before they are deployed on the roads, according to WMG's Prof Paul Jennings.

"There is a lot you can learn in real-world trials, which are hugely valuable, but we would like to focus on the most interesting parts of these trials and be able to repeat them in a safe and controlled environment," he said.

This will speed up the testing process and help the team to understand where best to position the sensors on the pods. "Effectively we can take some of the risks out of real-world trials and learn things much more quickly," he added.

The driverless pods will be tested in WMG's recently built 3xD simulator (or Drive-in, Driver-in-the-loop, multi-axis driving simulator), which was developed with £3.2m of funding from EPSRC and has been configured so that different vehicles can be driven into it for testing.

> "We can take some of the risks out of real-world trials and learn things much more quickly"
>
> Prof Paul Jennings
> WMG

It has been designed to carefully recreate the real world environment, said Jennings. "As well as being able to recreate the visuals, sounds and road surfaces of the real world, we wanted to recreate the wireless environment," he said.

This includes the different types of signal that autonomous and connected vehicles will receive, including GPS, optical and ultrasonic radar, and wireless communications.

"It's going to be important to know how both the car and the driver will behave if things don't quite go to plan, so we want to be able to look at those scenarios in a nice, safe, repeatable environment," said Jennings.

RDM Group is also taking part in the Lutz Pathfinder trial, which will test driverless pods in Milton Keynes.

The project will use autonomous vehicles developed by RDM Group

AEROSPACE

MoD orders two solar-powered Zephyrs

Ultra-lightweight high-altitude crafts can provide surveillance over land and sea for months at a time

The Ministry of Defence (MoD) has placed an order with Airbus Defence & Space for the build and operation of two solar-powered Zephyr 8 high-altitude pseudo-satellite (HAPS) craft.

Fitted with a range of communications links, the ultra-lightweight Zephyr 8 can fly at 65,000ft, meaning it can avoid weather systems and provide surveillance over land and sea for months at a time. The first 25m wingspan Zephyr 8 is under construction and due to fly in mid-2017 with heavier payloads than Zephyr 7.

The MoD has not disclosed how the aircraft will be used, although its 2015 Strategic Defence and Security Review refers to the procurement of advanced communications equipment for Britain's special forces, including advanced high-altitude surveillance aircraft.

Civilian applications for Zephyr include humanitarian missions, precision farming, environmental and security monitoring. **JF**

MOTION CONTROL

Magnetic gears hike marine propulsion

Motor developed without a mechanical gear box

HELEN KNIGHT REPORTS

A UK collaboration to build a motor based on magnetic gears could result in more efficient marine vessels.

The highly efficient and compact motor is being developed for marine propulsion as part of a £1.7m project co-funded by Innovate UK.

The project team – magnetic gear developer Magnomatics, Rolls-Royce and motor specialist ATB Laurence Scott – will design, manufacture and test a 2.5MW magnetically geared propulsion motor to prove its marine propulsion capabilities.

The motor will be powered by Magnomatics' Pseudo Direct Drive (PDD) gear, which uses magnetic fields generated by powerful permanent magnets to transmit mechanical power.

PDD consists of three rings, each separated by an air gap. The outer and inner rings contain permanent magnets arranged in a north-south pattern. A middle ring consisting of steel segments alters the magnetic field between the inner and outer rings.

The force of this magnetic field is transferred across the air gap, causing the rings to rotate without physical contact between each component.

A stator is fitted around the three rings. As current flows through the electrical windings in the stator, it causes the inner magnetic ring to rotate, which in turn prompts the outer ring to rotate.

The device is able to drive a large load without the need for a mechanical gear box.

The efficiency benefits of the new motor should allow more flexible propulsion systems to be used on different types of vessel, according to Andrew Myers, general manager of the drive technology division at Magnomatics.

"The use of a magnetically geared PDD compared to conventional permanent magnet propulsion systems will result in a compact, low-maintenance, robust and flexible propulsion system that could improve efficiencies and cut emissions for many types of vessel," he said.

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TRANSPORT

Capsule designed to go down tubes

Passenger vehicle takes second place in international competition

HELEN KNIGHT REPORTS

A European capsule, designed to travel at over 600mph per hour through reduced-pressure tubes, has taken second place in an international competition launched by SpaceX.

The concept capsule, designed by a team of students at TU Delft in the Netherlands, was also awarded the prize for the most innovative design in the Hyperloop competition.

SpaceX and its founder Elon Musk established the competition to stimulate the development of the new form of transportation, which has been dubbed Hyperloop.

> "In a full-scale system the capsule would accelerate out of the station using a linear electric motor"
>
> Tim Houter, TU Delft

The system consists of passenger capsules that are designed to travel through tubes in a partial vacuum, with the lack of pressure allowing them to reach very high speeds. This could allow a Hyperloop capsule to travel between the outskirts of Los Angeles and the San Francisco Bay area in around 35 minutes, for example.

The Delft team was one of 124 that presented designs to a jury of researchers and experts from Tesla Motors and SpaceX in the first stage of the competition. It will now join 20 other teams in progressing through to the next stage, in which it will build a half-scale version of its capsule and test it on a track in California in the summer.

Unlike the capsules designed by most other teams, the TU Delft design uses permanent magnets to allow the vehicle to hover approximately two centimetres above the track, as it moves over a conductive plate, said team captain Tim Houter.

"In a full-scale, commercial system, the capsule would accelerate out of the station using a linear electric motor, with the stator windings inside the track," he added. "Then because there is not much air inside the tube, it would just float along at very high speed, with only an extra boost needed on the way to stay at that speed, and then at the station you would decelerate your Hyperloop vehicle," said Houter.

Energy would be recovered using regenerative braking, he added.

"This makes it a very energy efficient system," said Houter.

Solar panels on top of the tubes themselves could generate additional energy to power the capsules.

In the competition's next stage, the half-scale capsules will race around a 1.6km test reduced-pressure tube in California.

The concept capsule designed by the students at TU Delft

ROBOTICS

Down on the farm

Initial tests will see agri-robot operating on steep grassland in dairy and sheep farms

A new self-driving agricultural robot known as IBEX is being trialled in the UK for the first time, identifying and destroying weeds on a farm in the Peak District.

IBEX is designed to operate on remote farmland where it is uneconomical to spray manually, or too dangerous to drive with a tractor or ATV. The initial test will see it operate on steep grassland in dairy and sheep farms.

Using treads to reduce ground pressure and enhance mobility, IBEX is capable of operating on slopes of up to 45°. The 1m-long robot employs a combination of sensors and Bayesian machine-learning software to navigate autonomously, covering a user-defined area or an optimised route.

The project is co-funded by the AgriTech Catalyst of Innovate UK, with the robot itself developed by Hunshelf Hall Farm, G32 Technologies and Digital Concepts Engineering. **AW**

ELECTRONICS

Surviving up to one million charge cycles

Funding boost for ultracapacitors

HELEN KNIGHT REPORTS

An ultracapacitor manufacturer from Estonia has been awarded €4m to further develop its technology and boost production.

Skeleton Technologies received the funding from KIC InnoEnergy to develop its ultracapacitors, including improving its electrode and cell design.

Ultracapacitors store energy in an electric field, which allows them to charge and discharge more quickly and survive up to one million charge cycles. They also have up to 60 times the power density of batteries, making them suitable for transportation and energy storage.

Conventional ultracapacitors are built with activated carbons as the active material in their electrodes. In contrast, Skeleton's ultracapacitors are manufactured with nanoporous carbide-derived carbon (CDC), or curved graphene, according to the company's CEO Taavi Madiberk.

"We finely engineer the carbon pore size and structure, and create one layer thick carbon structures inside the material," said Madiberk. "The pore size and distribution is important, because it gives us a perfect fit for the electrolyte ions, and we can utilise all of the surface area."

This gives Skeleton's devices twice the energy density and five times the power density of other ultracapacitors, he said.

The company now aims to increase this energy density even further, reaching a target of 20Wh/kg by 2020. "Currently the best competitors on the market have a maximum of 7Wh/kg energy density," said Madiberk.

As well as expanding the potential range of applications for the devices, this should also help to bring down their cost, he said, because around 70 per cent of the overall cost of ultracapacitors goes into the material used to produce them.

The company also plans to use the funding to increase manufacturing of its existing devices, he said. "We plan to ramp up our manufacturing capacity this year to about 300,000 large units."

Financing some bright ideas

Engineers are great at explaining technology but often bad at explaining their business, which can create difficulties when approaching investors

One of the most daunting challenges for engineers is to communicate their vision to those who have the money to make it happen. Engineers can have a completely different perspective to investors, to such an extent that we often seem worlds apart. Investors are naturally risk-conscious, commercially minded and may lack deep technical expertise; engineers, while often visionary, can get so caught up in the technical wizardry of their invention, that they can neglect its real-world commercial potential.

Engineers are great at explaining technology, but often bad at explaining their business. They sometimes struggle to outline the need it satisfies (what problem does it solve), the business model, the different potential revenue streams, the 'white space' the technology occupies, or its most lucrative USP. Engineers can also forget that technology is useless if no one wants to use it at that cost.

Yet, without the financial advice and expert guidance of investors, as well as the funding itself, many great ideas will never get off the drawing board. So how can we build bridges between the engineering and investment communities?

I recently had the opportunity to learn what makes investors tick, when I attended a Royal Academy of Engineering Reverse Pitching event where engineers can hear real investors explain the different funding options – from bond loans to venture capital – and learn how funders make their decisions.

For once, investors had the chance to pitch to engineers and explain the things every engineer needs to know if they are to get their dream deal.

Engineers must first understand the distinctions between different types of investor, their field of interest, what they look for in an investment and what engineers can do to sell themselves more effectively to each kind of funder.

We learned that angel investors, as high-net-worth individuals who are investing their own money, will only back companies that they feel passionate about and may want to be personally involved in each of their investments. This means they can be very hands-on and will routinely visit and advise a company they have invested in. Other angels prefer to join as part of a syndicate of investors and contribute primarily through the investment alone.

Venture capital funds, however, have very different expectations, because they are spending other people's money. Venture capitalists invest at a later stage than angels, are unlikely to invest before there is an actual product and, in some cases, they will not invest unless the company already has confirmed orders. Venture capitalists are far more 'hands-off' and probably won't come in and help to run a company – they may however want to appoint someone to your board. Engineers will also have to be prepared to open the innards of their company to a thorough audit as venture capitalists have to do more due diligence before making a deal because they have a duty to their limited partners.

It's also vital to understand the different types of venture capitalists and angels; some investors want to spend time scaling up the business before expecting a return, while others want rapid ROI. Every engineer must ensure their business model and growth plans match with the goals of their investor.

"Engineers do need to understand different investors"

Sorin Popa

Venture capitalists typically won't invest in two similar technologies in the same sector because this would produce a conflict of interest in their portfolio, so engineers must research their other investments.

It is important to research the sectors they invest in, as funders often will not invest outside sectors where they have particular expertise. There is no point in a biotech entrepreneur seeking funds from a venture capitalist specialising in B2B service apps.

You must demonstrate that you are business savvy, as well as an innovative engineer, because investors are risking their money on the ability of the founders and their team to run a successful business, not just the commercial potential of the technology. Investors know the wrong management team can ruin the chances of any business from becoming successful, and this is why building a strong team should be a primary goal.

You need to look for an investor with the right kind of 'risk appetite'. If you have very early-stage tech, that will take a good while to come to fruition, you need to make sure that the investors you approach are willing to take on that level of risk and you probably need to accept that you are likely to give away more of your equity at such a stage. Check how long any venture capitalist funds have been around for. If they are new, they are likely to have more appetite for risk; conversely if they have been around a number of years, chances are the fund will be closing soon so you might get a 'no' for that reason – it might not be anything to do with the viability of your business.

An investor-company relationship could last longer than the average marriage so it is vital to ensure you are a good match with any prospective investor and cultivate a good relationship from the outset.

To land an angel investor, it is vital that engineering entrepreneurs present themselves as motivated, goal-driven founders who have built or are willing to build a strong management team and can clearly communicate their vision. Angel investors do not just view their portfolio as an abstract balance sheet; they see each investment as personal and they have to be able to get behind the people as well as the product. Talking about your personal motivation, background, goals and ambition can be as important as talking about the product.

Stent Tek's minimally invasive vascular access catheter system

Sorin Popa is CEO of Stent Tek, which is currently developing a novel catheter system for minimally invasive vascular access

Mailbox

Thehottopic

Weighing up a potential 'Brexit'

Our coverage of the EU referendum has generated more letters than almost any subject we've covered

To date, nobody can explain what status the UK would achieve after a 'Brexit'. This would be a divorce of the highest order. Why would the EU give the UK much improved trading conditions? The argument that the EU exports more into the UK than vice versa, and that, as such, the UK holds all the aces is a myth. The EU is the biggest economic block in the world. It has negotiated favourable trade agreements with other trading blocks. The US has already stated that it would not negotiate a separate agreement with the UK because it is not worth their while. Why would China want to negotiate a better trading agreement with the UK than they currently have with the EU? And the myth that the UK can't currently trade with the rest of the world is just not true. A Brexit would mean watering down employment laws. Maternity, paternity pay, holiday and sickness pay would all be affected.
Margaret Wilson

I actually believe in the European ideal of a single state. In an increasingly globalised world, we should be working to reduce the number of borders and barriers between us all, not looking to build more. That said, I don't think we're anywhere close to this ideal at the moment, it will take another generation at least. The biggest issue I have with the EU is its lack of democracy and I'm dismayed that our prime minister has done nothing to improve the accountability of the EU to its citizens. Leaving the EU would give European companies one more excuse to close British factories and offices rather than European ones when they needed to make cuts. The EU is far from perfect and I want it reformed but I'm minded to reform it from the inside and will vote to stay in.
Eric

If we look at the figures, we are paying £58m per day into the EU and get less than half of that back. The first question most aware people would ask is why is the UK, one of the smaller original member states, paying the second-largest amount of money in, and why are we getting less than half back? What does £30m per day buy the UK? It allows us to close our borders to immigrants and enforce it; it allows us to subsidise essentials such as energy to benefit consumers and industry; it allows us to invest in engineering and other areas to create and maintain long-term jobs. It allows us to build a future for families with reasonable security instead of working for some multinational and wondering if and when our jobs are going to be exported to some third-world sweatshop, and it creates many third-party or support jobs. With money in the jobs economy it creates more government wealth through standard taxation, which reduces the cost of benefit payments, so a win-win.
S Martin

Armies exist to protect sovereignty. If that is transferred to Brussels, the army will go with it. Yes, British manufacturing wasn't great before the EEC but, since joining, industry has been withered to the bone. Britain exists as a statement of its people's intent to remain independent and broadly self-governing. Yes, the EU is democratic but its democratic structures are opaque and only weakly held to account.
Nathan

I don't think that it would be possible to transfer control of the army to Brussels. You have to ask who the army pledges allegiance to and who sets the size. There are 100 other moves that would have to be made, any of which would be the red rag to our inner bull. We can decide to walk away at any time and say to anyone who tried to stop us: "Make me." I think the prospect of EU membership is therefore less alarming.
Tim Murphy

Inyouropinion

Broadband puzzle

Our editorial on the problems of rolling out broadband internet in the UK attracted comment from some puzzled surfers

This 'last mile' for the copper cable to the fibre-linked cabinet is being 'stretched' in my case. I am told by the BT website I have fibre broadband, but with over 2.5 miles of copper cable to my cabinet, the speed I can get is less than with my current bog-standard broadband. I fear I am still counted has having access to 'superfast broadband', however. There is a fibre-connected cabinet only 0.5 miles away – but we are not connected to it.
Sue Underwood

I live 'out in the sticks' (according to many), yet I'm able to enjoy 17Mb uploads and a stable 75Mb download. All because I opted to have all my phoneline services provided by any company other than BT. When I had BT as my ISP/phone provider, it would frequently cut off my phone and having waited the three days, told me I needed to pay an outstanding bill which they had always neglected to notify me of. As soon as I switched my provision (including line rental) to another company, I ceased being cut off every few months. My internet speeds increased slowly at first, initially all I could have was 500k, then 2Mbs for many years, then, a couple of years ago, it suddenly jumped to my present speeds without any additional cost per month.
Adam

Having worked for GPO/BT, I remember when it offered to run fibre throughout the UK if the government would help with the cost of the infrastructure. Needless to say, the government turned the offer down – presumably it couldn't see the point. It's still the same problem: the government is unprepared to see decent internet connectivity as a utility, especially in non-urban areas with low population densities. I live in Dorset, where there was a concerted campaign to re-use the huge capacity installed for Olympic sailing events. You can perhaps imagine my incredulity when we asked what speed 'superfast' would mean to our rural customers? The answer: 2Mb/s! What we have currently could legitimately be called 'fast', but 'super' no way. It's just sales hype.
Graham Field

All in the mix

The issue of the UK's energy mix and the prospects for expanding gas use continues to be emotive

The first step should always be demand reduction. If you don't need it, you don't need to produce it.

