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Capture attention



Until relatively recently, carbon capture and storage (CCS) was regarded as a fringe technology: one of a number of low-carbon concepts that had more than its fair share of evangelists, but was decades away from being taken as seriously as many claimed it should be.

That has now changed, and as we report in this issue's cover story ('Super Store', page 22), after decades of inaction fossil fuel giants are now getting behind the suite of processes

that can prevent CO₂ from entering the atmosphere by capturing it at source and storing it deep beneath the ground.

It's hardly surprising really. If we want to continue burning fossil fuels without tipping the planet into oblivion we need CCS, and the industry therefore can't survive without it.

Of course, some will argue that the climate science is wrong, that CCS is completely unnecessary and that industry backing for the technology amounts to little more than a PR offensive aimed at derailing the divestment campaign that has gathered momentum in recent months.

Others will suggest that CCS is a harmful and expensive distraction, that the technology will never be deployed on a scale large enough to make a difference and that, rather than finding ways to prop up our fossil fuel use, we should simply stop, and invest the money in energy technologies that aren't underpinned by hydrocarbons.

But industry's growing acceptance of the importance of the technology is nevertheless, we would argue, to be welcomed.

CCS might give us the space to get used to the idea of a zero-carbon future

Mankind isn't done with fossil fuels yet. The reality is that whatever the scenario, however dire the predictions and real-time climate observations, we're going to take more time than we've really got to wean ourselves off oil, gas and coal. CCS might buy us this time, and give us the space to

get used to the idea of a truly zero-carbon future.

Finally, on a less apocalyptic note, a shout out for this issue's other main feature, which contains the startling and bizarre revelation that "no starfish has ever tried to lift a pumpkin". Intrigued? You should be. And if you want to find out what on Earth I am talking about, turn to page 27 and read our report on the emerging field of soft robotics.

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ELECTRONICS

Remote has a mind of its own

BBC device could enable people to control TVs using brainwaves

BY HELEN KNIGHT

It's a lazy Sunday afternoon, and you are catching up with your favourite television shows on BBC iPlayer. But you are just too tired to get up and find the remote control. So why not use your brainwaves to switch programmes instead?

That could one day be possible, following experiments carried out by the BBC to investigate the use of technology that allows people to control their televisions with only their brainwaves.

The mind control technology could ultimately give people with severe disabilities, motor neurone disease or locked-in syndrome the ability to control digital media by thought alone, according to Cyrus Saihan, head of business development at BBC Digital.

"For anybody who can't use standard remote controls for any reason, this technology has the potential to open up this completely new world of digital content that you and I may take for granted," he said.

The technology could also allow able-bodied people to access television programmes much more quickly and easily, he said. "This is building on work we have done using voice control on consoles such as the Xbox One, for example, to get to content as quickly and easily as possible."

Working with London-based company This Place, the BBC developed a prototype mind control television using a low-cost headset equipped with sensors that measure electrical activity in the brain.

The electroencephalography (EEG) brainwave-reading headset has a sensor that rests on the user's forehead, and another on a clip that attaches to the ear.

The user can choose to operate the device in either 'concentration' or 'meditation' mode. If they choose meditation, the headset and app monitor their level of relaxation, which is displayed on a volume bar on the side of the screen. "Then, when a certain threshold is

reached for that type of electrical activity, it sends a signal to the device on our tablet, which in turn sends a signal to the television," said Saihan.

During the experiment, 10 users were given a headset to wear, and sat in front of the television. The users either concentrated hard or relaxed their brain until the volume bar showed the threshold had been reached, at which point a signal was sent to the television to open the application, an experimental form of iPlayer.

The users were then presented with a screen showing the five most popular programmes on iPlayer at that time. Each programme was highlighted, in turn, for 10 seconds. To select a programme, the users waited until the show was highlighted, and then relaxed until the volume bar again reached the necessary threshold.

Some users taking part in the experiment found the technology easier to use than others. A few were able to pick up the technique immediately and begin watching programmes, while others found it harder to time their levels of meditation with the 10 seconds in which their chosen programme was highlighted, for example.

The technology is still at a very early stage, and currently only allows users to select either 'on' or 'off', explained Saihan. Whether the idea takes off will ultimately depend on how the technology evolves over the coming years, including both the sensors and neuroscientists' understanding of brain activity, he said. "It's very early stages in terms of this type of technology, so [this experiment] was very much a toe in the water for us," Saihan added.

The system is an internal BBC prototype, designed to give the organisation's programme makers, technologists and other users an idea of how the technology might be used in the future.

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AUTOMOTIVE

Riding to victory

Parker Hannifin-powered bike achieves podium finish at TT Zero



Road racer
and presenter
Guy Martin

BY HELEN KNIGHT

A prototype electric motorcycle powered by a motor developed by Parker Hannifin has taken third place on the podium at this year's SES TT Zero Challenge on the Isle of Man.

The TT Zero event, established in 2010, is a race for motorcycles powered without the use of carbon-based fuels.

The Victory Racing team's prototype bikes, ridden by 'General' Lee Johnston and road racer and television presenter Guy Martin, took third and fourth spot respectively in the all-electric race.

The prototype electric motorbikes, powered by Parker Hannifin's Global Vehicle Motor (GVM) PMAC

electric motors, weigh just 220kg each, and are capable of average lap speeds approaching 120mph.

Despite measuring just 8in in diameter and 5in long, the GVM motor can deliver 175hp, and has an efficiency of 97 per cent.

To develop a device that could generate a large amount of torque, and therefore power, for its size, the company designed a 12-pole motor, referring to the number of sets of north-south electromagnetic poles formed by the magnetic windings. The more poles a motor has, the greater its torque will be.

"Victory actually had the power turned down on the Zero bikes," said Kevin Holloway, the US strategic account manager for vehicle electrification at Parker Hannifin. "The motor was capable of more power, but there's only so much onboard energy the motorcycle has; therefore you have to ration the amount of energy in order to complete the course," he said.

The electromagnetic windings used in the stator also incorporate very short end turns, to increase the efficiency of the motor by reducing heat loss, according to Holloway. "These end turns are where a large amount of heat is lost in the winding, leading to inefficiency," he said. "The short end turn design reduces the winding resistance and in several types of vehicles has led to a 30 per cent increase in range – all with the same-size battery pack."

That is particularly significant since batteries are still the most expensive part of electric and hybrid vehicles, Holloway added.

The GVM motors also use a water-based internal cooling system, as water extracts more heat than oil.

"Our system is designed to reside within the motor diameter, rather than creating a jacket around it," said Holloway. "The smaller volume achieved means that the motor has a higher power density."

The technology is already being used in hybrid vehicles. The high power produced by the motor allows the onboard combustion engine to be used for battery charging, resulting in a smaller engine and greater energy efficiency.

inbrief

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Winds of change

The government is to end new public subsidies for onshore wind farms by legislating to close the Renewables Obligation across the UK to new onshore wind-generating stations from 1 April 2016. Up to 5.2GW of onshore wind capacity could be eligible for grace periods, which the government is prepared to offer to projects with planning consent, a grid connection offer and acceptance, plus evidence of land rights.

Track performance

WSP Parsons Brinckerhoff is to provide engineering consultancy and infrastructure planning services at Old Oak Common for the interchange station between the Great Western Main Line/Crossrail and HS2. The company will undertake an early-phase study to investigate the realignment of the existing tracks to create space for construction of a new station as part of the plan to allow easy rail interchanges.

Engine room

Rolls-Royce and Liebherr-Aerospace are establishing a joint venture to develop manufacturing capability and capacity for the power gearbox of Rolls-Royce's new UltraFan engine. The geared UltraFan is based on technology that could be in service from 2025, offering a minimum 25 per cent improvement in fuel burn compared with first-generation Trent engines.

Driving expansion

Nissan has announced a £37m investment in its Sunderland manufacturing plant. The investment will see the plant extended and a 5,200-tonne press installed, supporting UK production of the firm's Qashqai and Juke crossovers, the Note and the all-electric LEAF. Going into production in 2017, the new press line and panel storage area requires a building extension totalling 6,780m².

MATERIALS

Favourable spin

Electrospun coatings could protect health-promoting ingredients

BY HELEN KNIGHT

Spinning a protective coating around health-promoting ingredients such as probiotics and vitamins could help shield them from the harsh conditions inside the human body.

So-called functional ingredients, such as probiotics, prebiotics and stanols and sterols, are increasingly being added to foods to boost the immune system or lower cholesterol.

However, protecting these sensitive materials as they pass through the upper gastrointestinal tract and ensuring they are delivered safely to their target site within the

body is no easy task, said Dr Nick Tucker of the School of Engineering at the University of Lincoln.

Researchers have investigated various methods for encapsulating the materials inside a protective casing, but many processes, such as spray drying, are too harsh, and can damage the structure of the molecules, or harm the bacteria.

Instead, Tucker and his team at the Research Institute of Food Science and Technology in Iran have been investigating the use of electrospinning to encapsulate the materials. In electrospinning,

a solution is drawn through an electrically charged hollow needle onto a grounded target. As the solution is drawn towards the target, it stretches out into a very fine fibre.

Electrospinning can be done at room temperature and so is less harsh on sensitive materials, Tucker said.

In a paper in the journal *Food Hydrocolloids*, the researchers review the process and its potential for producing nanofibres suitable for use in foods. They hope to collaborate with industrial partners to develop electrospun nanofibres for food and other applications.



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JLR intends to use an onboard computer to analyse the data

AUTOMOTIVE

JLR concentrates on vehicle safety

Mind Sense research project monitors driver brainwaves to check alertness

BY ANDREW WADE

Jaguar Land Rover (JLR) has unveiled a new research project named Mind Sense that is exploring the possibility of using brainwaves to gauge driver concentration and improve vehicle safety.