Thesecretengineer

Our anonymous blogger reflects on getting his colleagues to embrace fresh ideas

I would like to think my arrival here at Sleepy Hollow Electronics Limited, with the influx of new and exciting ways to do engineering that I brought with me, is seen as a breath of fresh air.

For all I know it may actually be seen as a waft of something altogether more odious – one doesn't really like to ask about these sorts of things. Naturally though, I am not unaware of such possibilities and try to not be too overbearing; instead I try to be sensitive to the company's history, respectful of my colleagues' experience – and just generally avoid being a pain in the arse.

Even so, it's difficult to judge as Sleepy Hollow has been through a strange, glacial-like organic change over a number of years. None of the ideas I have introduced and championed are cutting edge, they are all tried and tested. However, in this environment, they have the air of stupendous novelty. I fear that any attempt to introduce the truly radical could well result in a catastrophic rift in the fabric of reality, so this is something I've avoided so far.

Despite this, when I have had various conversations with different members of senior staff they seem to be generally enthusiastic in embracing the brave new world put before them. Even those where I'd been warned that their reaction would probably be something akin to Eeyore's if presented with the opportunity of skydiving into a vat of custard.

These extreme circumstances and the small size of the team has given me the opportunity to re-evaluate the subtleties of my colleagues' characteristics. This has the advantage of providing a mechanism to change the way I interact with them, hopefully for the better. I find that dealing with larger groups generally brings my view of individuals towards a binary and simplified state.

Therefore, in this case those who seem wholly defined by truculence regarding new ideas, when stood back and viewed with a proper perspective, are only relatively so. It may even merely be that they see their role as providing a necessary brake, needed in the pursuit of due diligence, to the wild enthusiasm of others. They do not wish to inhibit progress as such but need to be sure that it is the correct strategy to adopt. Changing my viewpoint from seeing them as a problem to be overcome, to seeing them as a partner in finding a justification for my ideas in itself changes everything. The whole process becomes less daunting. If a suggestion is rejected this is now a position that can be changed rather than an absolute. Also it is a position that was adopted for a reason other than leaden inertia – the previous air of futility is thus avoided and hope for future ideas takes its place. All of which is encouragement enough, should it be needed to continue kicking over the tables in the fight against complacency.

Next would be energy storage. If your house could store heating energy, then intermittent heating would be sufficient to keep the temperature. Storage is always important to reduce peak demand and buffer peak supply. With a bit of smart technology you could reduce peak demand at home. For example, don't switch on the fridge compressor as long as you are ironing.
Ralf Mueller

Gas is too valuable a hydrocarbon to waste in power stations. Look at pre-combustion CCS, in-situ coal gasification or just sod the carbon emission targets and switch back to coal. Inject biogas to the grid for domestic use. Use the gas in Fischer-Tropsch Synthesis reactors to produce more added value hydrocarbons.
Ewan McDonald

I think everyone is missing the point here. Have you never noticed that it all comes down to 'investment'? When public utilities were just that it all paid for itself, no shareholders to pay out. I never thought I would come to this conclusion but I believe that it is time we started to urgently consider re-nationalising the utilities.
Paul Wickens

It currently takes three hours to charge electric cars, this would not be the case with hydrogen fuel-cell vehicles; we could even use it to power our homes. When are we going to wake up to this fantastic future of producing hydrogen from water using renewables? Why not?
Nick Woodward

Join the debate theengineer.co.uk

Attention-grabbing careers advice

The annual Big Bang Fair seeks to bridge the gap between what young people are taught at school and an exciting future in engineering

"Everyone hopes something they offer will inspire another young person to think differently about a career in STEM"

Paul Jackson

If among the extensive coverage around the EU referendum last month you also found yourself reading about how to rebuild society from scratch after a zombie attack, you'll understand what I mean when I say sometimes you have to go to extreme lengths to get people's attention. This is certainly the case when looking for fresh ways to draw the media's attention to the importance of science, technology, engineering and maths (STEM) skills. And it is an indication of how seeing things from a new or different angle can change your perception.

That is the challenge we face when showcasing engineering careers. Many young people (as well as their parents and teachers) don't make the mental leap between what is being learnt at school and how those principles are used in 21st century engineering. The annual Big Bang Fair, which takes place at the NEC this month, is there to make that link; to help build the talent of the future. How do you know what will spark someone's imagination? You don't and that's why, in contrast to a trade fair where you are hoping to attract future customers, everyone there is hoping something they offer will inspire another young person to think differently about a career in STEM.

Around 70,000 visitors will try out hundreds of attention-grabbing activities, including DJ robots, wind-power challenges and virtual reality. Shows will present the science and maths in special effects, the quantum mechanics of chocolate and we'll even be testing out the formula for scoring the perfect goal. Young people will have the opportunity to talk to professionals about their work and careers advisers about their own futures.

Professionals from a huge range of companies will share their stories, expertise and enthusiasm. Many of them are apprentices or recent graduates, people still early in their career that the young visitors can relate to. In fact, in the case of National Grid and Tata, it's their newest recruits who have designed some of the interactive activities they're showcasing; and one of the members of staff on the JCB stand first made contact with the company while competing at the fair in 2012.

Once again, the fair will host the national finals of the competition that will crown the UK Young Engineer and Young Scientist of the Year. For the students behind the competing 200 projects, reaching the finals is a huge achievement and for some it will be the first step on the road to a very rewarding career.

Linking learning with real career opportunities is the key to changing the choices of the next generation. Inspiring more young people to continue studying maths and science is the first step to more skilled workers in the industry. This understanding is behind the many efforts to share positive messages and engaging examples from the world of engineering.

This month, there is much focus on the fair but it is just one part of a year-round effort to change perceptions and change lives. If yours is not one of the UK companies represented at The Big Bang Fair you can still help build a future where we can draw on bright young talent to shape our industry. Together, we can show more young people how varied and rewarding our industry is to get them thinking about their role in it.

Paul Jackson
Chief executive, EngineeringUK

Professionals from a huge range of companies will share their stories and expertise at the Big Bang Fair

Talkingpoint

Inouropinion

Bright spots obscured by the skills cloud

The looming engineering skills shortage in the UK threatens to reach alarming proportions

The annual report from EngineeringUK, the organisation that promotes the interests of the engineering sectors to the public and to government, makes for encouraging reading while also being rather alarming. While setting out the state of the sector as profitable and productive, it also calls attention to the scale of the shortfall in engineers that the UK is facing in the coming decades.

The profile of the engineering sector is one that may surprise even insiders. Rather than being dominated by large players, almost four-fifths of all engineering companies employ four people or fewer, and although only 0.4 per cent of employers have over 250 people working for them, these employ 42.5 per cent of all engineers work. This still means that a significant majority of engineers work for what would be categorised as an SME; companies that often lack the funding or facilities for in-depth training.

The report added that Scotland saw the greatest growth in engineering enterprise turnover, although businesses in the London region showed the greatest revenue and growth. The report noted that think-tank Institute of Public Policy Research (IPPR) recommended a shift in job creation towards higher-productivity sectors, while encouraging firms to invest in their employees; while government intervention has focused on supporting infrastructure and skills.

But the skills gap is still a great cause for concern. The report said that between 2012 and 2022, UK engineering companies will need to recruit 2.56 million people; of these, 257,000 will be to fill new vacancies rather than replacing people. Of these recruits, 1.82 million will need engineering skills: that's 182,000 per year. Of these, 56,000 will have to be at the equivalent of Advanced Apprenticeship level (also known as Level 3), and 107,000 at undergraduate degree or HND/C level or above (Level 4).

But currently, the annual numbers entering at Level 3 are 27,000 and 66,000 at Level 4. Clearly the shortfall is large; and these numbers indicate it's not just a matter of attracting experienced people who want to change jobs. Possibly the resource difficulties of SMEs may be playing a part here.

The difficulty doesn't seem to be in keeping engineering graduates and apprentices in the sector: the report shows that very few end up in sectors such as finance and insurance; in fact, over two-thirds of engineering trainees in full-time employment after three years are in engineering occupations. Rather, it's our old familiar problem: getting

We need to ensure there are enough STEM teachers

schoolchildren into STEM-related courses; and that goes from picking GSCEs with physics and maths content, to taking science A-levels, and then studying engineering at university; or going into apprenticeship schemes at 16 or 18.

A larger amount of coverage of engineering and more favourable depiction in the media might be responsible; we've just learned that London's Victoria & Albert (V&A) Museum is launching its first ever engineering season this year, including a special exhibition devoted to Ove Arup. "We may not know it, but engineers organise the world we live in," commented V&A director Martin Roth. Really, Martin? You work over the road from Imperial College! If you didn't know it, what hope is there for anyone else? But sarcasm aside, this is a very welcome, if seriously overdue, development.

Lack of information about the realities of engineering is an obvious issue for schools. Going from school to engineering, whether as a degree or apprenticeship, is going to be a step into the unknown. Engineering employers have to engage more with local schools to give students more idea about what they do, and the engineering associations need to increase their involvement too. This is especially true for reaching out to under-represented groups, particularly girls.

Is money a problem? Anecdotally, yes: if there's one thing we can count on whenever we cover this issue, it's respondents bemoaning their lack of salary. But hard evidence doesn't bear this out: engineering starting salaries are 20 per cent higher than the average graduate starting wage. Is this skewed by London wages? Undoubtedly: all salary averages are.

What is certainly worrying is the comments we receive from people who say they wouldn't recommend engineering to their children. It's worrying because research indicates the one thing that's almost guaranteed to get young people to take seriously the idea of an engineering career, and the best way for them to understand what it involves, is to have a member of the family in the profession. Engineers complain – everyone complains – but this is something that they should be aware of.

EngineeringUK said we need to double the number of people entering engineering at the training and education level. We also need to ensure there are enough STEM teachers; which is no trivial matter. It's not something we can ignore, and it's something the engineering community needs to be more involved with.

Stuart Nathan Features editor
stuart.nathan@centaurmedia.com

"Engineering starting salaries are 20 per cent higher than the average starting wage"

Stuart Nathan

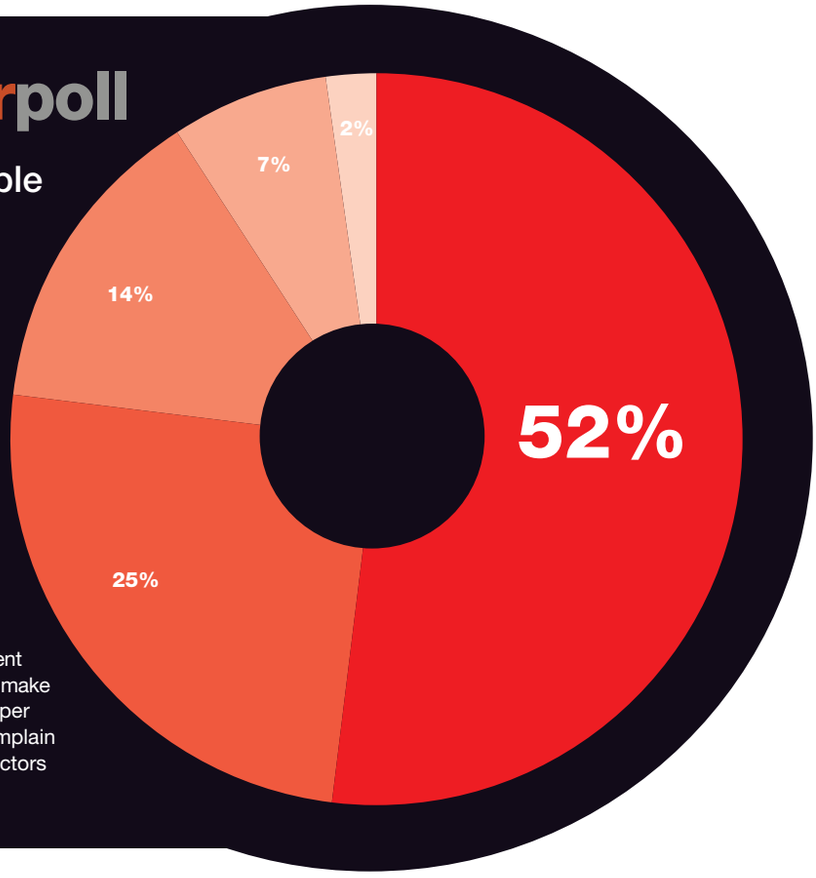
Theengineerpoll

Why aren't enough people entering engineering?

The engineering sector is in relatively good health but is still struggling to attract fresh talent, a factor that threatens to undermine the profession.

This is the conclusion of EngineeringUK's *State of Engineering* report, which warns the Britain will fall behind countries such as Germany if it fails to plug the skills gap.

But why aren't enough people becoming engineers? We asked this question in our weekly poll and found that over half (52 per cent) thought that the status of engineering is too low. Exactly a quarter of respondents thought industry should engage with schools, while 14 per cent thought teachers were not doing enough to make engineering attractive. Of the remaining 9 per cent, 2 per cent agreed that engineers complain too much, and 7 per cent thought other factors are at play.



Not enough people are entering engineering. With which statement do you most agree?

- The status of engineering is low
- Industry should engage with schools
- Teachers do not make it attractive
- None of the above
- Engineers complain too much

Inyouropinion

We need good people in engineering and that means people who can do the academic side but also have a 'feel for stuff', a feel for what will work and what won't. Schools mostly do an okay job on the academic side; there are some great teachers and lots of okay ones. But the practical side? It is far too small, whatever age you look at. That means we have to get smart children getting hands on, getting a feel for stuff. So get out there people, like I do; get down to it with Meccano, a shed, some wood and screws, and get them started making stuff. And when you've got your kids going, get going with other kids in schools, in science and engineering clubs. I've had a lot of fun doing this, and had the satisfaction of seeing quite a few kids go on to great careers.
Neil A Downie

What a shame it is that with our rich cultural heritage in engineering, we are renowned the world over, we cannot seem to get children excited about a career in engineering? I was trained in the Royal Air Force as an aircraft electrical fitter with added instrumentation skills but most fondly remember having a 'can-do' mentality instilled into me in whatever job was required to be done.
David Anderson

In summary, we need the companies that can design, engineer, manufacture and then sell the products they conceive. Creating these companies from scratch is very hard and there is no support to help you on your way. My company has been fighting for 10 years and we are slowly getting into a position to be able to push harder and develop further. We are starting to sell our products internationally as they are recognised as being exceptional in their field. But the personal cost has been high. As a company we have taken a long-term view and it is slowly starting to pay off as we make high-end products. Sadly, many in the UK have no concept of that long-term vision and what it actually takes to get into a position for a manufacturing company to succeed. In the words of Steve Jobs "An overnight sensation takes years to create."
Simon McLaughlin

My son is an MEng who's very creative and a most enthusiastic engineer who I'm sure would be a great asset to any company but he hasn't found a decent engineering job yet. The problem is that all graduate jobs seem to be via private employment agencies and it's in their interests to keep the applicants as far away from the employers as possible. Consequently, he's expected to apply for jobs, often without being told who or where the employer is and what they produce. I read recently there is a growing concern that what the recruitment agencies are passing to the employers are good 'box tickers' because they've been through the same filters but they're not the sort of people who step out of the box to be the future's innovators, movers and shakers.
Ventus

One problem is that everyone is an engineer – from the degree-qualified, apprentice-trained, experienced specialist, through to the six-week-trained, ex-estate agent who has just attended a course on basic plumbing skills. The alternatives to engineering appear much more appealing to school leavers and prospective students because of the generally unpleasant working environment; the prospect of spending their working life with semi-skilled individuals who are uninterested in doing little more than the bare minimum; and a general lack of respect from those outside the industry. All in all, not a career I would recommend.
Mick

The public no longer access anything that might spark an interest in practical engineering. Cars, domestic appliances and electronic gadgets are impregnable, bicycles are uncool among teenagers. Children are no longer allowed out on their own to 'experiment' or play with stuff; couple this with the common addiction to computer games and social media and it is no surprise that few young people get interested in engineering. My interest was sparked by Lego, Meccano, watching my father fix stuff, fixing stuff myself, followed by discovering a talent in maths, physics and drawing. I suspect places such as Germany have more well-off engineers to look up to. Additionally, Engineering is unlikely to appear in any 'best jobs' list.
Terry

Join the debate theengineer.co.uk

Meeting up with the gas puzzlers

New technologies for extracting and processing natural gas, and converting it to other useful hydrocarbons, are coming to the forefront. Stuart Nathan reports

Natural gas is increasingly the hydrocarbon fuel of choice in an ever-wider range of applications. It replaced coal as the main domestic fuel decades ago, even indirectly: cookers fuelled by coal-derived 'town gas' were converted to natural gas between 1967 and 1977. Electricity generation using natural gas increased in the 1980s and 1990s as the fuel displaced coal. Shipping is increasingly fuelled by liquefied natural gas (LNG) instead of the heavy oils that dominated the marine fuel market for many years, and LNG is an increasingly popular fuel for commercial vehicles and buses (although it still has a long way to go to displace diesel). It requires engines to be converted and is not available as widely as petrol or diesel, so its take-up in personal car transport has been slow to grow.

The reasons for its popularity are mainly environmental. When it's burned, methane releases less carbon dioxide per unit of energy than any other hydrocarbon. So, although it does still contribute to greenhouse gas emissions, switching from more carbon-intense fuels to natural gas is often an easy way to reduce emissions without too much trouble. The gains are particularly large when the fuel being replaced is coal, which releases the largest amount of CO_2 per joule, 10 times as much as methane; this is why the UK government is particularly keen to phase out coal-fired power stations and replace lost capacity with gas as fast as possible. Energy secretary Amber Rudd announced last year that the coal phase-out would be complete within a decade, with the cut-off point in 2025.

Shell is one of the world's largest natural gas producers, and recently presented several of its new technologies for extracting and processing natural gas and converting it into other useful hydrocarbons to the media at its technology centre in Amsterdam (STCA). Gleaming and almost intimidatingly spotless, STCA is a reminder that even in the petrochemical industry, engineering isn't always grimy.

According to Shell's manager for gas conversions, Jan van Schijndel, there are sufficient gas resources left for 235 years of supply, allowing for some expansion into new applications. Some of these are in well-known regions such as the Middle East; others are in less well-

01 Pearl GTL plant in Qatar

02 Scanning a core sample with a medical CT scanner

Indepth CT scanning and the recovery of oil

Gas is, of course, only one of the hydrocarbons Shell extracts; it devotes just as much resource to technologies to recover oil. One of the tools it uses to help with that task is the world's largest vertical computerised tomography (CT) scanner.

The main application for this piece of equipment, which occupies its own lofty space in the STCA and weighs 60 tonnes, is to investigate core samples taken from oil wells to see how well oil flows through the rock. According to Axel Makurat, team leader for rock and fluids, this is a particularly valuable technique when water or fluid mixtures are being injected into the oil well for enhanced oil recovery techniques.

The geology where oil tends to be found is either sandstone or chalk, both of which contain very different connected networks of pores or fissures that contain the hydrocarbon and through which it flows on its way to the surface. Originally, when Shell's scientists first had the idea of using CT scanning to investigate the behaviour of oil in rocks, the company simply bought a medical CT scanner and used it to study oil flowing through a short (typically around 30cm long) section of core sample – of the similar geology to the region of interest, although not necessarily actually taken from the precise location – which was placed inside the scanner in the same way that a human patient might be.

Although this did provide some valuable information, Makurat said, there were two big problems: the sample was placed into the scanner horizontally and oil was pumped through it from one end to another. This is not what happens in real wells, where the oil is pushed upwards against gravity, either by its own pressure within the reservoir, or by the pressure of the enhanced oil recovery (EOR) fluids. In the medical scanner tests, the oil tended to creep along the bottom edge of the sample in response to the gravity in its orientation. Moreover, the small size of the core sample inside the scanner made it rather difficulty to extrapolate the results to the size of an entire oil well, which can be many hundreds of metres or even kilometres deep inside the reservoir geology.

To get a more accurate and extrapolatable set of results, the company decided to invest in a vertical CT scanner. Although this works in exactly the same way as the medical system, scanning a series of slices through the core sample along its length to show how the front of the oil surge develops and progresses through the rock, the core sample can now be up to 3m long, placed vertically in the scanner, which moves up and down, and the slices are oriented horizontally rather than vertically. The scanner is six times larger than a medical system. The oil or oil/EOR fluid mixture rises up the column of the core sample, as it does in a real reservoir, and the longer length means the behaviour of the hydrocarbon is much closer to what happens in an oil reservoir.

The CT scanner system produces X-rays through an electrical process, rather than using a radioactive source material; this helps with safety, as the system only produces X-rays when it's switched on, according to Makurat.


02

exploited zones. These include the North Atlantic; parts of North Africa, such as Egypt; South Africa; and off Western Australia. The last of these, being very remote from any market, will be where the enormous Floating LNG vessel *Prelude* will be stationed once it has been fitted out in South Korea. Lacking propulsion, *Prelude* is not a ship; but is the largest floating structure ever constructed in terms of weight and displaced volume. It will compress the gas from the field to a liquid to make it easier to transport to markets or processing centres.

But gas that comes out of the ground is often unsuitable for use directly, because it isn't pure. Deriving as it does from the remains of micro-organisms, it also contains traces of the other elements that occurred in their bodies. Some of these trace elements occur in gas in compounds that are corrosive and toxic, such as foul-smelling hydrogen sulphide (H_2S).

Shell's technique for getting rid of sulphur impurities borrows from nature. Developed by a company called Paquell – a joint venture between Shell and Paques, a waste treatment biotechnology specialist – it uses natural microbes that digest H_2S and excrete elemental sulphur and water. "These microbes occur very widely," explained Marja Zonnevylle, general manager for gas processing. "Dredge some mud up from the bottom of any ditch and it'll have some of these microbes in it. And when you use a mixture of microbes in a process it'll optimise naturally to the feedstock – the ones best suited to the mixture of impurities in the feed will flourish, so you end up with a very efficient microbe population without having to do anything to it yourself."

The microbes are housed in a reactor through which gas is bubbled, and clean gas rises to the top while the sulphur excreted by the microbes falls to the bottom. This biosulphur is an off-white colour and tends to clump together, unlike chemically derived sulphur, which is a bright-yellow, free-flowing powder. Biosulphur is easily dispersed in water, Zonnevylle said, making it suitable as an agricultural fertiliser, for which there is a brisk market.

Fuels aren't the only thing to do with natural gas. Much of the chemical industry is based on hydrocarbons, but there, the feedstock tends to be small molecules with short chains of carbon atoms derived from 'cracking' larger molecules, over a catalyst at high temperatures and pressures. This is because carbon-hydrogen bonds are very strong and methane, the main hydrocarbon component of natural gas, is an extremely stable molecule and doesn't tend to react with anything; all it does is burn.

But Shell specialises in a process that transforms methane into larger organic molecules that can then form the feedstock for other processes. Known as gas-to-liquids (GTL), this is a multi-stage process that begins by partially oxidising methane to convert it into carbon monoxide. Unlike carbon dioxide (the fully oxidised form of carbon, which is even more stable than methane – it doesn't even burn), carbon monoxide is reactive. In particular, as Martijn van Hardeveld, >>

"Dredge some mud up from the bottom of any ditch and it'll have some of these microbes in it"

Marja Zonnevylle, Shell

"Each tube behaves exactly like the single-tube set-up in the pilot plant"

Martin van Hardeveld, Shell

03 Hendrik Dathe, research manager for refinery catalysts (left)

04 Axel Makurat, team leader for rocks and fluids

05 GTL pilot plant at STCA Amsterdam

>> general manager for GTL conversion, explained, it can be mixed with hydrogen to form a mixture known as synthesis gas or Syngas, and subjected to a reaction known as the Fischer-Tropsch (F-T) process, which removes the oxygen from the carbon atom and replaces it with a chain of hydrogen atoms. These units then join together to form long, linear carbon chains, and more hydrogen atoms cap off the ends of the chains to make stable long hydrocarbons.

The final product is a mixture of heavy hydrocarbon that is molten when it is produced, but solidifies to a wax. Because this is derived from purified methane, it consists only of pure hydrocarbons. It can be cracked in the same way as oil products to make smaller hydrocarbons of tailored molecular weight, some of which can be burned as fuels, generally substituting for diesel; and unlike diesel derived from oil, which is a natural product and contains sulphur impurities or aromatic compunds, which produce sooty particulates when burned, GTL diesel is purely simple hydrocarbon and burns much more cleanly.

Heavier cracker products – again with hydrocarbon molecules of known size – can be used in lubricating oils; once again, they are very clean and free of impurities. Even the solid wax that is the basic GTL product has a small market, in products such as cosmetics and coatings for paper products for the food industry. Other hydrocarbon products are used to make synthetic detergents; still others, plastics.

F-T synthesis isn't new; it was developed in Germany during the 1920s, and was used extensively in the Second World War to make fuel from the country's abundant coal resources (Germany has no oil). It was further developed in South Africa, another country with little oil but much coal.

Shell's interest in GTL began because the company wanted to make use of so-called 'stranded' gas, which comes from reserves located a long way from a ready market, and from where transporting it through pipelines or even compressing it into LNG would not be economic. It has devoted considerable resources into refining its cobalt-based F-T catalyst, testing many related compounds to find the right structure to speed up the reactions that make the desired products.

Catalyst research is done using a similar technique to one developed for the pharmaceutical industry. Known as combinatorial chemistry, it uses miniaturised flow devices to direct feedstock gases into small tubes packed with catalyst-bearing beads, tubes or particles. The product stream from each tube is analysed separately, but the time saved by running the experiments simultaneously allows Shell to test very large numbers of related compounds in a short time, explained Hendrik Dathe, research manager for refinery catalysts.

These catalysts are tested using a natural gas feed in the pilot plant laboratory at the STCA, before the process is scaled up for use at the enormous Pearl GTL plant in Qatar and a smaller one in Bintulu, Malaysia, the world's first fully integrated GTL plant, opening in 1993.

Pearl is the world's largest GTL plant. Jointly owned by Shell and the Qatari state-owned petrochemical company, it converts 45 million cubic metres of natural gas every day into 22bin litres of liquid hydrocarbons. Estimates of its cost vary to as high as £24bn and it is believed to be economic as long as the oil price is above around US$40/barrel.

Scaling up chemical reaction is a tricky problem; what works in a laboratory can behave differently in an enormous tank. But Shell has a more foolproof method. The reaction is tested at pilot-plant scale in a reactor whose form is a tube, around 2.5cm in diameter, packed with catalyst supported on ceramic beads and heated by steam. Van Hardeveld said: "To scale it up, we simply bundle many of these tubes together in a single vessel, with steam running in the spaces between the tubes to get them to the temperature we need – between 200° and 300°C. Each tube behaves exactly like the single-tube set-up in the pilot plant." ▣

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Geared for success

A Liverpool-based SME is leaving bigger supercar manufacturers in its wake. Andrew Wade reports

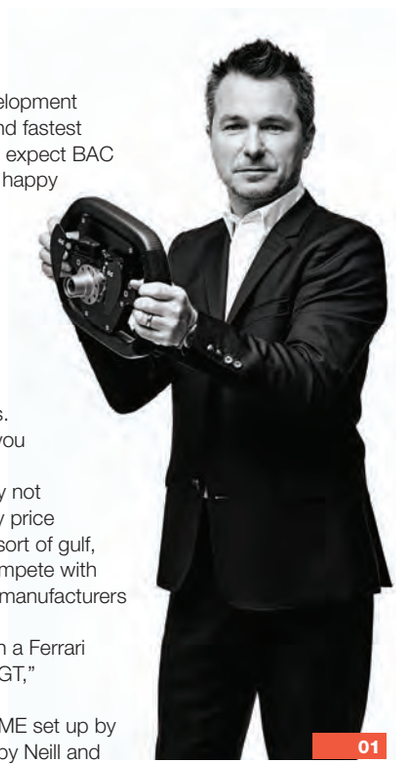
As the director of product development behind the car with the second fastest *Top Gear* lap ever, you would expect BAC co-founder Neill Briggs to be happy about the achievement. And he is. But he's also slightly irked by the fact that his company's BAC Mono was kept off the top spot by a Pagani Huayra suspected of running on modified slicks, contravening the *Top Gear* rules.