At a technology showcase at the company's Gaydon test centre, JLR explained how it hopes to monitor brain activity through steering wheel sensors, using an onboard computer to analyse the data.

"One key piece of new research is to see how we could measure brainwaves to monitor if the driver is alert and concentrating on driving," explained Dr Wolfgang Epple, Jaguar Land Rover director of Research and Technology.

"Even if the eyes are on the road, a lack of concentration or a daydream will mean the driver isn't paying attention to the driving task."

Human brains continually produce four or more distinct types of brainwaves that operate at different frequencies.

During daydreaming, theta waves are dominant, and by monitoring their prevalence JLR believes it will be able to detect when driver concentration is waning.

Traditionally, monitoring brainwaves has been performed using sensors placed on the

head, but JLR is experimenting with sensors in the steering wheel that use algorithms to amplify the signal and filter out the brainwave from background noise.

It is a method used by NASA and the US bobsleigh team to develop concentration in pilots and athletes.

According to JLR, it is working with neuroscientists to verify the results of the research, as well as to establish how accurate measurements from the hands actually are.

The Whitley-based company is also exploring a number of methods that could be employed to warn drivers that their attention was drifting from the road.

If a loss of concentration was detected, for example, haptic feedback could be given through the vehicle controls, prompting the driver to react.

"If brain activity indicates a daydream or poor concentration, then the steering wheel or pedals could vibrate to raise the driver's awareness and re-engage them with driving," said Epple.

He added: "If Mind Sense does not detect a surge in brain activity following the car displaying a warning icon or sound, then it could display it again, or communicate with the driver in a different way, to ensure the driver is made aware of a potential hazard."

MATERIALS

Gathering material

New technique from Oxford University produces high-quality sheets of graphene

BY BEN HARGREAVES

Materials scientists at Oxford University have developed a technique for producing graphene in large, high-quality sheets, its technology commercialisation arm has said.

Isis Innovation said the researchers had solved a "major barrier" to the development of the material – making it available in commercial-scale sheets of repeatable and uniform quality.

The invention, which is in the patent application process, permits the manufacture of commercial-scale graphene sheets using a transition metal substrate combined with an intermediate silicon containing liquid film.

Graphene sheets are made using chemical vapour deposition (CVD). Large, high-quality graphene flakes are produced. Synthesis times are reduced by 50 times, Isis claimed. It said it was looking for commercial partners.

"We are pursuing research into graphene and other important tailored nanomaterials with end-use applications very much in mind, and in close collaboration with SMEs [small and medium-sized enterprises] and internationally

leading industry partners," said Prof Nicole Grobert, head of the nanomaterials by design team at Oxford Materials.

"I believe this approach is the fastest way for commercial adoption of the new materials and, more specifically, nanomaterials such as graphene. It's only when engineers see the end use and benefits of graphene that public research will gain payback."

Graphene came to prominence in the UK five years ago when the Nobel Prize in Physics was awarded to Andre Geim and Konstantin Novoselov of Manchester University for their experiments with the material.

Despite this, the UK lags behind other industrialised nations in graphene's development. Korea's Samsung had more than 400 patents for the material in 2013. In that year, only one per cent of patents filed worldwide for graphene were in the UK: just 54 in total.

Other leading commercial developers include IBM and Ocean's King Lightning of China.

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AEROSPACE

Easy does it

Low-cost airline announces plans to employ drones for aircraft inspection

Low-cost airline easyJet has successfully completed an automated drone inspection of one of its aircraft.

According to easyJet, the tests indicate that pre-programmed drones can help cut the amount of time an aircraft is out of service following events such as lightning strikes or hailstorms compared with manual inspection that involves the use of gantry and staging.

Furthermore, such events can take an aircraft out of service for half a day or longer at locations away from a maintenance, repair and operations (MRO) facility where an engineer is not always available.

The system, which easyJet aims to bring into service in its engineering bases across Europe within 12 months, would relay information about the condition of an aircraft to engineers, who would then interpret the data and take appropriate action.

For the trial, Blue Bear and Createc's RISER quadcopter was used in conjunction with a T-Series tracking system from Vicon, which assisted in referencing the location of the quadcopter relative to the aircraft in 3D. **JF**

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The vehicle will be capable of travelling at up to 60mph

Photo: Keith Freeburn

AUTOMOTIVE

UK gears up for hydrogen city car

Two-seater vehicle will be built in Wales

BY HELEN KNIGHT

A two-seater hydrogen car designed for local driving is set to be built in the UK.

The production prototype car, being built by Riversimple Engineering in Llandrindod Wells, Wales, where the company has opened its new R&D headquarters, will be powered by a combination of hydrogen fuel cell and regenerative braking system.

It will be capable of travelling at up to 60mph (97km/h), with an energy-efficiency equivalent to 240 miles per gallon.

The car, which is being designed by Chris Reitz, previously design director at Fiat and Alfa Romeo, is equipped with four motors at each wheel to recapture energy from braking. The energy will be stored in a bank of supercapacitors to provide 80 per cent of the power needed for acceleration.

This means the fuel cell itself can be much less powerful, with an output of 8kW compared with the 85kW devices used in most prototype hydrogen cars, said Hugo Spowers, technical director and founder of Riversimple.

Consequently, the fuel cell will be much lighter and, with no gearbox or transmission system, the overall weight of the powertrain will be significantly reduced, said Spowers. "If the whole powertrain is lighter, you can also have a much lighter

structure, which has a knock-on effect in reducing the amount of power you need," he said.

The vehicle will be built with a strong but lightweight carbon-fibre shell, he added. "We are

“It is equipped with four motors at each wheel to recapture energy from braking

aiming for a complete vehicle weight of 520kg.”

Using a low-power fuel cell also allows Riversimple to keep costs down, according to Spowers. That is because the cost of a fuel cell rises directly in line with the amount of power it produces, meaning doubling the output will double the cost of the device. "We can have a much simpler and cheaper fuel cell, which will still provide enough power for our car," he said.

The car will have a range of 300 miles and will be capable of accelerating from 0–50mph in eight seconds. The prototype will be built with funding from the Welsh government.

If the vehicle achieves certification and goes into production, Riversimple plans to build 5,000 cars each year, creating 220 jobs in the process.

AUTOMOTIVE

New engine runs on liquid nitrogen

Zero-emissions technology undergoes tests

BY JON EXCELL

UK liquid-nitrogen engine pioneer Dearman has begun full testing of its zero-emission engine technology at its new liquid air R&D facility.

Claimed to be the first dedicated liquid air engine facility of its kind, the Dearman Technology Centre, located near Croydon, houses a range of custom-built test cells, in which the firm's technologies will undergo extended durability testing and new applications will be developed.

The firm's technology is based on a new kind of engine, developed by founder Peter Dearman, which runs on liquid nitrogen.

According to the company, the centre will become a hub of liquid air engine design, engineering, test and development.

When fully operational, it will enable the testing of four engines simultaneously, along with full system testing, supported by low-volume manufacturing and build capabilities.

Dearman's deputy chief executive Michael Ayres said: "Having a bespoke facility means that we can accelerate our rate of development and testing, enabling us to bring zero-emission cold and

power technologies to market even quicker.

Ayres added that having four test cells means that the company is able to work on several projects in parallel. "Already we are placed to commence work on the high-efficiency auxiliary power unit for

“The centre will enable the testing of four engines simultaneously

use on buses and heavy-duty vehicles next week," he said.

Meanwhile, Dearman's zero-emission transport refrigeration system is currently in extended on-vehicle testing at MIRA, and will be commencing commercial on-road trials later this year.

The company has recently been awarded funding from Innovate UK to develop its auxiliary power unit, and work on customising the transport refrigeration system for different vehicle types.

Dearman is working with the Proving Factory, an initiative set up to help bolster the UK's automotive supply chain.

RAIL

Track progress

SpaceX to stage Hyperloop pod competition

SpaceX has announced that it will host a competition to design and build half-scale pods for Hyperloop, the supersonic rail transport system conceived by the company's founder, Elon Musk.

The competition is aimed specifically at universities and independent engineering teams, with pods undergoing testing at the one-mile track being built at the SpaceX headquarters in Hawthorne, California.

Inspired by Musk's 2013 white paper, two start-ups have already begun working on commercial Hyperloop projects independently of SpaceX. Hyperloop Technologies is developing hardware for the system, while Hyperloop Transport Technologies plans to build a five-mile test track in Quay Valley, California, in 2016.

Although SpaceX said it is not interested in developing a commercial Hyperloop, a statement on its website claims that it is "excited that a handful of private companies have chosen to pursue this effort" and that it is "interested in helping to accelerate development of a functional Hyperloop prototype".

Teams must submit an initial application by 15 September. **AW**

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ENERGY

Making waves in Cornwall

Wind energy device set for development at UK's Wave Hub

BY JULIA PIERCE

Finnish utility company Fortum has announced a €24.5m (£17.4m) wave energy project at Cornwall's Wave Hub, involving partners including Plymouth and Exeter universities and renewable power generation company Mojo Maritime.

The CEFOW (Clean Energy From Ocean Waves) project has been granted funding from the European Commission's Horizon 2020 programme, and will use wave power converter specialist Wello's Penguin wave energy converter technology. This turns wave power to electricity using continuous rotational movement without hydraulics, joints or gears, and with all parts sealed inside the floating hull.

As the unit uses the same parts that are used in wind turbines, it should be cost competitive with offshore wind energy. It is also designed especially for use in rough conditions.

"Wave Hub is offering an excellent testing and development environment for this particular technology," said Mikko Huomo, Fortum's manager for R&D growth projects. "The grid-connected demonstration site is deep enough and Wello will be able to develop its device in all possible sea conditions. The concept of the Penguin device will remain the same, but we are putting efforts into optimising the software, which is directly linked with power production. The wave energy converter itself will also see small improvements here and there."

Wello's Penguin has recently completed several years power production and survivability testing off Orkney.

"In the long run, we hope that wave power will be an important renewable energy source, together with wind and PV [photovoltaics], and wave power could become a competitive energy source without any subsidies," Huomo added. "We have still long way to go, but we believe this project is exactly right to get wave power and the Penguin closer to commercial deployments."



RAIL

Seamless performance

Xerox set to trial global near-field communication transport system

BY ANDREW WADE

Xerox is developing a near-field communication (NFC) ticketless payment solution designed to provide access to public transport systems all over the world using a single smartphone app.

Known as Xerox Seamless, the system will consist of NFC tags installed on transport networks, on which users will tag in and out using their NFC-enabled smartphones. Encrypted transaction data will be communicated to the Seamless app and then sent to the Xerox servers once the smartphone is connected to the internet.

According to Géraldine Lievre, chief technology officer, international public sector at Xerox, the tags will be fully autonomous, free from an external power source and unconnected to the internet, with battery life lasting two years. Lievre told *The Engineer* that Xerox is currently working on the second generation

of tags, but was unable to share further details at this stage.

Seamless will undergo its first trial in France in September, with 200 users travelling across four transport lines. If successful, Xerox hopes it could be rolled out across multiple cities, providing a single system for users regardless of where they are or what transport network they are using.

Xerox would install and manage the system for a fee, with network operators retaining control of their data and pricing structure. Richard Harris, director of international transportation at Xerox, said that Seamless would allow network operators to benefit from NFC technology without committing to investing directly in it.

"One of the main challenges for cities and operators is when to invest in new technology," said Harris. "With NFC, there's been a lot of hype about it, but we believe the pick-up in NFC phones is

going to accelerate quite quickly in the next couple of years.

"If TfL [Transport for London] wanted to change all its validators, it's millions of pounds; thousands of machines. We don't think that payment through NFC Seamless is ever going to be 100 per cent anywhere, but it's going to be an additional way that people can pay easily and conveniently."

Xerox envisions a future where people see the symbol for its app in a foreign city and are encouraged to use the public transport system. The app would also contain a mobility companion, helping users to navigate at home and abroad.

The prospect of increasing users and being part of a global Seamless network has generated interest from operators around the world, according to Xerox.

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ROBOTICS

Collaborative effort

There has been widespread backing for a UK robotics network

The Engineering and Physical Sciences Research Council (EPSRC) has launched a robotics network that aims to foster academic and industry collaboration.

The UK Robotics and Autonomous Systems Network (UK-RAS Network) will have a strong academic foundation, with a number of universities acting as founding members. According to the EPSRC, the network has already had strong support from major industrial partners, as well as from professional

bodies such as Royal Academy of Engineering, the Institution of Engineering and Technology and the Institute of Mechanical Engineers.

Globally, the market for service and industrial robots is estimated to reach \$59.5bn (£38bn) by 2020. A primary aim of the network will be to bring the UK's academic capabilities under national co-ordination, fuelling innovation in the robotics sector and taking advantage of the growth in the industry.

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ADDITIVE MANUFACTURING

3D printer speeds up production

Machine can create anything from car parts to trainers

BY HELEN KNIGHT

A 3D printing machine capable of rapidly producing anything from aerospace components and car parts to running shoes as cheaply as traditional manufacturing techniques is being developed.

The machine, being built at Sheffield University, will be able to produce plastic parts three times larger and 100 times faster than existing 3D printing or additive manufacturing (AM) machines.

Crucially, it is also the first AM device capable of producing parts as cheaply as conventional injection-moulding techniques, according to its developer Prof Neil Hopkinson in the Faculty of Engineering at Sheffield University.

The technology is based on a process known as high-speed sintering (HSS), developed by Hopkinson while at Loughborough University, in which a polymer powder is selectively fused together layer by layer, in order to produce a specific shape.

But unlike existing AM techniques, in which a laser is used to fuse the powder, HSS uses an infrared-absorbing ink. This ink is printed onto the powder bed in the desired pattern, and an infrared lamp is shone onto the powder, said Hopkinson.

"The energy from the lamp is absorbed by the ink, which gets hot, melting the particles that are lying underneath," he said.

Meanwhile, the rest of the powder, which has not been printed on with the ink, remains cooler, he said.

The machine will be capable of producing parts of up to one cubic metre, or approximately the size of a washing machine.

The researchers estimate small components could be produced at a rate of less than one second per part.

The machine, which is being developed with funding from EPSRC, will be built at Sheffield's Advanced Manufacturing Research Centre. It will then be transferred to the university's Centre for Advanced Additive Manufacturing for further research.



The carbon-fibre wheelchair will be light but still capable of handling rugged terrain

AUTOMOTIVE

Moving mountains

All-terrain wheelchair set to scale the heights of Kilimanjaro

BY GLYNN GARLICK

Engineers building an all-road wheelchair made from carbon fibre have given themselves a mountain to climb in the form of Mount Kilimanjaro.

Five Airbus engineers, who are members of the Spanish Group of the Institution of Mechanical Engineers (IMEchE), will accompany a Paralympic athlete using the wheelchair on a journey to the Tanzanian mountain in September.

Airbus head of supply chain quality procurement Manuel Santaolalla said using carbon fibre will make the design light but still capable of handling rugged terrain. At 15kg, it will be 50 per cent lighter than other all-road wheelchairs.

The team has finished a prototype, which will be tested on mountains outside Madrid.

"From a design point of view it is accurate, but from a manufacturing view it will bear no resemblance to the one that will go up, because basically we have riveted most of the components rather than manufacturing in one shot in composites," Santaolalla said.

"We need to be able to move the seat, the chest plate and the leg supports, as well as other areas, so that we can implement modifications on the final design, which will be a one-shot that will eliminate a lot of the weight."

The wheelchair has two wheels at the front and one at the back to provide stability, while hand levers provide power.

"We use a similar mechanism to what we use on a normal bicycle, except they are shaped for the hands and they have a pinion

and a chain that go to the back wheel," Santaolalla said.

The steering mechanism has been designed to lock in place so that the athlete can then use the hand levers. "The difficulty with these is you cannot pedal at the same time as you steer, as with a normal bicycle," Santaolalla added.

The chest plate allows the user to lean forward to hold the hand pedals. It incorporates foam for comfort and a liquid gel that also provides heat, as cold is an issue on Kilimanjaro, which is almost 6,000m above sea level.

The expedition, which will follow the Marangu route, will take place on 3–15 September.

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MARINE

Running a tight ship

Rotor Sail Solution puts a new spin on the Flettner rotor

A Finnish company is offering a wind propulsion system that it claims offers significant fuel savings for ships.

Norsepower said that savings of 2.6 per cent were made in a six-month trial using one of its 18m rotor sails on a route in the North Sea.

"It is the first-ever modern auxiliary wind propulsion system that has this kind of proof of concept," said Norsepower chief executive officer Tuomas Riski.

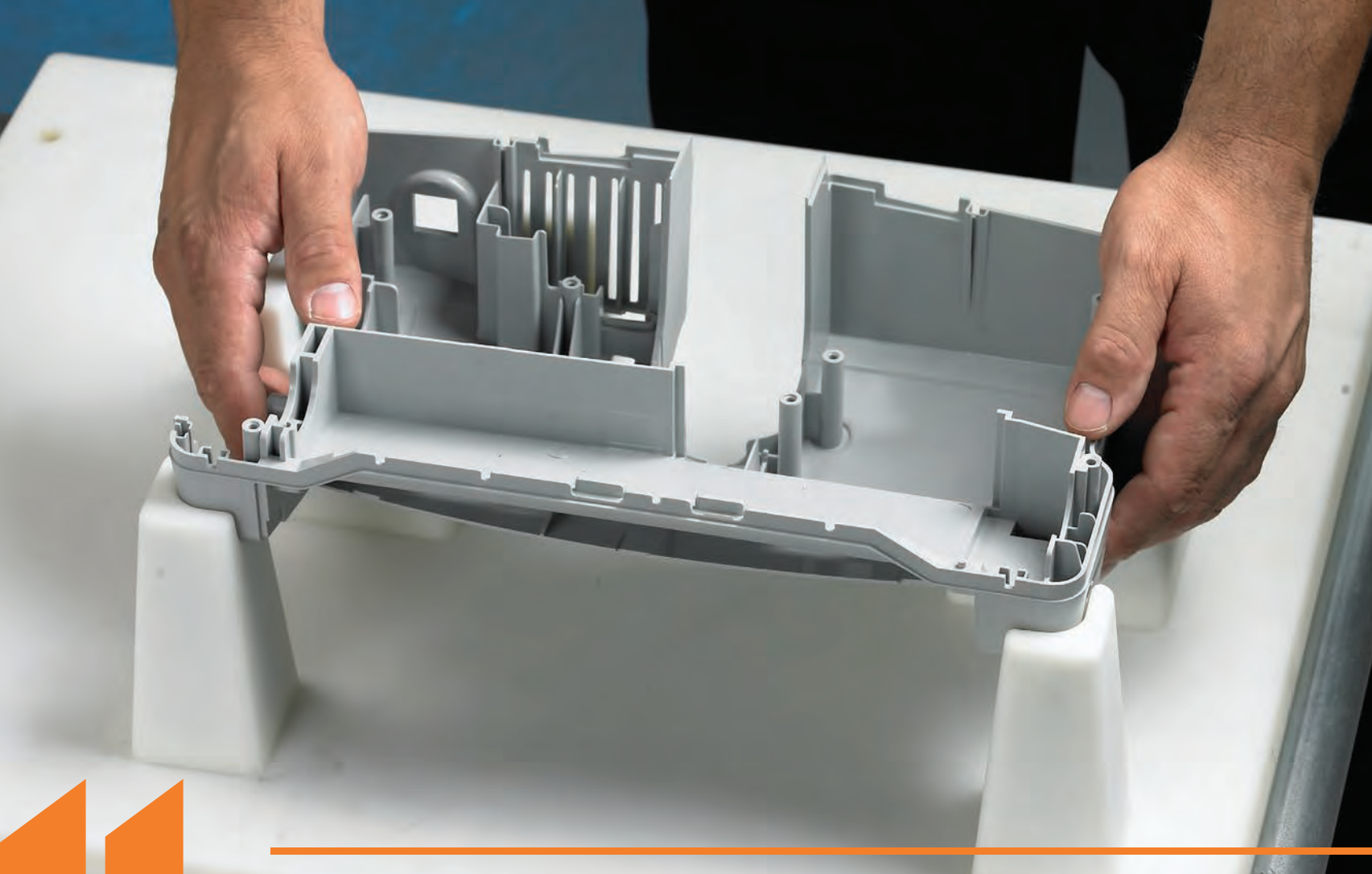
The Rotor Sail Solution is a modernised version of the Flettner rotor – a spinning cylinder that uses the