"We say we're the fastest on road-legal tyres," said Briggs. "You can make your own mind up about what Pagani did. If you search online you can read all about that."

Rather than dwelling on what the £1m Huayra may or may not have done, Briggs prefers to focus on the Mono, whose entry price happens to be a comparatively meagre £125,000. With that sort of gulf, it's incredible that the Liverpool-based company is able to compete with those such as Pagani, not to mention leaving other supercar manufacturers in the dust.

"To put it into perspective, we're five seconds quicker than a Ferrari Enzo and we're six seconds quicker than a Porsche Carrera GT," according to Briggs.

These are giants of the motoring world, and a Liverpool SME set up by two local lads is eating them for breakfast. Founded in 2009 by Neill and his brother Ian, Briggs Automotive Company has become one of the most intriguing success stories of UK engineering.



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Neill is an engineer with experience working at both Bentley and Ford, playing a key role in the development of the latter's Focus RS. His brother Ian is BAC's design director, and has previously worked on luxury yachts and the Airbus A380 fleet, as well as with OEMs such as Porsche, Mercedes and Audi. They've combined their expertise to create a car that gained almost instant cult status, an automotive experience they say is truly unique.

"Obviously the first thing that sets us apart is the fact that we're the first and only road-legal single-seater car in the world," Briggs said. "We've redefined what we call a niche within a niche, which is the purist supercar sector.

"We identified this trend when we started the project in 2007, and we asked how would a car look if it wasn't based on a concept that in essence was a slightly flawed or compromised concept of transportation – moving two people around, and luggage and golf clubs and all the rest of it."

The result is a beautifully crafted machine that resembles a Formula car, but with enclosed wheels and other design details that make it perfectly legal to drive on UK roads. Although perhaps more at home on the track (particularly with the combination of British weather and the vehicle's open cockpit), BAC has found that around 70 per cent of its customers use the Mono on the road at some point.

When it launched in 2011 the car's 2.3-litre Cosworth engine – combined with a kerbweight of just 540kg – produced a top speed of 170mph, the 280bhp taking you from 0-60mph in 2.8 seconds. Numbers like that, in tandem with a much lauded gearbox and precise handling aided by the longitudinal placement of the engine block, led to the Mono being named The Stig's car of the year for 2011.

"It's a great accolade because it's something they've never repeated on *Top Gear*," said Briggs.

By 2013, when the Mono debuted on the *Top Gear* track, BAC had just six employees. That number has grown rapidly, a team of 24 now producing 40 bespoke vehicles a year, with long-term plans to ultimately produce 150. Originally based in Cheshire, the Briggs brothers were enticed back to their roots by Liverpool Mayor Joe Anderson following his election in 2012. The company now operates out of an 11,500ft² facility in the Speke area south of the city, with the nearby John Lennon Airport serving as a convenient test track.

> 'We asked how would a car look if it wasn't based on a slightly flawed concept"
>
> Neill Briggs, BAC

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01 Neill Briggs founded BAC with brother Ian in 2009

02 The Mono is the world's only road-legal single-seater

The location also puts BAC in close proximity to large automotive manufacturers such as JLR (Halewood), Vauxhall (Ellesmere Port) and Bentley (Crewe), and the supply chain that has grown up around them. About 40 per cent of the car's components are sourced from the Liverpool region. Having that resource on the doorstep has been mutually beneficial for company and community, according to Briggs, with BAC's 'repatriation' to Merseyside helping the expansion of the local engineering base. **>>**

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>>"If you use Innovate UK's multiplier, it's around 40 jobs we've created in the supply chain, so 60 jobs [in total] in just under two years is quite an impact. Our supply chain is a 'best of British' approach. We're very proud of that. So the vast majority of the parts that we use are sourced from the UK. They're a mixture of motorsport suppliers and regular OEM suppliers, and we've got a really good balance there."

When it comes to manufacturing, the localised supply chain helps provide a degree of flexibility that other automotive companies simply can't match. The Mono also has over 450 parts machined from solid billet, and because BAC doesn't invest in the costly stamping tools that larger OEMs use for mass production, it can modify and refine individual parts at will.

"This is how we turn a so-called disadvantage as an SME to an advantage," said Briggs. "A stamped part is not particularly nice, but it does its job. In our case, we machine it from a solid piece of 6082-T6 aircraft-grade aluminium – the best you can get."

What this means is that each part can be optimised for the function it needs to perform, and there is flexibility for the car to constantly evolve. To test out possible improvements, BAC uses a suite of tools from Autodesk, many of which were used in the original design of the Mono. The advanced CAD systems coupled with machine-tooled parts provide BAC with an impressive level of agility.

"We can make a change in about a week," said Briggs. "So we can do the analysis, we can then send a DXF [CAD] file straight out to our supplier, and then he can change the programme on his machine."

Change is something the BAC team is well accustomed to, owing to the level of personalisation it offers and the exacting standards of its clients. Each car is fitted with a unique seat moulded to the customer's body, manufactured by the same company that provides the seats for Formula One. On top of this, the steering wheel can be customised, built to fit the grip of each individual client.

While each car is ultimately unique, BAC has also introduced some underlying improvements to its 2016 Mono, including carbon ceramic brakes that save 2.5kg per wheel, and a more powerful Cosworth engine. These changes could prove pivotal when a certain BBC motoring show returns later this year.

"You can imagine that when we get invited back that we will be beating that lap time by quite a considerable margin," said Briggs, "not least because the business has moved on since then, but also because we've introduced our 2016 model year car, which is a 2.5 litre engine versus a 2.3, giving us an extra 10 per cent power and torque."

That Pagani Huayra had better check its mirrors.

03 Some owners use the Mono exclusively on track days

04 The steering wheel can be moulded to fit a customer's hand

05 New carbon ceramic brakes will save 2.5kg per wheel

06 The Mono is hand-built at BAC's Liverpool factory

> "The vast majority of parts we use are sourced from the UK"
>
> Neill Briggs, BAC

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Loading up the Catapult

New technology chief has ambitious plans for the High Value Manufacturing Catapult. Jon Excell reports

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Whether it's being criticised for a lack of long-term vision, or slammed for failing to support fledgling technologies, the UK government typically gets a pretty rough ride from industry and possibly rightly so.

One of the notable exceptions to this in recent years has been the establishment of the Catapult Centres, a network of organisations designed to help innovations from a variety of sectors fulfil their economic potential.

The most established of these, the High Value Manufacturing (HVM) Catapult, which this year celebrates its fifth birthday, has enjoyed particularly notable success: today boasting over 1,500 paying members, and, according to a recent economic impact assessment, generating £15 for every single pound of investment. Dr Phill Cartwright, the centre's newly appointed chief technology officer, has bold plans to build on this in the months and years ahead.

A veteran of the aerospace and power sectors, with key roles at Rolls-Royce, ABB and Alstom under his belt, Cartwright joined the HVM Catapult in November 2015 from construction giant Laing O'Rourke, where, as director of the engineering excellence group, he was charged with applying the lessons learned in industry to the construction sector.

He achieved some notable successes in this role. The City of London's distinctive Leadenhall Building, aka the cheese-grater, was built ahead of schedule thanks to the heavy use of off-site construction techniques (85 per cent of the building was produced in factories). The Manchester Metrolink, another project in which he had a hand, was also completed early, thanks in no small part to the use of virtual design and production techniques more commonly associated with the automotive industry.

And as the HVM Catapult charts a course for the future, Cartwright's experience applying lessons learned in one sector to the challenges faced by another will be a key asset.

"From an innovation and technology perspective, UK manufacturing is held in high respect all over the world. I think the area where we've lacked in the last 10, 20 or 30

years is turning our great ideas and innovations into GDP and growth," he told *The Engineer*. And while the HVM Catapult has arguably done a pretty good job of addressing this famed shortcoming, Cartwright believes it can become even more effective if the seven different centres that make up the Catapult can be encouraged to work in a more joined-up way.

"I think it's widely recognised that the Catapults have been successful," he said. "But I think it's also been recognised in the HVM that while we have seven centres all doing extremely well there isn't necessarily a technical strategy at various levels that maximises the benefits of pulling those centres together."

A more joined-up approach should, Cartwright added, enable technologies to flow more rapidly between different sectors. "Automotive is now investing heavily in hybrid drives and autonomous vehicles. That technology is finding its way into next-generation cars very quickly. It will not find its way onto aerospace programmes for at least five to 10 years. Taking an over-arching view of all the centres and the cross-sector attributes means we can get those technologies into aerospace much sooner, to the benefit of the industry partners and to society as a whole."

A big challenge is encouraging this collaborative process without being too proscriptive, and one of the keys to achieving this, he said, is the centre's technology officer's forum, where representatives from each of the centres work together to identify cross-centre opportunities.

Once you start working like this, he said, a host of untapped opportunities begin to emerge: from the advantages of applying lean, safety-critical aerospace processes to the civil sector, to the ways in which fringe innovations such as new non-invasive surgical techniques could benefit the aerospace sector. "There wasn't a mechanism to do that before, other than by accident."

One particularly promising area of expertise with real cross-cutting potential is, he said, digital engineering, and there's a major focus within the centre on how the kind of virtual design and production approaches developed for the automotive sector (where every aspect of a car's design and the processes used to make it are planned in detail before anything's built) could be used to improve safety and quality across a range of sectors.

"Imagine applying that process to big infrastructure build," said Cartwright. "Imagine you were building a nuclear power station in the virtual world, with all of the supply chains, three or four years before you stick a spade in the ground. On a £23bn project that would provide absolute certainty on the project and increased safety."

Such an approach could also have a transformative effect on the home-building sector, he claimed. "You don't buy a car expecting a load of blokes in white coats to come and tinker with it for the next six months. But if you buy a house today you'll spend the next six months with builders turning up finishing the thing off. You don't know what the performance is in terms of energy rating, but you know how much fuel your car's going to use. We're looking at how do you take those lessons learned in aerospace and designing in that virtual world, and apply it to house building."

In a related project, the centre is also looking at using processes developed in jet-engine manufacture to improve the efficiency of hospitals.

Cartwright explained how with the help of the Sheffield Advanced Manufacturing Research Centre (AMRC) – one of the members of the Catapult Centre – Rolls-Royce has changed its business model to the point where almost half of its revenues are from the services market. "They put sensors and diagnostic techniques on an engine, which our centres have been helping them with – they know where every one of their engines is in the world, how hot it is, how fast it's spinning and they're able to trade that service."

CareerCV

Dr Phill Cartwright
Chief technology officer at the High Value Manufacturing Catapult

Career
Cartwright recently joined the HVM Catapult from Laing O'Rourke, where he was director of the Engineering Excellence Group and has a track record of senior roles in advanced engineering, including five years as head of electrical power and control systems at Rolls-Royce. He previously set up and was the chairman of the IET Power Sector Executive and has been an adviser to the UK's Nuclear Industry Council and the industry sub-group of The Nuclear Innovation Research Advisory Board.

"While we have seven centres all doing well there isn't a technical strategy that pulls them all together"

Applying the same approach to the construction and operation of hospitals could, he claimed, help make hospitals vastly more efficient. "If you took a similar approach and put diagnostics into the design and build process you could knock out at least 30 per cent of their operating costs."

As well as ensuring the centre exploits the full value of all of its parts, another key aspect of Cartwright's role is helping government understand the economic potential of manufacturing technologies. And a particular priority is encouraging an appreciation of the importance of long-term planning: not a concept that sits naturally with a short Westminster career. "I think we lead the world in a lot of areas, but to be successful we need to invest in the long term," he said. "This is not something you do on a 12-month by 12-month cycle. Look at Rolls-Royce: its success is all about developing a single crystal alloy that took 25 years to develop from its original investment."

"Where we're weak is we don't have consistent funding mechanisms, policy and infrastructure that supports long-term investments. In Singapore, China and the US, for example, the thinking is more long term, but in this country the public focus is too short term. Part of my role is to put together examples to show where investing in the long term will generate a significant uplift for the UK."

Nevertheless with the government's most recent comprehensive spending review increasing funding for the HVM Catapult, Cartwright is optimistic that there's an appetite for dialogue: "It's positive and they're listening. The challenge is to keep that focus on the long term."

In the longer term, he also sees some significant potential in encouraging the different catapult centres to work together. Such collaborations could, he said, be key in helping address some of the UK's most pressing problems, such as fears over energy supply. "The lights are not going to go out this year – we hope – but we are getting quite close. We haven't allowed for successful collaboration and innovation in energy market over last 20 years; since we've invested in catapults we ought to use the wisdom of that to focus innovation in the UK energy sector as well."

01 Digital engineering is changing the factory floor
image: MTC

02 Technology developed for the automotive industry could have applications elsewhere
Image: WMG

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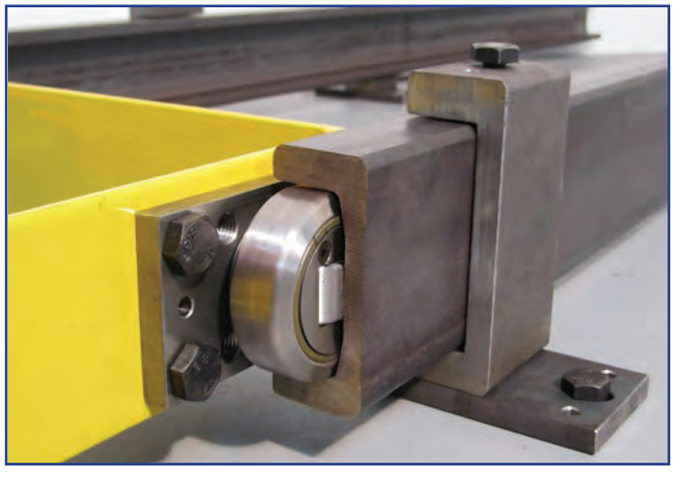

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The future is in our grasp

Novelist Jon Wallace considers the science fiction implications of engineering stories that have caught his eye. This month: how robotic limbs are propelling us into the future

This month, *The Engineer* reported on A-Gear, robotic arm supports developed by researchers at The University of Twente as aids for those affected by Duchenne muscular dystrophy. The active support is designed to amplify residual function in the arm, restoring a measure of independence to its users.

This noble effort is one of many exoskeleton and smart prosthetic projects underway around the world, with applications ranging from Darpa's Revolutionizing Prosthetics project (designed to create prosthetics for wounded US military personnel) to additional limbs intended to augment the human form.

Such projects make for exciting news. Perhaps more than any other branch of engineering, the robotic limb calls to mind science fiction, its rapid development serving as a kind of benchmark in the public consciousness for humanity's technological advance. This is reflected in the reporting on such projects, which is often accompanied by headlines speaking of 'Turning science fiction into science fact'.

The invocation of science fiction in this context is understandable. Artificial limbs have a distinguished history in the genre, helping to define hundreds of characters. They often appear in cinema: from Rotwang's black hand in *Metropolis*; through the Skywalker family's prosthetics; to Imperator Furiosa's scrap metal paw in *Mad Max: Fury Road*. They play a big part in comic books too: see Dr Octopus's tentacle arms, and Mean Machine's huge metal claw in *2000AD*.

Such depictions use robotic limbs and prosthetics in fairly simple fashion. In film, the artificial arm is often limited to a biographical stain, a visual cue that imbues a character with a history of suffering and endurance. In comic books, the purpose is much the same, but can also make a monster of a man, endowing him with superhuman strength, or acting as a weapon.

This is where developments such as A-Gear can be a refreshing tonic for the science-fiction writer. They remind us not only of the tremendous positive potential of artificial limbs, but also suggest that robotic arms can serve as more than a visual cue, but as the crux of a story.

It's tempting to imagine bionic limbs being put to military use, as augmentations for the grizzled veterans of future wars – such as Lieutenant Rasczak in *Starship Troopers*. But rather than battlefield weapons, might they serve as the arbiters of peace? A possible story could follow a designer of bionic limbs for use in some brutal intergalactic war. Sick of the conflict, she hacks the limbs' brain computer interfaces, forcing soldiers on both sides of the battlefield to drop their rifles and vigorously shake each other's hands instead.

Exoskeletons have also often been depicted in conflict: but A-Gear shows that exoskeletons promise most for those with limited mobility, using myoelectric sensors and brain interfaces to provide paraplegics, stroke survivors and the elderly with a new lease of life. We might write about the adventures of an alternative *Robocop*: a centenarian policeman with a sharp mind but exhausted body, brought back to the force by means of a symbiotic, barely visible exoskeleton. His experience helps break open a case that stumps his able-bodied, younger colleagues.

The cost of artificial limbs has the potential to draw the science-fiction writer towards dystopia: we might imagine a world where metallic bionic arms have become an easily exchanged fashion accessory for the super wealthy – a diamond-studded Rolex that has spread over and become one with the forearm that sports it. A story could follow some desperate future mugger, an amputee who steals a rich man's claw. Wearing it, he soon discovers it can open all kinds of doors, acting as a pass into a world of privilege and debauchery.

Open-source designs promise a future of progressively more refined and cheaper products, created by their users for maximum comfort and utility. Perhaps those with limited mobility will create exoskeletons that benefit all humanity? We could tell the tale of a Duchene sufferer who invents leg supports of such efficiency and capacity that the wearer can run great distances and barely tire. An alliance of shadowy oil executives dispatch a hit squad to assassinate him before his inventions destroy the motor industry – they try to run him down, but he's wearing his prototype, and he outmanoeuvres and outruns their car.

However artificial limbs develop, the feedback loop between science fiction and engineering is strong: a decade ago this month author Margaret Atwood signed books in New York… while sitting in London. She did this by means of a signal beamed to a robot arm that tracked and duplicated her signature. In such a world, one thing feels certain: the more robot limbs advance, the more the future feels within our grasp.

> "The cost of artificial limbs has the potential to draw the science-fiction writer towards dystopia"
>
> Jon Wallace

Perhaps more than any other branch of engineering, the robotic limb calls to mind science fiction

Jon Wallace is a science fiction author living and working in England. His new novel, *Steeple*, is published in paperback this month. Check out his website jonwallace.co

Leonardo the engineer

The Science Museum's Leonardo da Vinci exhibition shows him as the gifted engineer he truly was. Stuart Nathan reports

London's museum cluster in South Kensington is going through a bit of a purple patch for those with science, engineering and maths interests. The Natural History Museum has a stunning exhibition of enormous photographs of the solar system; the Victoria and Albert Museum has a long-overdue engineering season on the cards (see p22). The Science Museum is still showing an amazing collection of Soviet space relics in its 'Cosmonauts' exhibition and, down in the basement, has arranged a space for a touring exhibition originating with the French organisation for public science communication, Universcience, and Milan's Museo della Scienza e della Tecnologia Leonardo da Vinci (MUST), displaying models and other materials related to one of the best-known, but most enigmatic and misunderstood, figures in history, Leonardo da Vinci.

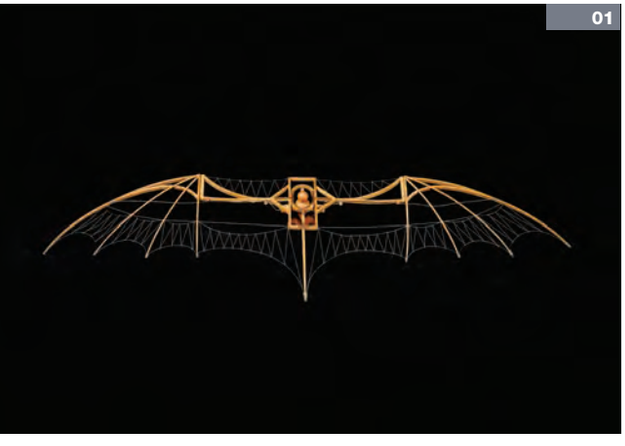
Entitled 'Leonardo da Vinci: The Mechanics of Genius', this exhibition presents 39 models of the machines Leonardo designed, including flying machines, weapons and tools. In doing so, it presents a side of the archetypal Renaissance man that many people will not be familiar with, and one that engineers in particular will find fascinating.

Today, we think of Leonardo primarily as an artist. We know he was a polymath, and his anatomical studies are well known (although even those are more often linked to their use as research for art than anything else). What becomes clear from the exhibition is that Leonardo was, possibly, above all other things, an engineer. That was how he made his living: the princes who paid his salary might have commissioned the odd fresco from him, but it was his machines they were really after.

Living in 15th century Italy, Leonardo's world was one of city-states that were constantly at war with each other, and Leonardo spent a lot of his time compiling what we might see as prospectuses to show prospective employers what he could do for them. An important part of these documents were designs for siege engines and weapons; and it's clear that these were as much to terrify the enemy as anything else. One of the first objects in the exhibition is a huge crossbow, placed vertically and about 3m high. From Leonardo's drawings, we can see this is a scale model: he intended the actual thing to be the height of a house and its purpose was to fire flaming projectiles into the midst of the enemy. Leonardo's letters often talk of the damage and great injury his designs could cause, but they also make a point of stressing the panic and terror they would inspire. Clearly, Leonardo would have completely understood the deterrent theory of today's nuclear states. You'd only have to see a house-sized crossbow once before you ran like hell.

Leonardo didn't build these machines; but what he did do was draw them. He drew everything. "Nobody drew machines like Leonardo; his designs have an incredible vivacity that still speaks to us today," explained Martin Kemp, emeritus professor of the history of art at Oxford University, one of the world's leading authorities on Leonardo and a guest at the exhibition viewing. It wasn't just the way the machines looked on paper that was so revolutionary, Kemp added: it was the thinking and analysis behind them, and the methods Leonardo invented to depict them.

For Leonardo, invention began with observation. Aged 20, his first proper job was as an apprentice in a workshop on the enormous building site for Florence's cathedral, the Duomo. He would have been familiar with the machines on the site, such as the cranes that were being used to lift the dressed stones, designed by the artist/architect Brunelleschi. He observed them and drew them. "He visualised things, understood things and drew things in three dimensions, so they appear as solid objects," Kemp said. "But the point about that is that sometimes important parts of the mechanism would be hidden behind something closer to >>



01 Leonardo's batwing hang glider *Image: Archivo Museo Nazionale della Scienza e della Tecnologia Leonardo da Vinci – Alessandro Nassiri*

02 Prof Martin Kemp with Leonardo's flying machines *image: Science Museum*

"Nobody drew machines like Leonardo; his designs have a incredible vivacity that still speaks to us today"

Martin Kemp, Oxford University

>> the observer. So Leonardo drew what he called elementi but we would think of as components: detailed diagrams of how the mechanisms worked and the parts they were made up from. Nobody had done that before." What is now very familiar to us as an exploded diagram was something pioneered by Leonardo.

One of the things that marked Leonardo out was his curiosity. It's clear that he sought out mathematicians, talked to them and read their texts, and his machines are based on a rigorous understanding of their underlying principles (or at least as rigorous as the science of the time allowed; Leonardo didn't know much trigonometry, Kemp said, because the Ancient Greek texts on the subject weren't translated into Italian at the time).

Leonardo also experimented throughout his life in phenomena such as the properties of materials and friction, using instruments he designed himself. The exhibition includes models of instruments he used in his investigations of his lifelong obsession with flight, including an anemometer consisting of a flexible flap that the wind would blow against a curved scale to indicate its speed, and a hygrometer, consisting of a balance that weighed a wax sphere against a piece of wadding of equal weight when dry, but which would become heavier as it absorbed moisture from the atmosphere. They are brilliant pieces of instrumentation engineering, and, as curator Jim Bennet, an emeritus keeper at the Science Museum who worked on the exhibition pointed out, completely unprecedented.

Bennet worked on the Science Museum's contribution to the exhibition: a series of small mechanical models produced in 1952 for an exhibition to mark the 500th anniversary of Leonardo's birth, which was staged at the Royal Academy and was the forerunner of the blockbuster art shows we know at the Academy today (if any of our readers remember this show, we'd love to hear from them).

The other models in the exhibition were made for MUST, also in the 1950s; but the British ones, commissioned from a company in Wimbledon called Goacher Model Engineering, came first, Bennet said. "We are claiming some primacy here," he said. Much smaller than the Italian models, the Goacher set is labelled 'Leonardo for a time of austerity', reflecting post-War Britain's lack of funds.

The distinction we see between engineer and artist simply didn't exist in Leonardo's time, Bennet said; our view of him today is coloured by the fact that the artwork survives whereas the machines didn't. Never in charge of his own workshop, Leonardo would have known that most of his designs would never be built. There is no physical trace today of the completed engineering works that we do know of from his journals, such as a sluice that formed part of the defences of Venice; and the precious drawings were not known until relatively recently. Bennet thinks that it's more a Victorian hangover than a modern view: art was seen as much higher status in the 19th century, and engineering had the taint of 'trade' about it.

> "Contemporary accounts say that Leonardo was a really nice man; easy to talk to and fun to be around. He was very witty and loved to talk"
>
> Jim Bennet, Science Museum

Kemp said that Leonardo saw his role as being "a second nature". He added: "[Leonardo] looked at what was around him, understood it very often by drawing it, and then took the principles he had learned and used them to create something new. When he was designing a flying machine, he knew that you couldn't copy feathers; you had to understand how they worked, how they created lift, and then devise something that did the same thing." Kemp added that Leonardo knew full well that his ornithopter – a flying machine with flapping wings operated by a pilot pulling levers – would never fly because of the power-to-weight ratio; after 1500 he switched to designing hang-gliders, but even these incorporate a mechanism to spread the wing-tips to improve their flight characteristics.

Equally, some of the machines were just for show. The famous screw-aerofoil helicopter was designed as an entertainment (an important part of Leonardo's role at court); equally, a self-propelled vehicle driven by the energy stored in crossbow-like components wasn't a weapon, but was intended to carry the figures of gods in an elaborate court masque.

Kemp's description of Leonardo's process has to be one of the most eloquent statements of an engineer's job I've ever heard; and the exhibition shows it off to a fascinating extent. Who knew that Leonardo designed machine tools? Yet there's a fully working mechanism that automates the production of files. Interested in ropes and fabrics? Here's a machine to twist 15 cords into a rope, and a spinning wheel that anticipates designs from the 18th century. Here are modern-looking bearings on a table for conducting friction experiments; and architectural designs based on the mathematics of budding flowers that wouldn't be out of place, apart from their 15th century ornamentation, on the Stirling Prize shortlist.

A small section shows how some of Leonardo's ideas on mimicking nature are being carried forward into the 21st century; *The Engineer*'s old friend, Festo's robot seagull, is displayed in skeletal form next to Leonardo's ornithopter with its almost identical spars and levers.

Leonardo was a man out of time and yet completely of his time; a humblingly broad and restless intellect that couldn't be pinned down in his own life and still can't today. Bennet admitted that if there had been a line manager overseeing him, Leonardo would probably have driven him insane. "But contemporary accounts say he was a really nice man; easy to talk to and fun to be around. He was very witty and loved to talk." We'll never know for sure, of course. But if you want to see how much you have in common with this amazing man, I urge you to get along to the Science Museum before 4 September.

03 Giant crossbow
Archivo Museo Nazionale della Scienza e della Tecnologia Leonardo da Vinci – Alessandro Nassiri

A clockwork homage

After picking up a few tips from the Swiss, Nick and Giles English are striving to recreate British watchmaking's glory days. Helen Knight reports

Back in the 17th and 18th centuries, Britain was at the forefront of the science and engineering of watchmaking and the measurement of time.

But despite making half of the world's watches in 1800, the British industry failed to keep pace with mass manufacturing in Switzerland and the US, falling into a decline from which it never recovered.

Fast-forward two centuries, and a small British company is attempting to bring watchmaking back to these shores.

The Bremont Watch Company, based in Henley-on-Thames, was founded in 2002 by brothers Nick and Giles English.

Having started as a small workshop in Switzerland, the company now has a headquarters and assembly workshop at Henley and a parts manufacturing facility at Silverstone, and employs more than 25 watchmakers.

As well as its consumer ranges, Bremont supplies watches for military squadrons such as the Royal Navy Clearance Divers, the 9th Reconnaissance Wing and the US Navy Test Pilot School. Costing upwards of £2,000 each, the watches are not what you might call cheap. But they have all been designed and engineered to be 99.998% accurate, and meet the rigorous chronometer certification requirements of the COSC (Contrôle Officiel Suisse des Chronomètres).

To ensure the cases are tough and scratch-resistant, each is subject to a hardening technology in which the metal is heat-treated, diffused with carbon and then bombarded with electrons. This results in a case seven times harder than the stainless steel used in conventional watches, the company claims.

To protect against the impact of magnetic fields, many of Bremont's watches are also fitted with a soft-iron Faraday cage, encasing the movement itself. This routes any harmful magnetic fields safely around the movement.

This focus on engineering and technology reflects the heritage of watchmaking in the UK, according to co-founder Nick English. "Wearing a British watch used to be a real sign of wealth, like turning up to

01 An engineer at the firm's Silverstone manufacturing facility

02 The watches are designed to be 99.998% accurate

03

04

a party in an Aston Martin," he said. "They were beautifully engineered watches."