Magnus effect to harness wind power. When wind meets the spinning rotor sail, the airflow is accelerated on one side of the equipment and restricted on the other.

The resulting pressure difference creates a force perpendicular to the wind flow direction – a lift force.

An electric drive system powered by the auxiliary grid in the vessel is used to rotate the rotor sails.

When wind conditions are favourable, the rotor sails allow the main engines to be throttled back, saving fuel and reducing emissions. **GG**



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The appliance of science

Collaboration is the linchpin of modern scientific progress, says the chief executive officer of the UK's Diamond Light Source

A recent online poll asked readers for views on the UK contribution to large science projects around Europe. This question taps in to a key issue in modern science: what are the core benefits of collaboration? Why is working together, both internationally and across industry and academia, perceived as so significant to scientific progress?

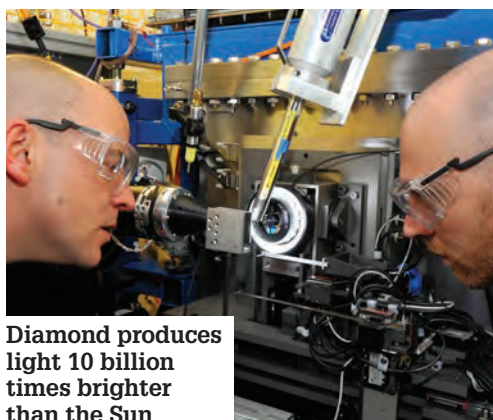
As chief executive officer of one of the most advanced scientific facilities in the world – the UK's national synchrotron, Diamond Light Source – I see constant examples of how collaborations support our pioneering capabilities and keep the UK at the forefront of scientific research.

Diamond produces light 10 billion times brighter than the Sun, which scientists can then use to study the atomic and molecular nature of matter; this is useful for designing new medicines, engineering and technology. An internationally recognised facility, Diamond attracts some of the world's best scientists, engineers and industry leaders, and we currently have 42 nationalities represented on staff.

However, we could not have achieved our success without significant support from the government, the UK taxpayer, the Wellcome Trust, universities, industry, science foundations, the global synchrotron community and the engineers who come from all over the world to use Diamond. Scientists are tackling increasingly complex problems, many of which require a combination of techniques and access to experimental equipment that one institute or company cannot afford on their own.

Collaboration across disciplines and countries enhances the capabilities of everyone involved and improves scientific output overall. In our case, it helps us deliver a broad range of impactful science, including drug therapies and vaccines, smart materials with novel properties, cutting-edge technology and more. We help to grow our facility in partnership with industry and academia, and scientific research at Diamond brings benefits to all of society.

Diamond became operational in 2007 and it has expanded rapidly; in the last year alone, we delivered almost 8,000 shifts in which scientists came to use the powerful synchrotron light. About a quarter of these shifts involved industry, with companies either paying for access or being



Diamond produces light 10 billion times brighter than the Sun

“Diamond attracts some of the world's best scientists, engineers and industry leaders

involved in industry-academic collaborations, which are free of charge, providing the results are published in the public domain.

Industrial involvement plays a vital role at Diamond and our industrial base is becoming broader. We have a dedicated Industrial Liaison Team to help these users get the most out of their experiments. The team supports users in experiment design and planning through to final results and reporting. So far, 85 companies have paid to use Diamond.

Diamond serves the needs of industry and we hold events throughout the year to showcase outstanding science and highlight its relevance to industry. Diamond is a key component of the R&D chain in the pharmaceutical industry; indeed, we support the work of many major multinationals in the UK.

But it's a two-way street; industry contributes significantly to the development of our synchrotron's scientific agenda. Commercial companies have driven huge improvements in the pace and scale of analysis that we carry out, delivering huge benefits to all users.

For us, partnerships with academia, industry and other facilities are critical in ensuring the increasing challenges of 'big data' are met. They enable the 'zeros' and 'ones' produced by our detectors to produce new scientific insights. This is why we are so committed to advancing our capabilities.

No facility can afford to be an island, entire of itself. By working alongside our users and the international community, we keep ahead of the curve. Collaboration drives modern scientific progress. There's no doubt in my mind that we, the scientific community, are far stronger together than we are alone.

Two recent projects with industry include:

■ **Drug characterisation with GlaxoSmithKline (GSK):** GSK is using this national facility as part of its commitment to using the best science to answer important structural questions.

“Without the use of I11, we would not have been able to reach these detection limits that have led to greater understanding and control over the solvate material, thereby allowing us to have confidence in the reproducibility of our manufacturing process.”

– Dr Matthew Johnson, GlaxoSmithKline

■ **Rolls-Royce – strain in fan blades:** Rolls-Royce needed to find a non-destructive strain measurement for a Trent Engine 1000 fan blade. The diffraction measurements at Diamond enabled Rolls-Royce to look effectively inside the fan blade and measure through-wall residual stresses. The measurements were shown to be less time consuming and more accurate than lab-based methods, and the non-destructive method allows further use of the components.

“The information we can now obtain from I12 will help us develop new processes, improve material properties and reduce cost. This detailed, in-situ examination of advanced engineering materials will enhance the durability of aerospace components.”

– Prof David Rugg, Rolls-Royce

Prof Andrew Harrison Chief executive officer, Diamond Light Source

Join the debate at theengineer.co.uk

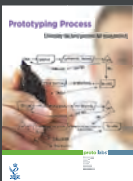
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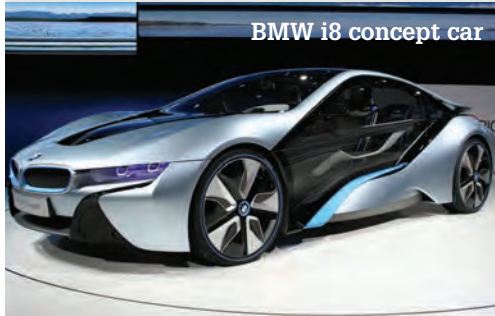
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Electric dreams or nightmares?



BMW i8 concept car

Our poll on whether attitudes towards electric vehicles has changed revealed that, among our readers at least, some attitudes are hard to shift

There are four main reasons for not buying an electric car:

- Cost. The cost. Electric cars, even those aimed at the mass market such as the Nissan Leaf and the Renault Zoe are significantly more expensive than similar ICE cars.
- Next, fear. Range anxiety is the fear of running out battery juice before you reach your destination and being marooned.
- Lack of recharge infrastructure. There is a perception there are insufficient fast-recharge points in our cities, towns and highways.
- Finally, fear again. This time, financial fear. Residual costs. Most fleet buyers are suspicious

of the new or unknown. They rely on historical RV data and are reluctant to think past these numbers cast in stone from a trusted industry source. These people are often accountants, analysts or specialised underwriters in leasing corporations. They are all risk averse because their jobs are on the line if they get it wrong.

Ash Gupta

I don't know about other people, but for me it's cost. Insurance cost. As a first-time buyer, I'd need to pay £100 per month just for insurance. In addition to everything else. Renting a car for the weekend to have a short holiday every two months costs me less. For commuting I use the bicycle, and my hubby walks.

Ralf

I agree with Ash Gupta particularly. Further, it is not about a charging infrastructure, but the whole scale of one. Imagine having to provide just one recharging station to replace a busy supermarket ICE one. Eight petrol pumps might service 120 vehicles an hour with each driver on site for five minutes. A two-hour fast charge would call for 240 spaces, and the significant cost and architecture of a consistent power supply. Very few drivers have the luxury of their own secure garage to enable them to charge overnight. We live in flats or houses where we must park on the street.

Anonymous

I have had an electric Smart for four years and it is excellent for the purpose intended: commuting. [It is] cheap to run, maintain and insure; unfortunately there were no chargers available to me due to my location. I am pleased these are now being installed on the motorway network. We need to take on board the problem of carbon emissions, and government incentives and punitive taxes on fuel containing fossil carbon. The nonsense concerning Formula E and hybrid hypercars is irrelevant unless the technology can be transferred to make regenerative braking and improved fuel consumption a possibility for everyday vehicle design.

Paul Stevenson

As someone who is lucky enough to have a short commute, the Leaf/Zoe/i3 style of electric vehicle would be perfect for me. The cost of the Zoe is less than £20,000 so is more or less competitive with mid-range ICE cars. While the outlay may be higher, how does this equate to overall expenditure when recharging costs around £2? That makes £20 for the same range as £60 of fuel from a roadside outlet. Where they fall down is on longer ranges, but are they really designed for that? As the vast majority of journeys are short ones, range anxiety is largely a misplaced fear.