The company aims to engineer watches of the same quality as these 18th-century timepieces, but produced using modern manufacturing technology, rather than by hand. "That engineering side has always been key for us, because it is a very congested market, so the quality has to be good or you'll never be taken seriously," said English.

Growing up, the two brothers had always enjoyed tinkering with mechanical devices such as cars, aircraft and clocks, alongside their father, Dr Euan English, an ex-RAF pilot. They also took part in air displays together.

But in 1995, when Nick English and his father were flying a WWII Harvard aircraft in practice for one such air display, they were involved in a serious accident. Euan English died, while Nick English broke more than 30 bones.

Six months after the accident, Nick English discharged himself from hospital, and the brothers decided that life was too short to remain in their corporate finance jobs in the city. Instead, they decided to pursue their passion for making mechanical watches.

"So in 2002, we went over to Switzerland and set up a little workshop, to try to understand the workings of the Swiss supply chain and manufacturing and design process, with the aim of trying to bring as much of the process as we could back to the UK," said English.

After five years of "tinkering", the company launched its first watch in 2007.

Initially, the watch cases were built in Switzerland and then hardened in the UK. Today, however, all of the cases and a number of the watch movement parts are made at the company's Silverstone facility.

"Now, if you go to Silverstone, you'll see a bar of metal going in, and a finished case coming out the other side, and then hand-polished," said English.

The company currently machines the cases directly from metal bars produced in Scandinavia, due to their high purity and grain structure, which reduces the need for post-processing. This is likely to change as Bremont's production capacity increases, though, when the company expects to move on to the use of pre-sized and heat-treated blanks to reduce manufacturing times.

Manufacturing the high-end cases is a complex process, so the company has been working closely with machine tool specialists DMG Mori on its CNC milling equipment. Using a DMG Mori Mill/Turn NTX machine, which has precision control and a high-capacity tool storage system to allow for quick transfer between different case designs, the company is able to produce a fully machined case in a single load with no operator intervention, according to Steven Green, operations manager at Bremont.

"Bremont has undertaken a steep learning curve with respect to machining and finishing a product that is not mass-produced within the UK, and is even limited to some key producers within Europe and the rest of the world," he said. "Work holding, tool wear, swarf management: these are all minor issues individually, but all play significant roles when starting to produce cases from scratch, with no previous knowledge apart from the experience of our staff and the support offered by our machine tool partners."

Once through the milling stage, the cases go through specialist machines designed specifically for the company, such as an automated finishing machine built in Switzerland. This gives the cases a brushed, or satin, finish. It is also used on cases that ultimately require a polished finish, to prepare them for final polishing by hand, said Green.

03 The company hopes to eventually move all production to the UK

04 Inside Bremont's Henley workshop

05 Modern manufacturing technology is at the heart of the operation

"Designing a new movement is like designing a new car engine. It is phenomenally difficult and expensive. People are unforgiving – it has got to work beautifully"

Nick English

05

"Cases that require the standard Bremont satin finish only need a small manual pre-operation to prepare them before the machine (processes) them to the required finish using a series of grinding wheels and belts," he said.

"A high-speed, air-driven drilling head is then used to produce the strap fitting holes."

Polished cases, in contrast, undergo two satin and four manual polishing operations to produce the finished article.

The watch cases are all laser engraved with their batch number, and pass through a multi-stage ultrasonic wash operation to remove any residue from previous machining operations that might produce defects when they go through their final polish.

Finally, all the cases are inspected by an internal quality control team, before and after they are coated with the hardening surface treatment in order to improve their scratch and damage resistance.

The movement used in Bremont's watches was designed to the company's requirements in collaboration with Swiss company La Joux-Perret. From this design, the company is now beginning to manufacture some of the movement parts, such as the bridges and base plates, at Silverstone, said English.

"It is like a learning and prototyping stage, as our first step towards manufacturing movement parts in the UK," he said.

Through its partnership with Boeing, Bremont is also working with the Advanced Manufacturing Research Centre at Sheffield University, to harness their expertise in materials and machining technologies.

As part of this collaboration, the company and AMRC's researchers have been exploring ways to minimise machining times on cases and other parts, as well as investigating gear ratios and different types of steel.

For the past few years, Bremont has also been working on a wholly new movement design, which it hopes to complete in 2016.

Ultimately, Bremont hopes to be able to manufacture all of the parts for this new movement in the UK, although this is likely to take some time to achieve, according to English.

"Designing a new movement is like designing a new car engine – it is phenomenally difficult and expensive," he said. "People are fairly unforgiving. You can't have a movement that roughly works – it has got to work beautifully."

If successful, though, the company will truly be able to boast that it has brought watchmaking home to the UK in its entirety.

Precise moves towards a keener, chip-free edge

DMG Mori Lasertec 20 Precision Tool aids special tooling for aerospace. Supplier: DMG Mori

The demand for Polycrystalline Diamond (PCD) cutting tools is growing across industry, particularly for applications involving machining of carbon fibre. And in order to help meet this demand one of the UK specialists in the field, Coventry firm Exactaform recently added a DMG Mori Lasertec 20 Precision Tool to its arsenal.

The firm produces special tooling for aerospace OEMs and Tier One suppliers, and its products have been used on projects including the 787 Dreamliner and the Lightning II. According to director Jamie White the new machine has extended its capabilities from forming the edge profiles to including chip breaker geometry in its PCD tools.

"We carried out trials on several laser machines and we found that the DMG Mori Lasertec 20 Precision Tool was the ideal fit for us," he said. "We can make whatever profile shape we like, simply importing a 2D profile into the software and following a question and answer session to arrive at the CNC programme. We found that the Lasertec 20 Precision Tool produces a keener, chip-free edgeand is slightly faster than the conventional machining methods. However, the possibility of adding a chip breaker on our PCD tips, was the main reason for the investment."

As an example, one of Exactaform's customers was cutting soft aluminium with a carbide tool, where a chip breaker is easy to grind, but moved to PCD once Exactaform was able to supply chip breaker technology.

The machine has a pulsed five-axis laser, is fitted with Celos and the Siemens 840D solution line, and has the capacity for 42 HSK tools ready for automatic loading and cutting with the PH 10|100 linear magazine. Changing workpieces takes 30 seconds or less, and, with Celos, a queue of work can be automated and monitored to give the ultimate in flexibility for single part and low volume production.

Using laser has some significant technical advantages for PCD as it can work through both the diamond and its binding material, which is especially relevant for coarse-grained PCD grades. Erosion cuts only the binding material, while grinding can cause break-out of the diamond grains resulting in a rougher edge, which affects the quality and life of the finished tool.

Furthermore, the production of chip breaker geometry in PCD is straightforward on the Lasertec 20, but impossible with grinding and wire erosion, opening up a huge range of possibilities for Exactaform.

Welding equipment goes up high for hydropower

Construction of pumped storage power plant is taking place deep within a mountain. Supplier: Fronius

Specialist welding equipment supplied by Fronius has played a key role in the construction of a new hydropower plant deep in the Austrian Alps.

Currently under construction at 2,500m above sea level in the southern Austrian state of Carinthia, much of the work on the 430MW pumped storage power plant is taking place deep within a mountain, where over 5km of steel piping have been installed in order to make use of an existing lake.

At the heart of this is an 800m-long pressure shaft lined with 3,963 tonnes of thermomechanical steel with a strength class of 690N/mm². This is the first time this particular metal has been used in Europe. Unlike quenched and tempered steel, this steel has the advantage that it is cheaper to manufacture and can be welded more easily.

However, one of the key challenges was the quality of the weld-seam on the shaft lining. Until recently, plant engineers used a process specially developed for one-sided root passes which, rather than keeping current or voltage constant, adapted the current automatically to the heat requirements of the arc. While this meets the requirements, it's a complex process requiring high levels of experience.

The introduction of Fronius's latest MIG/MAG TPS/i power source enabled Bilfinger VAM Anlagentechnik, the plant-engineering firm responsible for the project, to simplify the welding operation and reduce the number of devices.

In the case of conventional Manual metal arc (MMA) welding, a root seam can be welded at a speed of approximately 9cm/min – provided that it is performed by an experienced welder. Nevertheless, the slag on the inside and outside has to be removed and the weld seam also needs to be ground. TIG welding produces an optimum weld seam appearance, but only allows a low welding speed of approximately 5.5cm/min. With a conventional dip transfer arc the process is much quicker. In a vertical down position, welding can be performed at a rate of up to 25cm/min, although there is a risk of incomplete fusion due to the low-arc pressure and the advancement of the weld pool. This is why a root pass could usually only be welded in a vertical up direction using MAG devices. In order to prevent the weld seam dropping through, welding had to be performed using a lower heat input and at half the speed (approximately 12cm/min).

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Cryogenics on the finishing line

Machining system works on F-35 programme. Supplier: Okuma

Lockheed Martin has acquired an Okuma MA-600HII horizontal machining centre equipped with 5ME's patented cryogenic machining system to perform roughing and finishing operations on large titanium airframe components for the F-35 programme.

Test cuts performed on 6Al4V titanium produced a 52 per cent increase in cutting speeds, while maintaining equal cutter consumption. The tests, using a 5ME solid-carbide cryogenic end mill, also produced improved surface integrity and part quality, as well as reduced white layer. According to Lockheed, cryogenic technology will help lower the cost of large titanium parts by an estimated 30 per cent. The new Okuma HMC with liquid nitrogen-based cryogenic system will operate in Lockheed's Dallas/Fort Worth production facility, and represents the efforts of 5ME, Okuma, Hartwig, and Lockheed Martin.

"The tests we conducted with Lockheed demonstrate the true business advantages of using cryogenic machining for tough-to-cut materials, such as titanium," said Pete Tecos, executive vice-president marketing and product strategy, 5ME. "This has a significant impact on cost savings for initiatives such as the F-35 programme, not only in increased cutting speeds, but also through lower-energy consumption, improved worker safety, and the elimination of the infrastructure and disposal required with flood coolants."

5ME's patented liquid nitrogen-based cryogenic technology allows LN2 to flow through the spindle and inside the tool just below the cutting edge, which provides optimum cooling. The reduction of temperature facilitates faster cutting speeds, which makes liquid nitrogen-based cryogenic machining suitable for tough to machine materials. The system is self-pressurised eliminating the need for pumps and other power-consuming assets. Three options for storage include a vacuum container (or 'dewar') for individual machines, micro-bulk vessels for machining cells and central/external storage for large-scale installations.

To ensure that critical components are not exposed to cryogenic temperatures, the feed system uses vacuum-jacketed insulated lines between the LN2 source and sub-cooler, as well as to the spindle. The system feeds super-cooled liquid nitrogen at a prescribed pressure and flow rate for the specific tool and/or application. The patented sub-cooler removes pressure-generated heat out of the system and condenses dual phase liquid nitrogen back to 100 per cent liquid, preventing the formation of gases from downstream heat leaks and pressure drops.

The integral Cryo Controller allows operators to program the flow rate to match requirements of the application. The patented cryogenic machining system is easily retrofitted to almost any OEM spindle. 5ME's cryogenic tooling is specifically designed for the system and includes holders, turning and grooving tools, solid carbide mills and drills, indexable mills, drills, and boring tools.

America's Cup gets third dimension

Race boat constructed with 3D-printed parts. Supplier: Renishaw

Renishaw has joined Land Rover BAR's Technical Innovation Group (TIG) as an official supplier – joining the quest to bring the America's Cup home to Britain. The company will contribute its expertise in metal 3D printing and position feedback encoding.

The America's Cup is the oldest international trophy in world sport, predating the modern Olympics, the Ryder Cup and the World Cup; and Britain has never won it. It's the world's premier sailboat racing contest, and the 35th edition will be held in Bermuda in 2017, in foiling multi-hulls. Land Rover BAR is the British challenger, and Ben Ainslie, winner of four Olympic gold sailing medals, is the team principal and skipper.

The Land Rover BAR Technical Innovation Group was formed to bring together the best of British talent and industry. The goal is to find advanced technologies and develop them to give the team a competitive edge. The TIG complements the existing Land Rover BAR design team and allows it to rapidly develop, test and prove these technologies.

The TIG has already engaged a number of key partners and suppliers from British industry, including Land Rover, BT and BAE Systems. The TIG is governed by a steering group, chaired by PA Consulting's Dr Phil White, with the BAR team represented by Andy Claughton, Land Rover BAR's chief technology officer.

"As a British engineering company with core skills in precision and performance, combined with expertise in position encoding and metal 3D printing, we are delighted to have the opportunity to make a valuable contribution to the TIG and help Land Rover BAR bring the America's Cup back to Britain," explained Robin Weston, marketing manager of Renishaw.

Renishaw's contribution will be through its expert metal additive manufacturing knowledge, helping to optimise the design and construction of critical, 3D-printed metal parts of the team's race boat. It is also contributing by providing ongoing expert advice on position encoder technology.

Ben Ainslie said: "We don't underestimate the challenge ahead of us. We are a first-time challenger for the America's Cup, and only one challenger has ever won it at the first attempt. We want to leave no stone unturned in our search for new technologies that will help us to bring the cup home. That's why we have developed the Technical Innovation Group and are pleased to have the support of Renishaw with its heritage of over 40 years of breakthrough innovation."

Space Station spin-off

Remote ultrasound technology developed to check up on astronauts is having a major impact back on Earth. Helen Knight reports

Spending long periods of time in space can put a huge strain on the human body, so astronauts need to be carefully monitored for signs of ill health.

But the International Space Station is a very long way from the nearest hospital, so researchers have had to develop imaging technologies that can be operated from Earth, to allow specialists to keep a careful eye on the astronauts during time in orbit.

Now this remote imaging technology is being used to help give people on Earth better access to specialist medical scans. The technology, known as tele-ultrasound, was developed in a series of projects by the European Space Agency (ESA), according to Arnaud Runge, a biomedical engineer at the agency.

"Upcoming long-duration ISS stays and future manned exploration missions will require the use of different medical tools in order to diagnose potential crew health problems," said Runge.

01

01 The TESSA system in action

Consisting of a remotely controlled ultrasound probe, the system was also designed to image astronauts' hearts as part of ESA's research into the effects of microgravity on the cardiovascular system.

The heart can undergo changes to its structure and performance during prolonged periods in microgravity, since it does not have to work as hard. Over time, this may lead to deconditioning and a decrease in the size of the heart, according to the US National Space Biomedical Research Institute.

"Ultrasonography provides medical experts with real-time access to anatomical and functional information about the patient while being non-invasive and harmless," said Runge. "However, its main drawback remains its operator dependence, as skilled personnel are required to capture and interpret dynamic images," he added.

So the TESSA – or Tele-Echography for ESA – system was designed to allow a team of experts on the ground to operate an ultrasound scanner on the ISS or a spacecraft, which can then beam back images of the astronauts' hearts to Earth.

But it is not just astronauts who find themselves a long way from the nearest doctor.