Paul Arondelle

inyouropinion

Heathrow expansion

Our comment article about the Airport Commission's recommendation for Heathrow expansion gathered comments about other options.

■ Stuart – you start this piece by saying: "From the point of view of engineering, the report of the Airports Commission unanimously recommending the expansion of Heathrow Airport with a third runway is good news." Do you speak for all engineers? I for one want to see the expansion of aviation curtailed with immediate effect. So the recommendation to build a new runway is not good news for me. Good news would be the government deciding that enough is enough, and we have to live within our means (austerity?) and stop fooling ourselves that another runway, another road, another power station, another high-speed railway line will somehow create a perfect, peaceful and prosperous world. We simply cannot afford to continue damaging the climate and the environment by excessive consumption. Much air travel is simply unnecessary. Even the claims that air freight is key to our economic future are ill founded. Look at the global freight patterns and ask why

we export about as many chocolate biscuits to Italy as we import. Engineering isn't just about big muscular projects that politicians can boast about and that enrich corporations at the expense of ordinary people. It's a profession that should be making the most of a limited set of resources (our planet) and steering policy makers away from ill-informed, destructive and wasteful projects such as Heathrow expansion.

Robert Palgrave

■ An estuary airport may be the answer but in the Severn, not the Thames. A non-stop high-speed rail link to Paddington could deliver passengers to London in an hour. Birmingham and Manchester would have much better access than to Heathrow. End-to-end journey times to the Americas would reduce.

Philip Owen

■ Business people are increasingly doing business online through Skype and other teleconferencing facilities – the future reduction in the need to travel as often in this sector could skew the capacity figures downwards in the near/medium future. As for air freight, the same's true; reshoring of manufacturing will slow the increase here too,

and, to be frank, freight terminals need to be in the Midlands, not in the congested south east.

Bruce Renfrew

■ A Heathrow expansion is delusional. Really, the UK needs to show far grander ambition for its engineers. By the time a proposed Thames Estuary hub airport is built (2030), it's highly likely that Heathrow will still be heavily needed for European Flights plus freight plus private aviation, looking at current aviation trends from Airbus, Rolls-Royce and Boeing. A Thames Estuary airport would also rely on extensive use of HS1 [High Speed 1] and an extension, drastically limiting pollution.

Mike Brennan

■ The above comments precisely illustrate the problem: we spend years and millions on multiple expert reports that come up with the same answer but still, people and politicians above all somehow believe they know better. For goodness (and our economy's) sake, get on with it. Heathrow is far more important to the economy than HS1+2+3 will ever be. Fat chance, though. I'm wondering how Cameron is going to kick this into the long grass for another five years, at which point we will most likely to

theseecretengineer



Our anonymous blogger wonders if the shortage of skilled engineers has forced recruitment agencies to up their game

I have had cause to start looking for a new position (more on this, possibly, next month).

Although I had a bit of a dabble not long ago, it is only this time around that I've picked up on what seems like a significant change in approach.

Back when design engineers used pencils and French Curves, you approached an agency who essentially acted purely as an introductory service. There may have been a bit more to it than that, but based on what I saw of it this is what happened. As a system it was rather successful too, but perhaps that was just my innate genius doing all the work, or perhaps not.

Anyway, now it appears that contacting an agency is merely the first step in something akin to an elaborate mating ritual. One has to undertake phone calls and discussions so that they can build up an idea of the sort of person you are, and to get a real feel for the areas of industry you would like to go into. This is followed by talk of 'portfolios' and the like. It is all so much more personalised now with, I am led to believe, a desire on the part of the agents to only work with the engineers who they can form a professional relationship with.

I must admit that part of me is sceptical, but the people I have spoken to on the other end of the phone – and they do come across as people rather than drones – seem sincere.

Having considered this, I believe a couple of factors may have helped lead to this change.

Firstly, the 'job for life' is now rare, so there is more likelihood that any given engineer will be a 'repeat customer', making more moves than before. The time taken in building up a rapport and mutual trust will be repaid in the long term, especially as this is compounded with each engineer knowing more people to whom he or she can recommend the agency. Secondly, it could be one of the first signs that the shortage of engineers is becoming a real issue. The emphasis has moved from spending the time and effort with HR departments to spending it with us. If this is the case, a good engineer is a rarer commodity than a vacancy.

Of course this is merely conjecture on my part, but if I'm right then perhaps, at last, that oft-muttered complaint of insufficient wages will be addressed? After all, we live in a capitalistic society and when demand outstrips supply, money is to be made.



Engineers previously used French Curves

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blessed with Boris Johnson, who will cancel it in favour of Boris Island, which will never be built.

John Yeatman

SalarySurvey

Our Salary Survey attracted some responses from readers commenting on what it's like to work in engineering.

■ The survey concentrated on salary, and certainly pay has been far too low for many decades. But this is only one aspect of the very poor (and often unethical) management in Britain for at least the last century. Management is not easy, and there are few with a natural talent for it; and the management in some countries seems to be better than in some others, but in Britain it is generally much worse than in most other places. Governments often think of solving the problems by training the workers to become more skilled. That will never work until managers are taught better ways, and are themselves managed better – not by fear.

Anonymous

■ The stark reality is the divide between the upper levels of management, who seem to look solely at profits, and those engineers doing

the job. It is apparent that the upper levels of management have no concept (in most cases) of what engineers do, and what added value they bring to their businesses. They look at balance sheets and qualifications and not at actual skills or experience, then go for an engineer who looks good on paper for the cheapest price.

S Martin

■ The most difficult part of management is to shield your subordinates who shall bring in the money from the upper management who want to rule with fear. For that, most middle managers are underpaid. As are those who bring in the money, i.e. do the work, and have customer contact. Most companies would do better if they could chuck out the uppermost level of managers. They are expensive and don't work.

Ralf

Well, after years of being told I'm exceptional by my line managers, it's nice to see your survey shows it too.

Cynical old engineer

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WE CREATE MOTION

Diversity is key

Work experience has been identified as one way employers can reach young people from a wide range of backgrounds



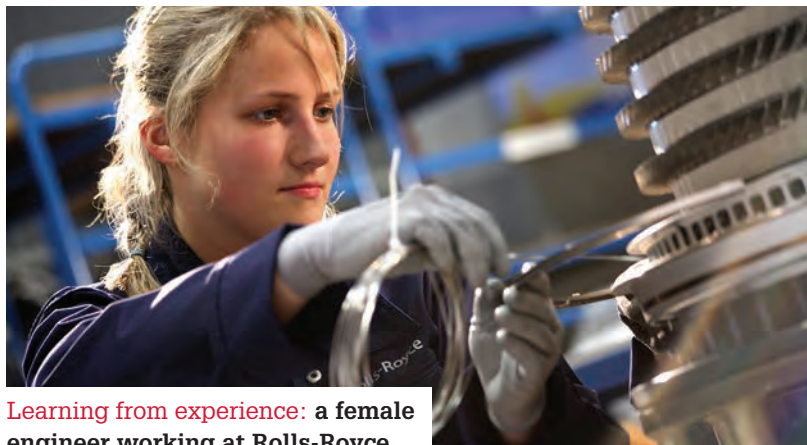
The under-representation of women in engineering was brought into sharp focus on National Women in Engineering Day. There's no doubt we need a more representative and diverse workforce, not only to address skills shortages but to improve the range of perspectives from which we draw inspiration. We

need to actively promote the industry to that diverse audience and make a point of providing opportunities and inspiration to young people from all ethnicities and socio-economic backgrounds.

I chair a subgroup of the Royal Academy of Engineering's Diversity Leadership Group, which has identified work experience as one way in which employers can reach young people from different backgrounds. By broadening the reach of work

“Many employers have a policy of an equal gender balance for work experience intake, and this is what all employers should be aiming for

experience programmes, we can ensure it reaches beyond friends, family and young people already considering a future in the industry. Broaden the reach and you broaden the talent pool. Drawing on contributions from a number of employers and organisations, that sub-group has produced an employer's guide to support engineering employers (particularly small and medium-sized enterprises) in improving the reach of their work experience offer.



Learning from experience: a female engineer working at Rolls-Royce

We need more girls to consider a career in engineering. Many employers have a policy of an equal gender balance for work experience intake, and this is what all employers should be aiming for.

We must also ensure more black, Asian and minority ethnic and more disabled students, as well as those from lower socio-economic backgrounds, are actively encouraged to participate. Could your business adopt the National Grid policy of allocating a percentage of work experience places to young people at risk of finding themselves not in employment, education or training?

National data will give you basic information about schools in your area. Through the Tomorrow's Engineers network, employers also have access to a searchable schools database that captures employer-led engineering careers activity. This continually expanding heat map helps target schools more efficiently. Having identified the school, teachers can find students that meet your chosen criteria. Advertising is also likely to bring in students you might not normally reach.

There is no one-size-fits-all model, but what is clear is that establishing a work experience policy that outlines the application process, roles and responsibilities and who it is available to creates a solid foundation on which to build an inclusive and successful programme. Take the 'quality, not quantity' approach to offer a first-rate experience.

For Angela Malynn, a fortnight of work experience was a very positive experience. In fact, she is now a mechanical engineer at Arup – living proof of the impact of relevant, engaging work experience.

We want young people to be better informed about routes into engineering and know more about what is involved in engineering jobs. We want them to see how rewarding an engineering career could be.

Offering an inclusive work experience programme can't be a box-ticking exercise; it needs to offer an insight into careers in engineering to young people regardless of background, ethnicity or gender. By all means reserve a number of places for friends and family, but then cast the net wider to reap greater rewards. This won't just happen; you'll need a policy of active inclusion that attracts students from diverse social and demographic backgrounds. Start by reading the *Engineering work experience guide*. ©

Paul Jackson is chief executive of **EngineeringUK**

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Super store

As the economic consequences of climate change begin to bite, the oil and gas sector is taking carbon capture and storage technology increasingly seriously. George Coupe reports

As the world struggles to gain control of greenhouse gas emissions, it is slowly becoming clear that failure will be guaranteed without the large-scale use of carbon capture and storage (CCS).

Last month, the G7 set the year 2100 as the target for total decarbonisation of the global energy system. Despite strong campaigns for divestment from fossil fuels, and the growth of renewable energy, it is realistic to expect that oil, gas and coal will continue to be extracted and burnt and the emissions released into the atmosphere for the remainder of the century. This perhaps is why researchers, policy makers and even the oil bosses themselves have recently started to talk up the need for a global effort at "mitigation".

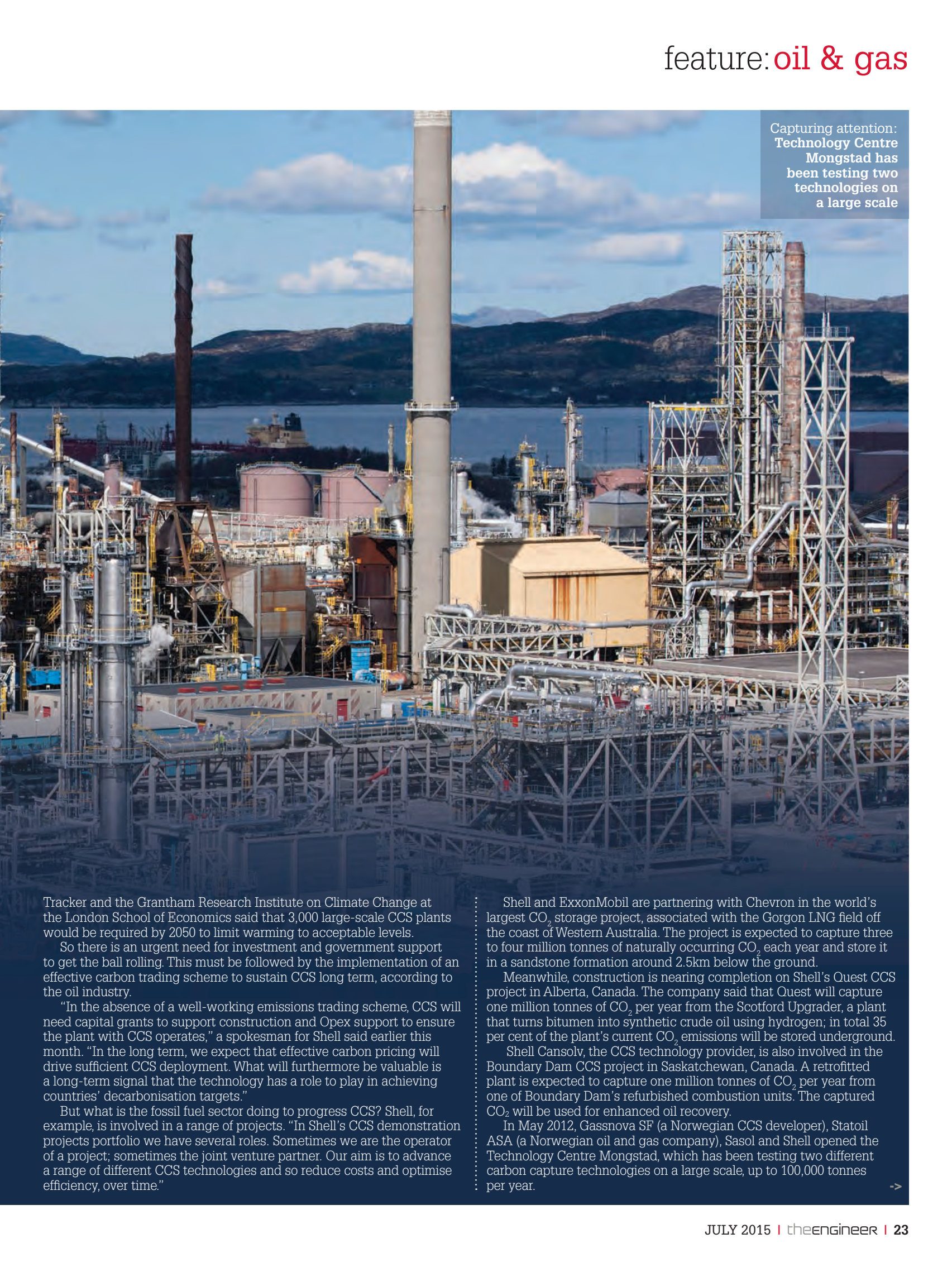
Mitigation means CCS: trapping the CO₂ produced by power generation and other industrial processes and storing it for all time beneath the surface of the Earth in exhausted oil and gas reservoirs.

The technique of injecting liquid CO₂ has been used by the oil industry for more than 40 years to assist in extraction. But over the last 18 months, CCS has been invoked again and again for its potential role in the fight against climate change; it has even been referred to as the only means left by which humanity might limit future rises in temperature to within 2°C, the level beyond which governments agree the effects

of global warming would be unacceptable. Last month, Ben van Beurden, Shell chief executive, called on policy makers to support the large-scale implementation of CCS. He was echoing a view put forward by the International Energy Agency and the Intergovernmental Panel on Climate Change, which said in its last assessment report that, without CCS, the cost of mitigation would double, making the 2°C boundary unaffordable.

The question is: can CCS live up to hopes and expectations? First, there is the developing headwind to take into consideration. Public understanding of CCS is still quite weak, but there is the potential for it to firm up into significant opposition. Anything championed by the oil industry is viewed in some quarters with outright suspicion. In particular, the movement for divestment from fossil fuels would see CCS as an industry-sponsored ruse to keep itself in business. Also, questions have been raised about cost and the long-term safety of transporting liquid CO₂ and re-pressurising extinct oil and gas reservoirs. The anxieties over fracking might easily grow to encompass CCS as well.

The next problem is that progress is slow. According to the latest survey by the Global Carbon Capture and Storage Institute, there are 22 large-scale projects around the world, but these are primarily demonstration and development ventures. A report published last year by Carbon



Capturing attention:
Technology Centre
Mongstad has
been testing two
technologies on
a large scale

Tracker and the Grantham Research Institute on Climate Change at the London School of Economics said that 3,000 large-scale CCS plants would be required by 2050 to limit warming to acceptable levels.

So there is an urgent need for investment and government support to get the ball rolling. This must be followed by the implementation of an effective carbon trading scheme to sustain CCS long term, according to the oil industry.

"In the absence of a well-working emissions trading scheme, CCS will need capital grants to support construction and Opex support to ensure the plant with CCS operates," a spokesman for Shell said earlier this month. "In the long term, we expect that effective carbon pricing will drive sufficient CCS deployment. What will furthermore be valuable is a long-term signal that the technology has a role to play in achieving countries' decarbonisation targets."

But what is the fossil fuel sector doing to progress CCS? Shell, for example, is involved in a range of projects. "In Shell's CCS demonstration projects portfolio we have several roles. Sometimes we are the operator of a project; sometimes the joint venture partner. Our aim is to advance a range of different CCS technologies and so reduce costs and optimise efficiency, over time."

Shell and ExxonMobil are partnering with Chevron in the world's largest CO₂ storage project, associated with the Gorgon LNG field off the coast of Western Australia. The project is expected to capture three to four million tonnes of naturally occurring CO₂ each year and store it in a sandstone formation around 2.5km below the ground.

Meanwhile, construction is nearing completion on Shell's Quest CCS project in Alberta, Canada. The company said that Quest will capture one million tonnes of CO₂ per year from the Scotford Upgrader, a plant that turns bitumen into synthetic crude oil using hydrogen; in total 35 per cent of the plant's current CO₂ emissions will be stored underground.

Shell Cansolv, the CCS technology provider, is also involved in the Boundary Dam CCS project in Saskatchewan, Canada. A retrofitted plant is expected to capture one million tonnes of CO₂ per year from one of Boundary Dam's refurbished combustion units. The captured CO₂ will be used for enhanced oil recovery.

In May 2012, Gassnova SF (a Norwegian CCS developer), Statoil ASA (a Norwegian oil and gas company), Sasol and Shell opened the Technology Centre Mongstad, which has been testing two different carbon capture technologies on a large scale, up to 100,000 tonnes per year.



Left to right: an absorber tower; the Goldeneye platform; a CO₂ stripper at Canada's boundary dam CCS project; and a CO₂ injection well on the Quest project

"Testing CO₂ capture technologies at scale is a critical step in scaling up CCS, supporting cost reduction through learning over time, providing the opportunity to assess the relative merits of different capture technologies and obtaining valuable learning for the design and execution of large-scale commercial integrated CCS projects," said the spokesman.

"Shell Cansolv SO₂ [sulphur dioxide] and CO₂ capture technologies can be used across a wide variety of industries including oil and gas, power generation and chemicals. It can be added to an existing plant or incorporated into a new installation. There are more than 20 units licensed worldwide."

Last week, Aberdeenshire council gave Shell planning permission to build the onshore facilities for what would be the world's first commercial-scale, full-chain project to demonstrate the feasibility of CCS at a gas-fired power station. The proposal is to fit CO₂ capture to one of the existing gas turbines at Scottish Southern Energy's Peterhead power station, which would trap 10–15 million tonnes over the lifetime of the project. The gas will be transported offshore by a new pipeline to Shell's Goldeneye platform and then injected into the gas reservoir 2.5km down.