In countries with a large rural population, such as France or Canada for example, patients can be forced to travel tens or even hundreds of miles to reach the nearest medical centre with a specialist radiologist, according to Nicolas Lefebvre, managing director of AdEchoTech based in Vendôme in central France, which has worked with ESA on the technology's development.

"France, like many countries, is suffering from medical 'desertification' issues, meaning we have some small cities and many Department (counties), without any radiologists," said Lefebvre. "This means people are forced to drive 50-100km to find the nearest radiologist."

This may be just an inconvenience for routine scans, but it could be potentially life-threatening in an emergency.

So the company, founded in 2008 by Lefebvre's father, Dr Eric Lefebvre, has developed a terrestrial version **>>**

>> of the tele-ultrasound system, which they have dubbed Melody.

The system allows a specialist radiologist at a large central hospital, for example, to perform remote ultrasound scans on patients at smaller regional medical centres hundreds or even thousands of miles away.

"The Melody system can be used for emergency cases where an ultrasound is needed, for example, for carrying out abdominal, pelvic, obstetric, or gynaecological scans," said Lefebvre.

At the patient site, the technology consists of three components: the ultrasound machine, which works in the same way as a conventional device; the Melody system itself, in the form of an ultrasound probe that is attached to a robotic arm; and a video-conferencing system.

This video-conferencing system is then linked via an internet connection to the radiologist's location. "On the expert's site you will find the same video-conferencing system, to allow the radiologist to see and speak to their patient, and also to speak to the technician holding the robotic system over the patient's body," said Lefebvre.

This technician could be a nurse or other member of the medical team, as the system is designed to be guided by someone without specialist radiology skills, he said.

Also at the radiologist's location is a computer interface to allow them to view the ultrasound images in real-time, and to remotely operate the Melody system. The radiologist can control all of the settings on the system, allowing them to change parameters such as the frequency of the ultrasound, for example, to improve the amount of detail in the image, said Lefebvre.

Finally, a joystick with three degrees of freedom, which was designed by radiologists to very closely resemble the probes used to carry out a conventional ultrasound, allows the specialist to move the robotic arm over the patient's body.

A patient requiring an ultrasound scan of their unborn baby, for example, would lie on the hospital bed, with the nurse or other technician positioning the robotic arm over their body. The patient can discuss their concerns with the remote radiologist via the video conferencing link, and the specialist would then use the joystick to move the ultrasound probe attached to the robotic arm over their body.


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"The Melody system can be used for those emergency cases where an ultrasound is needed, for example, for abdominal scans"

Nicolas Lefebvre, AdEchoTech

02 Experts can remotely operate the equipment

03 The technology was developed to monitor astronauts aboard the ISS

The company has already sold the system to more than 15 hospitals and health institutes in France and elsewhere, with other centres taking part in trials.

It could be used in any remote location, including prisons, islands, and ships, or to provide medical assistance following a natural disaster, using either an internet or satellite link.

ESA also recently completed a trial of the technology with four European defence ministries, making it available to military garrisons based in Lebanon and Afghanistan.

The technology has also been tested successfully on oil platforms off the coast of West Africa, and at inland medical clinics in French Guiana.

To develop the system further, AdEchoTech and ESA are also working together on a new generation of the technology, for both space and terrestrial applications, said Lefebvre.

"We are currently working on a third-generation system for echocardiography in space," he said. "The idea is to reduce the size and weight [of the robotic arm] using new technology, but to have the same specifications."

If successful, the new system could make it even easier for specialists to monitor the health of astronauts, and those of us on Earth, even from thousands of kilometres away.


03

In motion for ultrasound breast-screening system

Nine-axis scanning arm motion system includes elevating scanning frame. Supplier: LG Motion

UK motion control specialist LG Motion has made a major contribution to the development of a novel ultrasound breast-screening system claimed to be safer and lower cost than existing technologies.

Developed through funding from Innovate UK, the new technique, known as ultrasound computed tomography (UCT), has promising potential to overcome the problems of diagnosing breast disease using conventional X-ray mammography and ultrasound scans.

The system is underpinned by work carried out by project leader the National Physical Laboratory (NPL) on the optimisation of pyroelectric sensors. These employ a patented detection method that converts ultrasonic energy into heat; generating electrical signals that are processed to form an ultrasound image.

LG Motion's contribution to the project is a nine-axis scanning-arm motion system, including an elevating scanning frame. This motion system, which is submerged in a water tank, positions and rotates an ultrasound transmitter and receiver array around the breast with the resulting scan processed through tomographic reconstruction to build a 3D image of the tissue characteristics. The system is based on LG's durable and submersible Unislide positioning elements, and is a combination of manual and motorised elements.

A handwheel-driven dual-axis linear positioner that shares two moving table tops on the same linear bearing is used to pre-positon the separate ultrasound transmitter and receiver that are each mounted on vertical motorised axes. To finely pre-align the array the transmitter stage positioner includes a horizontal cross axis while the receiver positioner stage also supports a custom-designed motorised tilt axis with a 30° range, which is continuously adjusted in-situ to maintain a perpendicular geometry for the sensor. A separate motorised scissor jack vertically positions a special electromagnetic locator tool that senses and references the position of a fundamental component used in the UCT scanning process. The complete assembly is mounted on a stepper-motorised precision-grade rotary table with additional sealing and IP68 protection. The basic scanning procedure comprises a scan-step sequence

rotating the complete assembly through +/- 180° while extending the sensor array vertically, in small increments up to 120mm. The overall positioning repeatability of the complete scanning arm is within 0.05mm.

A 19in subrack motion control and drive system powers the motorised elements of the scanning arm, which has a total of six stepper-motorised axes. Its combination of 3A and 8A microstepping drives and two four-axis PMS series motion controllers, from LG Motion's US distribution partner Arcus Technology, allow NPL to program motion sequence and synchronisation routines using the powerful controller's BASIC-like standalone programming language that is networked with their own host control system through a 10Mbps Ethernet communication link. The PMS controller was selected to allow NPL flexibility to accommodate potential future motion-control upgrades – for instance, adding encoders for position feedback or high-speed registration or synchronisation of position moves and I/O.

All of the positioning elements are contained in a water tank with approximate dimensions of 500mm^3, which required the motion system to be fairly compact. Cable management for motors, stage overtravel limits and home switches allow adequate flexibility so as not to drag the mechanics during scanning.

A breathy alternative to blood tests for ammonia

Breath sensor uses polyaniline — an electricity-conducting polymer formed into nanoparticles

Image: UWE Bristol

A new breath sensor for testing ammonia could reduce the need for certain patients to take blood tests, including those with liver conditions such as cirrhosis and hepatitis.

The device, known as AmBeR, was developed by Prof Tony Killard from the University of the West of England (UWE Bristol). It came about while he was investigating new nanotechnology sensor materials. AmBeR uses polyaniline, an electricity-conducting polymer that Killard formed into nanoparticles. He discovered that this made the material extremely sensitive, and it could also be deposited in layers just thousandths of a millimetre thick using low-cost printing technology.

"That was kind of the eureka moment," said Killard, head of biomedical sciences at UWE Bristol. "What we had was a cluster of new characteristics which allowed us to do new things we couldn't do before. Previously, this material [polyaniline] was just a laboratory curiosity to scientists and you would play around with this stuff."

According to Killard, the device could have a significant impact for those who need to test regularly for ammonia levels. The technology will deliver pain-free testing with greater accuracy than many alternatives, while also allowing more frequent monitoring and ultimately even self-testing at home.

"No one has been able to do ammonia breath testing in a way that is accurate without using a large piece of equipment," he said. "There are instruments in existence which can do it but they are not economically viable. The AmBeR device will be more like glucose testing strips where you use the sensor test strip once and throw it away when finished. We are trying to make this a game-changer commercially."

A company called BreathDX has been set up in order to further develop the project and explore commercial opportunities. The device is currently in production and will undergo clinical studies in May. Killard said the technology could be used to measure trace breath gases for other diseases, including, potentially, diabetes.

Mapping the trends as show time nears

Exhibitors consider key industry market trends and expectations before MACH 2016 – a showcase for manufacturing technology improvement

Engineering manufacturing faces a tricky year, with the oil and gas crisis, overall manufacturing output and exports down (January ONS figures) and the EU referendum uncertainty hanging over industries such as aerospace and automotive. Exhibitors at MACH 2016 – the busiest show for many years – are in a generally positive mood, with some caveats.

The main factors that drive manufacturing technology improvement – accuracy, speed and productivity, tool wear and lower cost – do not change. At MACH, the UK's biggest such technology showcase, what changes is the application improvements, and occasional brand-new technologies, that are demonstrated at the NEC every two years.

Exhibitors from five different technology classes explained to us current market conditions and trends, and their expectations for MACH 2016.

Machine tools

NCMT – stand 5310
Dave Burley, managing director

"So far this year the UK market has been tough. The downturn in oil and gas has had a knock-on effect into some of the general engineering areas, and we have a downturn. However, to balance that, we've seen an increase in strength in the aerospace business, where NCMT does particularly well – about 65 per cent of our machine tools business is aerospace.

"For MACH, this is a concern because we will probably see this drop-off reflected in the numbers [of visitors] at MACH. We are focusing fully on our core product, Okuma and Makino machines, and introducing new technologies from both companies for MACH and bringing them to the UK market. For Makino, we are known for our large aerospace profilers and Viper grinders for engine components – people won't know us as well for our EDM product [wire electrical discharge machine]. We are reintroducing those products, with more technical support and have two machines at MACH that will feature this EDM technology. We are recruiting new people, sales and applications, to support this and increase this side of the business. For Okuma we are ramping up the branding at MACH, which reflects Okuma's activities globally to present a united look.

"Generally in the market, we are seeing more five-axis, multi-function machines being purchased. The dividing line between what is a lathe and a machining centre is totally blurred now – the big growth of this hybrid machine that does not sit in either camp as they used to. We are also focusing more on EDM because we see growth of die moulding in the UK, where some work is being repatriated from low-cost economies."

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"External market factors have slowed the market for machine tools"

01 Makino machines are a core product for NCMT

02 XYZ Machine Tools' 2-OP vertical machining centre

XYZ Machine Tools – stand 5661
Nigel Atherton, managing director

"External market forces, such as the debate around Brexit and the decline in investment in the oil and gas sector due to the fall in crude prices have slowed the market for machine tools slightly. That said, we are expecting MACH to be a very positive event for XYZ Machine Tools, an assumption based on other exhibitions we have attended this year, such as Southern Manufacturing Show, where we saw a 20 per cent increase in enquiries over the previous year. With MACH proving to be popular with visitors and exhibitors in 2016 we look forward to reporting similar figures when the show closes.

"As in 2014 we will have a 204m^2 stand [5661 Hall 5] with 20 machines on display… All of the machines on show will feature the new XYZ livery and upgrades and we are anticipating MACH 2016 to continue the consistent positive growth trend that we have witnessed since achieving our best year ever at MACH 2010."

Tooling

WNT – stand 5641
Tony Pennington, managing director

In the tooling market, WNT's Tony Pennington said that dry machining is becoming more popular, for several reasons. "There is the cost to purchase and dispose of coolant, and the associated potential health risks caused by atomisation of coolant as machines and tools run at ever higher speeds." Also, he added that modern coatings are designed to be super-hard and wear resistant, and provide a heat shield to the carbide substrate to meet the requirements of dry machining. This permits the use of tougher carbide substrate so the tools are less brittle than they have been.

"We are also seeing more and more high-tech materials being machined, heat-resistant alloys, titanium, carbon fibre, aluminium alloys and so on, so tooling is evolving to meet the requirements of these materials.

"The current market situation in the UK and Ireland is being adversely affected by the oil and gas, and heavy-industry sectors, but all other sectors are performing well."

And there are positive signs that even in those sectors that are down that things are starting to pick up, with necessary maintenance and replacement work still needed by the end-user.


03

"MACH is our industry's biggest exhibition and gives all suppliers the chance to show their latest innovations in technology, products and technical support. For WNT at MACH 2016 that means 1,000 new products in our 2016 catalogue with the latest cutting-tool technology and our brand-new vending solution that will be launched at MACH.

"For visitors they get to see everything the industry suppliers have to offer in one day, to help them gain a competitive advantage going forward."

Metal profiling

KERF Developments – stand 4466
Craig Walsh, sales director


04

MACH 2016 is where Rochdale-based Kerf Developments (stand number 4466) will launch its new Plasmaster 3015 cutting machine. Described as an entry-level plasma cutting machine, it is built using high-grade components and offers a good entry point for companies looking to start profiling their own components. "The flexible design of the machine makes it ideal for a wide range of applications and can be configured to cut materials from 1mm through to 25mm if required," said sales director Craig Walsh.

There is also a Kerf RUR 2500p high-definition plasma on show, currently the company's best-selling plasma-cutting machine that uses the UltraSharp process, and new exhibits that cover Kerf Developments' range of three-, four- and five-axis cutting technology using oxy-fuel, plasma and waterjet processes.

"Throughout 2015 Kerf has seen significant level of interest for its UltraSharp cutting process particularly for structural applications where bolt ready holes and slots help to significantly reduce production costs," said Walsh. "The speed and power that modern high-definition UltraSharp plasma systems offer make them a highly cost-effective alternative for laser users who need to cut thicker materials."

Walsh added that the attraction of plasma is cost. While laser cutters are known for speed, a good laser can cost £500,000 or more. "A Kerf UltraSharp plasma costs a fraction of that at around £90,000 for a good-quality machine."

CADCAM

Delcam – stand 4011
Bart Simpson, senior director

CAD/CAM software is essential in the evergreen automotive and aerospace markets, so could be seen as being better insulated from external factors that affect other engineering sectors.

"The state of the UK CADCAM market is still promising this year, particularly in the aerospace and automotive sectors. Confidence in these areas should be buoyed by ONS figures reporting record levels of output in the fourth quarter of 2015 for both automotive and aerospace. It is clear these sectors are set to continue to grow, representing a growing opportunity for CADCAM in the UK for 2016.

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"[For MACH] we are looking forward to meeting both new and existing customers at MACH to demonstrate our latest product developments, including FeatureCAM and our extended range of manufacturing software.

"At MACH 2014, our engineers carried out over 250 demonstrations on the stand and we closed a significant number of sales. We're looking to achieve similar results this year. MACH also provides an opportunity to reinforce our relationships with machine-tool and cutting-tool suppliers, which help us to provide a better service."

Additive manufacturing

EOS UK – stand 4861
Stuart Jackson, managing director

EOS's Stuart Jackson is a little perplexed by the UK additive manufacturing (AM) market. Britain has a lot of AM expertise, he says, especially in research and development but the translation of this into factories is very slow. "Additive manufacturing has been really strong but at the moment industry is struggling to translate it as an upscale, productionised technology."

EOS supplies polymer and metal powder AM machines and currently has 15 metal machines installed in the UK. Industries such as aerospace and automotive are using AM machines discreetly but not at mass scale, and yet the technology is viable at this scale. "We are well positioned to do the end-of-line work because we have all the knowledge here, and have in fact educated many other countries and companies in additive manufacturing… I struggle to find an aerospace site in the UK that sees AM as a production technology, and yet it happens in other countries."