Goldeneye ceased production in 2011. As the natural gas was drawn from the reservoir, it was naturally replaced by saltwater. Shell said the injected CO₂ will drive the saltwater back into the adjacent rock formations from where it came.

Peterhead is one of two projects that have progressed to the next stage of the government's CCS commercialisation competition, an initiative that provides funding for commercial-scale CCS projects in the UK. The project is now coming to the end the front-end engineering and design (FEED) stage. Construction would depend on a "positive investment decision" from Shell and the government, said Bill Spence, Shell's project lead for Peterhead. "If the project goes ahead... it would be the first project to capture CO₂ from a gas-fired power station, transport it and store it permanently underground."

"In Canada exists the world's first project at a coal-fired power station. It uses the same Shell Cansolv capture technology we propose using at Peterhead. Elsewhere in the world, there are projects that capture CO₂ from heavy industry but this would be the world's first from gas."

The works at Peterhead to retrofit CCS would include a range of new facilities and modifications to the existing site, said Spence. "These [are] the construction of flue gas infrastructure, a new carbon capture and compression and conditioning plant and infrastructure including a control room, power supply and substations, an access road, storage tanks, a workshop, drainage and a wastewater treatment plant."

A chemical absorbent is used to bond with the CO₂ post combustion, which Shell said would cut emissions by 90 per cent. Once captured, the CO₂ would be compressed to a liquid prior to transportation and storage.

The availability and access to suitable storage capacity is an obvious barrier to the wider implementation of CCS. However, Spence said lengthy analysis had shown that reservoirs such as Goldeneye could hold many millions of tons of CO₂. Indeed, there was an earlier proposal for a

CCS project at the Longannet power station on the Firth of Forth to store 20 million tons in the same reservoir, nearly double that of Peterhead.

"Reservoirs like the one at Goldeneye have stored gas for about 50 million years. We assess the reservoir to have the capacity to store 34 million tonnes of CO₂. We are aiming to store 10–15 million tonnes of CO₂ over the 10- to 15-year period of the project."

Spence said that Shell now has a mass of data to support the belief that Goldeneye was "an excellent storage site". He said the company's efforts to understand the reservoir started before the field came on stream in 2004. "We spent 70,000 man hours on CO₂ transport and storage issues within a project-wide FEED study."

When Shell decided not to go ahead with Longannet, it continued to study the reservoir for Peterhead, taking into consideration the integrity of the formations that lie above it, the caprock and the overburden, which provide the seal to keep the CO₂ in place.

"We also looked at what happens when you re-pressurise the reservoir and sought to determine the best conditions for injecting CO₂," said Spence. "To make sure that our study conclusions are valid, we will monitor the reservoir throughout the injection period – and for a time afterwards. One of the existing

wells will be equipped with electronic and fibre-optic instruments for this purpose."

While Spence and his team wait for the go-ahead to begin construction, a key objective of the project will have already been achieved: knowledge sharing. As part of the CCS commercialisation programme, a total of 90 reports will be published during the course of this year and 2016.

His own view is that while the pace of development of CCS has been slow, projects such as Peterhead would push the technology forward in terms of efficiency and affordability. He said the UK's infrastructure and experience meant it was ideally placed to take

a lead, particularly in enabling the development of CCS hubs. This would make it more affordable for new and smaller CCS projects to come online, by plumbing into an existing pipeline network and reservoir infrastructure.

"When mobiles first came out, they were big and expensive. But they were the starting point for a revolution, a transformational technology, and, over time, they have become smaller, cheaper and highly efficient. The same will happen to CCS. The more we do it the cheaper it will get."

"The UK is in a great position to take a lead – and this project [Peterhead] can help. We have an existing power station, an existing pipeline [network] and an empty gas reservoir perfect for storing CO₂."

"In fact, with the right support, the North Sea could store CO₂ from many more projects. As fields come to the end of their life, like Goldeneye, there's potential to put them, as well as the associated infrastructure, and all the knowledge and skills built up over time, to new use for CCS. But one step at a time. We know a lot about the Goldeneye reservoir, so it's a great place to start." ☺

Testing CO₂ capture technologies at scale is critical in scaling up CCS

Spokesperson

Crude truth: construction is nearing completion on Shell's Quest CCS project



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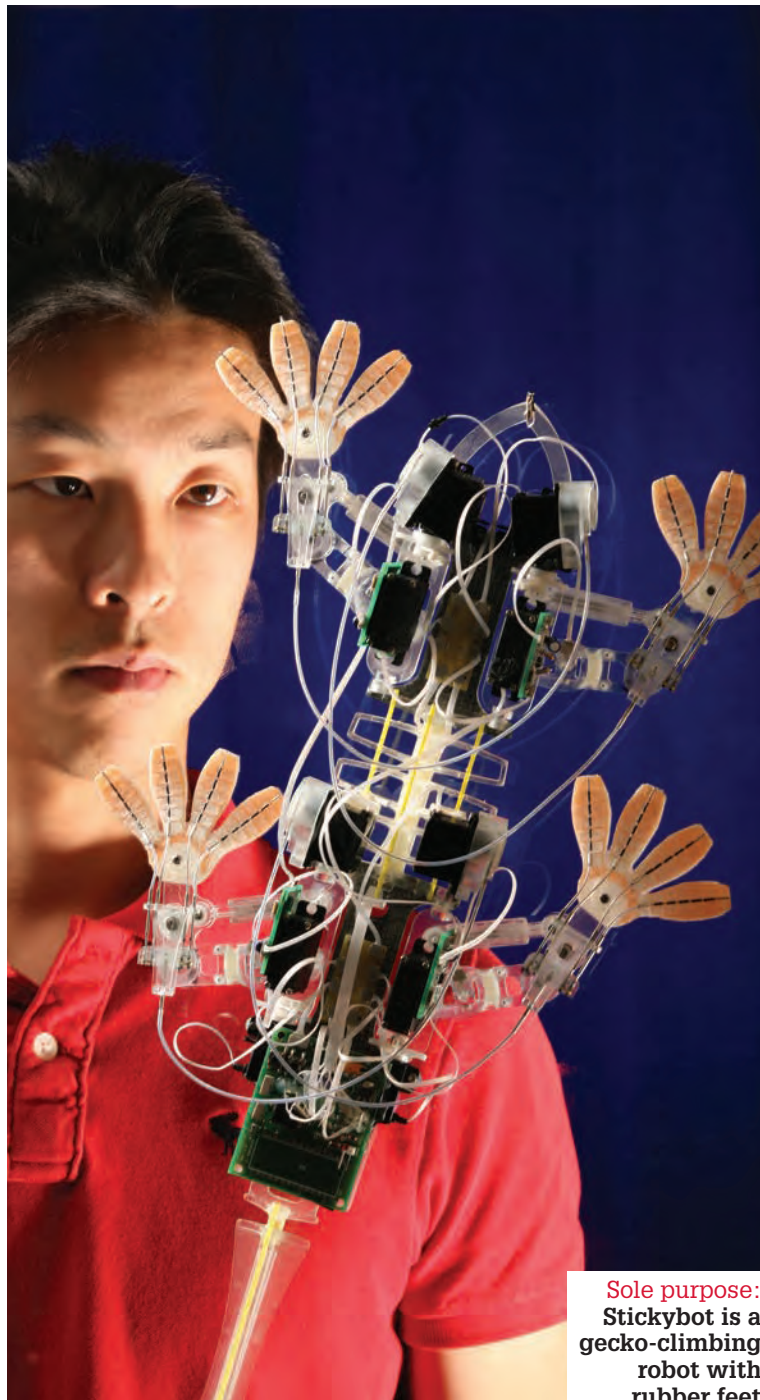
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Forces of nature



Sole purpose:
Stickybot is a
gecko-climbing
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Bioinspired devices are helping robotics engineers to solve many problems.

Stuart Nathan reports

Nature just does things better than humans. It is a galling fact for engineers, but it is very often true and, in all honesty, not surprising; given millions of years to work on a problem, the random mutations and gradual change of evolution will often find a solution where mere human ingenuity, even assisted by computers, cannot.

Mimicking nature's solutions has, therefore, always been a part of the job of an engineer; and robotics, possibly the most important field where engineers try to copy the abilities of living beings, is providing fruitful ground for bioinspired technologies. Investigating nature's solutions is the preserve of biologists, but their insights into the often surprising and even seemingly perverse ways that organisms achieve what might seem impossible — such as climbing a sheer, smooth surface — can often give engineers ideas for how to solve completely different problems. For example, no starfish has ever tried to lift a pumpkin, but studying how their feet work and allow them to grasp and manoeuvre their limbs over

“We're trying to understand the mechanics of a tentacle so we can mimic some of its characteristics”

George Whitesides, Harvard

the complex and textured topologies of coral reefs can lead to robots that can handle awkwardly shaped, delicate objects.

George Whitesides of Harvard University is best known as an eminent chemist and author of textbooks, but is currently working on developing bioinspired systems for

activities such as grasping and handling. “What we're doing isn't biology,” he told a recent meeting at the Royal Society. “For example, the processes — the combination of systems of sensors, muscles and brain [and other organs that process information] — that allow a squid to control its tentacles are still beyond us. All we're doing is trying to understand the mechanics of a tentacle to the extent that we can mimic some of its characteristics, even if the mechanisms used in that mimicry are unrelated to those used by the squid.”