He added: "We want to engage in the broader manufacturing zone – we like MACH because it's a chance to merge AM with subtractive manufacturing."

03 WNT will be showing the latest cutting tool technology

04 Kerf will launch a new plasma cutting machine

05 Delcam is demonstrating a range of product development

Driven in pursuit of new talent

The UK automotive industry is undergoing a huge renaissance, with talented engineers urgently needed across the board. Evelyn Adams reports

The UK automotive industry has seen a dramatic revival since the recession. Last year was the best year in a decade for car production with 1.59 million vehicles and 2.4 million engines built. The growth has helped sustain around 800,000 jobs with more than 40 companies making cars in the UK. And that trend is set to continue. By 2020, production volumes are expected to reach a record two million.

Major companies are already investing heavily in the UK. At the end of February, Aston Martin, announced that St Athan in Glamorgan, Wales, will becoming a major hub for manufacturing its DBX crossover vehicle. Production of the all-electric RapidE is also to be located at Gaydon, starting in 2018. Aston Martin claims both these moves will create up to 1,000 new jobs in the UK between now and 2020.

But the automotive industry is struggling to recruit enough engineers to keep up with demand. During the recession, more than 100,000 people left the industry through voluntary severance, retirement or redundancy. Many of these experienced engineers have not returned, leaving a huge skills gap. According to a recent report by the Automotive Council, the industry is having difficulty filling 5,000 vacancies, causing a major impact on business.

"Skills are a major contributor to productivity and as a nation we are not doing well enough," Nick Boles, minister of state for skills, said in an introduction to the report. "We must raise our game, in areas ranging from basic skills to high-level technical and engineering capability. Employers have a central role to play in this."

The report, which was developed by automotive industry consultants SMMT Industry Forum, asked a range of British-based automotive firms to identify the areas of employment most difficult to recruit. Around 19 per cent of the unfilled vacancies cited in the report are identified as "critical" and having a significant impact on company operations. Of the top 10 job types for which recruitment is most difficult, the majority are in engineering – with the top two in-demand roles being design and production engineers.

The knock-on effect is that companies are hiring temporary contractors and increasingly recruiting from abroad. "These are very significant findings that present a valuable basis for government and industry to jointly tackle this issue head-on and ensure that the growth potential of the industry in the coming years is fulfilled," said Jo Lopes, head of technical excellence, Jaguar Land Rover. "The Automotive Industrial Partnership has already made some important steps, including the introduction of a range of training programmes."

As competition heats up with electric cars, and work progresses on self-driving vehicles, the type of skills needed in the industry are changing. For instance, the report highlights a need for mechanical, electrical and

01

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Top10

The most needed jobs in the UK automotive sector

1 Design engineer
2 Production engineer
3 Buyer
4 Senior design engineer
5 Maintenance technician
6 Programme manager
7 Quality operations engineer
8 Manufacturing team leader
9 Programme engineer
10 Quality operation technician

03

electronics production engineers. Overall, 71 different types of learning are required for more than 20,000 people working in the industry – 15 per cent of whom have an immediate need for new training. The industry is working together to create training programmes that can address this.

One example is the Maintenance Upskilling programme, which has been developed by companies across the automotive industry. The course provides a 13-week conversion programme that allows electricians in other industries to transfer their skills over to automotive. Alongside this, a Trailblazer apprenticeship training programme has been developed in mechatronics for future recruitment into this area.

Meanwhile, government initiatives such as Make it in Great Britain and See Inside Manufacturing are aiming to transform outdated opinions of modern manufacturing by giving potential engineers an inside look at some of the country's world-class automotive facilities. And the Automotive Industrial Partnership has developed a 'jobs framework' – an industry standard hierarchy of roles – to make it easier for companies to structure positions and for employees to follow clear career development paths.

"Our automotive workforce is the most productive in Europe and this goes a long way to explaining why production hit record levels last year," said skills minister Nick Boles. "[But] we cannot be complacent. The sector needs to maintain its high productivity and international competitiveness, and address the required demand of skilled workforce, engineers and designers. That's why our apprenticeship reforms are putting employers in the driving seat, to deliver the high-tech, long-term skills our economy needs."

Nick Carter has worked as an apprentice at Aston Martin's Gaydon factory, and said the hands-on skills he learned have been invaluable in getting ahead in the industry. "Here, I have learnt the practical skills of interior trim development, a limited skill set in this country," he added. "In an engineering environment there is a need for communication, especially when working cross-functionally with other departments. The apprenticeship scheme has helped build my confidence and communication skills inside and out of work."

But Mike Hawes, Society of Motor Manufacturers and Traders (SMMT) chief executive, believes more such initiatives should be rolled out across the sector. "The automotive industry has already invested heavily in apprenticeships and training for existing staff to grow and develop a new generation of skilled worker. However, even more support is needed. The struggle to fill vacancies is holding back growth and opportunities for business, and it is essential that both government and industry work together quickly to identify ways to plug this gap."

For now, many companies enjoying the automotive renaissance in the UK are attempting to keep up with demand by recruiting temporary contractors. But with huge investment going into training programmes in the coming years, the workforce could change dramatically. If these programmes are successful, future engineers in the UK could become a formidable manufacturing force.

"Skills are a major contributor to productivity and as a nation we are not doing well enough"

Nick Boles, minister of state for skills

01 The Aston Martin DBX

02 The DBX will be made at a new facility in St Athan, south Wales

03 The rise of driverless cars is changing industry's skill needs

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Mar 1861

Chunnel visions

Plans to connect the UK to the European mainland have been around since the 19th century

Come June 23, the UK could well find its ties with Europe diminishing in the wake of the Brexit referendum. This island nation's relationship with the continental mainland has always been fraught, and conflict between the major powers has punctuated European history, from the Spanish Armada and Napoleon to the Great War and the rise of fascism.

Despite – or perhaps because of – this almost ever-present tension, plans to connect the UK to mainland Europe have been around for centuries. In March 1876, *The Engineer* compiled an extensive round-up of concepts from the time, including tunnels, tubes and bridges. But according to that same edition, proposals to create a link between Britain and France go much further back.

"The first proposition to unite England and France was made in 1802 by Monsieur Mathieu," wrote our predecessors, "whose plans were laid before the First Napoleon, then First Consul, and were afterwards exhibited at the Luxembourg and public galleries in Paris. They have, however, long since been lost, and with them the proposed method of carrying out the work".

Another Frenchman is singled out for praise for his lifelong dedication to the project. Thomé de Gamond, known today as the 'father of the tunnel', died in 1876, just a month before the article's publication. He devoted more than 40 years of his engineering career to researching a tunnel under the Straits of Dover, his "scientific attainments" and "irreproachable character" winning him "the love of many and the regard of all."

De Gamond made more than 1,500 experimental borings in France and England to examine the strata, as well as carrying out three dives to the bottom of the channel to examine its bed. The last of these saw him "attacked by conger eels or dogfish", resulting in serious injuries. Although he didn't get to witness his vision become reality, de Gamond did live to see his ideas "adopted by eminent engineers in both countries, and supported by financial authorities".

Those eminent engineers would include Sir John Hawkshaw and Sir James Brunlees, founders of the original Channel Tunnel Company in 1872. They proposed a tunnel of 31 miles between St Margaret's Bay in England to a point roughly midway between Calais and Sangatte. This line was chosen to take the tunnel entirely through the lower chalk, assumed at the time to be homogenous. Although a serious challenge, it was technically possible, according to *The Engineer*.

"For the execution of the work, as far as mechanical aid is concerned, there need be no apprehension, there now being ample means in the way of tunnelling machinery, and ample experience in its extensive use," it reported.

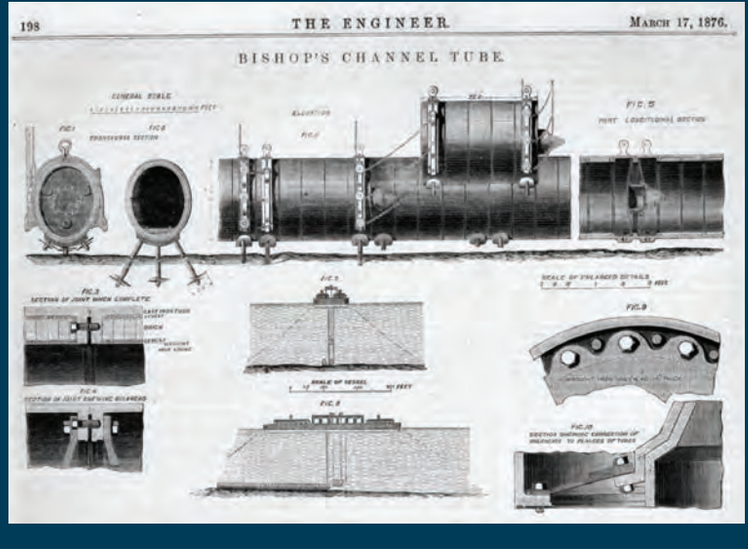
"The tunnel will be a single one of circular or of the ordinary tunnel section, the chalk boring being 36ft in diameter at the arch springing, and when lined with brickwork in cement it will have an interior diameter of 30ft."

Our predecessors declared that "preliminary operations will shortly be commenced", but we, of course, know that the endeavour would never be attempted, and the Channel Tunnel would not be completed until over a century later.

Another intriguing concept from the time was Bishop's Channel Tube, a railway tube that sat on top of the seabed rather than boring beneath it. Sections of cast iron lined with bricks and cement, each measuring 25ft and weighing 273 tons, would be lowered to the seabed from a floating pontoon 400ft long by 100ft wide.

Workers on the pontoon would be in electronic communication with those working in the slowly advancing tube. Using glass sight-holes in the tube's bulkhead, the workers could help guide the iron sections into position. The structure would be protected from the "injurious" effects of the seawater through the application of Calley's Torbay oxide paint. It was an innovative approach, but probably not one that would've passed EU health and safety checks of today. A reminder, perhaps, that Brussels has given rise to good ideas as well as bad. **AW**

"There need be no apprehension, there now being ample means in the way of tunnelling machinery"
The Engineer


198 THE ENGINEER. MARCH 17, 1876.
BISHOP'S CHANNEL TUBE.

The Bishop's Channel Tunnel Tube, made from cast-iron sections lined with bricks and cement, was designed to sit on the seabed's surface

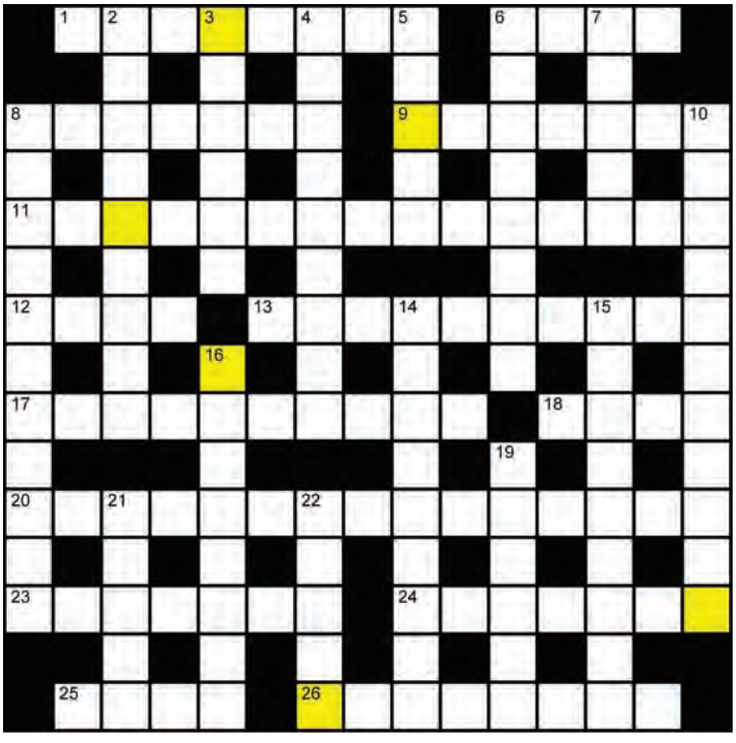
Word of the issue

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

Metric, self-tappers, BA, and that old favourite whitworth are just four of the many threads to have enabled us to assemble everything from the abacus to the zither. It may come as a surprise to find it used in the engineering sense as early as 1670. This is not very much later than the 14th century record of the sense 'needle and thread'. Regular readers will not be surprised to learn both uses ultimately come from the same source. In England we find the Saxon thraed meaning 'fine, twisted cord' as the earliest reference. While we would view the thread as a cut spiral furrow in a screw, originally the thread described the ridged spiral – hence our ancestors looked at what is present, while we tend to do quite the opposite. Viewing the twisting spiral of the ridge, it is easy to see how it was seen as similar to the twists of twine, cord and so on, and traceable back to Proto-Indo-European tere meaning simply 'to rub by turning'.

Big picture

The latest incarnation of Atlas from Boston Dynamics is electrically powered and hydraulically actuated, using sensors in its body and legs to balance, and LIDAR and stereo sensors in its head to avoid obstacles, assess the terrain, help with navigation and manipulate objects.



Prize crossword

When completed rearrange the highlighted squares to spell out a bond used in masonry. The first correct answer received will win a £20 Amazon voucher. Email your answer to **jon.excell@centaur.co.uk**

Across

1 Turn from an upright position (8)
6 Tapering shape whose base is a circle (4)
8 Produced by the action of intense heat (7)
9 Electric current is proportional to voltage and resistance (4,3)
11 Cover against loss due to illness (6,9)
12 Heat to change from a liquid to vapour (4)
13 Where no progress can be made (10)
17 Compacted tightly (6,4)
18 Someone dazzlingly skilled in any field (4)
20 Serial execution of computer programs (5,10)
23 Tiresomely long (7)
24 Material used to form a hard coating on a porous surface (7)
25 Material effigy that is worshipped (4)
26 Materials that remain after something has been removed (8)

Down

2 Wilful damage to property (9)
3 Shelters with perches for birds (6)
4 Very generous (9)
5 Interior angles formed by two meeting walls (5)
6 Squeeze or press together (8)
7 A thermoplastic polyamide (5)
8 Fit for living in (11)
10 One who makes and repairs frames with spokes (11)
14 Current affairs programmes (9)
15 Having many complexly arranged elements (9)
16 Light volatile flammable poisonous liquid (8)
19 Land mass that is surrounded by water (6)
21 Grooved surface of a pneumatic tyre (5)
22 Measuring stick (5)

February's highlighted solution was pavement. Winner: **Carl King**

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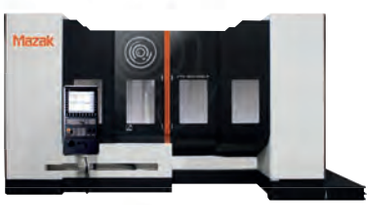

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