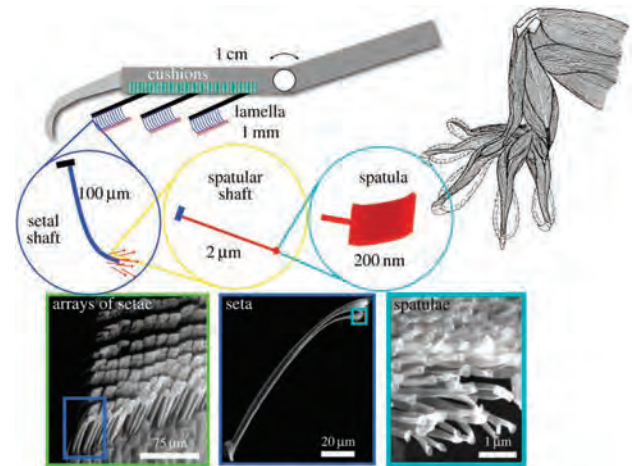
Systems based on nature are attractive to engineers for several reasons, Whitesides said. “They tend to work well with humans because their functional parts are frequently soft, so they aren't as hazardous as heavy industrial machinery with fast-moving metal components. Also, they tend to be simpler, because a lot of the time we replace complex electronic or mechanical control systems by simply making use of the properties of the materials of construction and how we actuate them. ->

That often means they're relatively cheap, so they can be built for a single use. For example, a soft, bioinspired robot built for the search part of a search and rescue mission – such as for locating survivors of an earthquake in the rubble of collapsed buildings – can just be abandoned in the ruins."

The starting point of Whitesides' bioinspired work was the starfish, because the star shape was helpful to make a gripper system. "There's a lot of industrial interest in grippers," he explained. "Companies such as Amazon are looking for new ways to handle items in their warehouses that have a wide variety of shapes and sizes, so a flexible, versatile gripper that self-modifies to handle the variety of objects is of great interest."

The body of such robots is made from polydimethylsiloxane, a soft silicone rubber, cast with networks of pneumatic channels and inflatable cells along the fingers. Simply inflating these chambers causes the fingers to curl up. "They curl from the tip towards the root, and that's not a result of mechanical actuation; just from the structure and property of the material," Whitesides said. "You can introduce more structure, like less flexible sections along the length of the finger. They'd then act like joints; knuckles in the finger."

The climbing ability of the gecko has intrigued engineers and scientists since Aristotle, and is the subject of research by Mark Cutkosky, a mechanical engineer from Stanford University. Cutkosky noted that the dry adhesion exhibited by gecko's feet (sticking to surfaces without any oil or adhesive) is particularly interesting to the space community, because it is one of the few techniques for sticking that works in a vacuum, at low temperatures, on non-magnetic surfaces and requiring low forces to attach and detach items onto surfaces and off them; as such, they are a subject of research for items such as fuel tanks and solar panels. "A few synthetic dry adhesives have even demonstrated levels of adhesion that, for small areas and under controlled conditions, considerably exceed those of the gecko," Cutkosky said. "However, no



Good contact: the gecko owes its adhesive ability to hair-like spatulae on its feet

synthetic adhesive fully captures the desirable properties of the gecko system for climbing. Perhaps for this reason, although there are many publications on dry adhesives, the number of gecko-inspired climbing robots remains small."

Cutkosky's own research is looking at developing climbing robots that use gecko-like mechanisms to stick to surfaces, and also at developing mechanisms that would allow humans to use the same techniques,

Spider-Man like, to climb and cling to smooth walls without harnesses or devices that have to be embedded into the wall. Gecko adhesive is a function of the structure of their toes, he explained; the skin on their soles divides into fine, hair-like structures called setae, about 100μm long, which terminate by dividing further into even finer hairs, some 2μm long, which are tipped by flat structures called spatulae.

When the gecko presses its foot down, these spatula edges contact the surface; then, as the animal pulls its foot along the surface, the faces of the spatulae are pulled onto the surface. This allows very small forces called van der Waals interactions – the same tenuous forces that hold liquids and vapours together (for example in clouds) – to act. Individually the forces are tiny, but the cumulative effect of the spatulae all over the gecko's foot is sufficient to hold the whole animal against the surface, even if it is vertical or a ceiling. In fact, it is so strong that a gecko can hang from a single toe.

One key factor is that it is directional, Cutkosky stressed; it only works when a force is applied pulling from the palm of the 'hand' towards the tip of the toes. Otherwise, it isn't sticky at all. "If you touch a gecko's foot, it doesn't feel sticky, even if it's sticking to you at the time," he said.

Cutkosky's initial experimental gecko-climbing robot, which →



Sticking point: geckos' feet do not actually feel sticky

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went by the name of Stickybot (perhaps not the best name, because as we have seen geckos aren't actually sticky), had feet whose soles were made from thin wedges of silicone rubber, 20µm wide at the tip and 80µm long. In an 'unloaded' state, as these feet touch a surface the tips of the wedges come into contact first; hence they are not sticky. But with a small and increasing shear force, the edges bend over, bringing their flat faces against the surface.

"Thus they represent a greatly simplified analogue to the gecko's setal stalks and spatulae, which also present a small contact area when unloaded, but flatten out for a much larger contact area when pulled in the preferred direction," Cutkosky said. "Although the microwedges have a much lower maximum adhesive stress than gecko setae, they are adequate for climbing robots and other applications."

Incorporating a mechanism like this into robots is fruitful both for engineers and biologists, Cutkosky argued. For engineers, it is the only way to proceed. Agreeing with Whitesides, he noted that we can't possibly replicate how animals operate; we can only approximate. In fact, he said some biomimicking engineers, such as Prof Bob Full, director of the biomechanics laboratory at Berkeley University, argue that engineers shouldn't try to copy nature at all, because evolution works on the basis of "what is just good enough" and optimises from there: that is not a good way for engineers to develop technologies. "Because we cannot exactly reproduce complex biological structures, we attempt to identify the most important effects, so we can incorporate them into simplified approximations of what we observe in nature," Cutkosky said. "We then fabricate robotic mechanisms that embody those principles and test them." For Stickybot, the team, used a technique called shape deposition manufacturing, which allows them to combine hard and soft polymers with embedded fibres.

"It is at this stage that robotics can provide useful information for biologists as well as engineers, because it is much easier to conduct comprehensive tests on robots than on animals," he said. "Even geckos and insects sometimes aren't in the mood to co-operate with inquisitive scientists, and you can't force a lizard to climb a wall when it doesn't want to. We then analyse the results and invariably have to refine our hypotheses and robotic implementations, and so the cycle repeats."

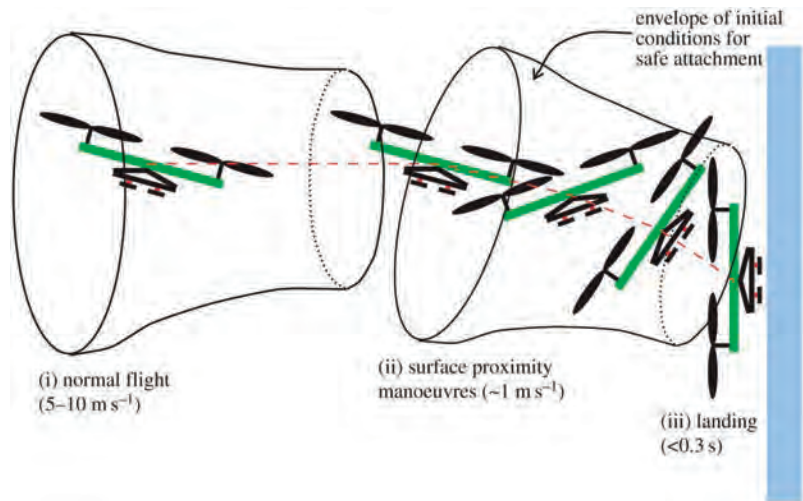
Some of the gecko's feats are hard for roboticists to copy; for example, they can run down walls as well as up them, but to do this they have to turn their hind feet around so they face in the opposite direction. This influences how roboticists have to think around problems, Cutkosky said. "It is useful to recast the observations regarding the gecko's directional adhesive structures in terms of robot force and motion planning. For robot control, it is useful to think of constraints and

Adopting a loading and unloading strategy was essential for getting the Stickybot to climb smoothly and reliably

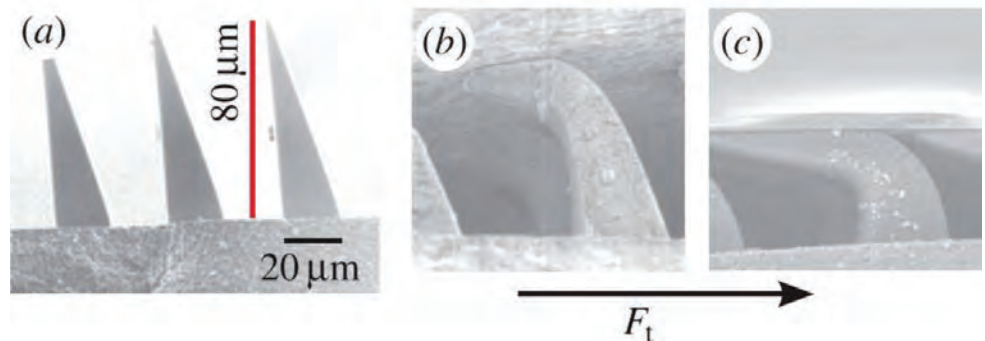
Mark Cutkosky, Stanford University

regions of allowable forces in a multi-dimensional force space. The objective is to plan force trajectories for the robot foot, so that contact forces remain in a safe region."

To give an example of this, he explained that the adhesion force is variable; it depends on how hard the gecko pulls its foot along the wall, and this can also be applied to robot motion. When taking a step up a wall, the gecko (and therefore the robot) has to apply a large shear force for maximum adhesion. When ready to detach its foot at the end of a step, it relaxes the shear force, bringing the combined normal force



Researchers are looking at giving micro-UAVs a gecko-style perching ability



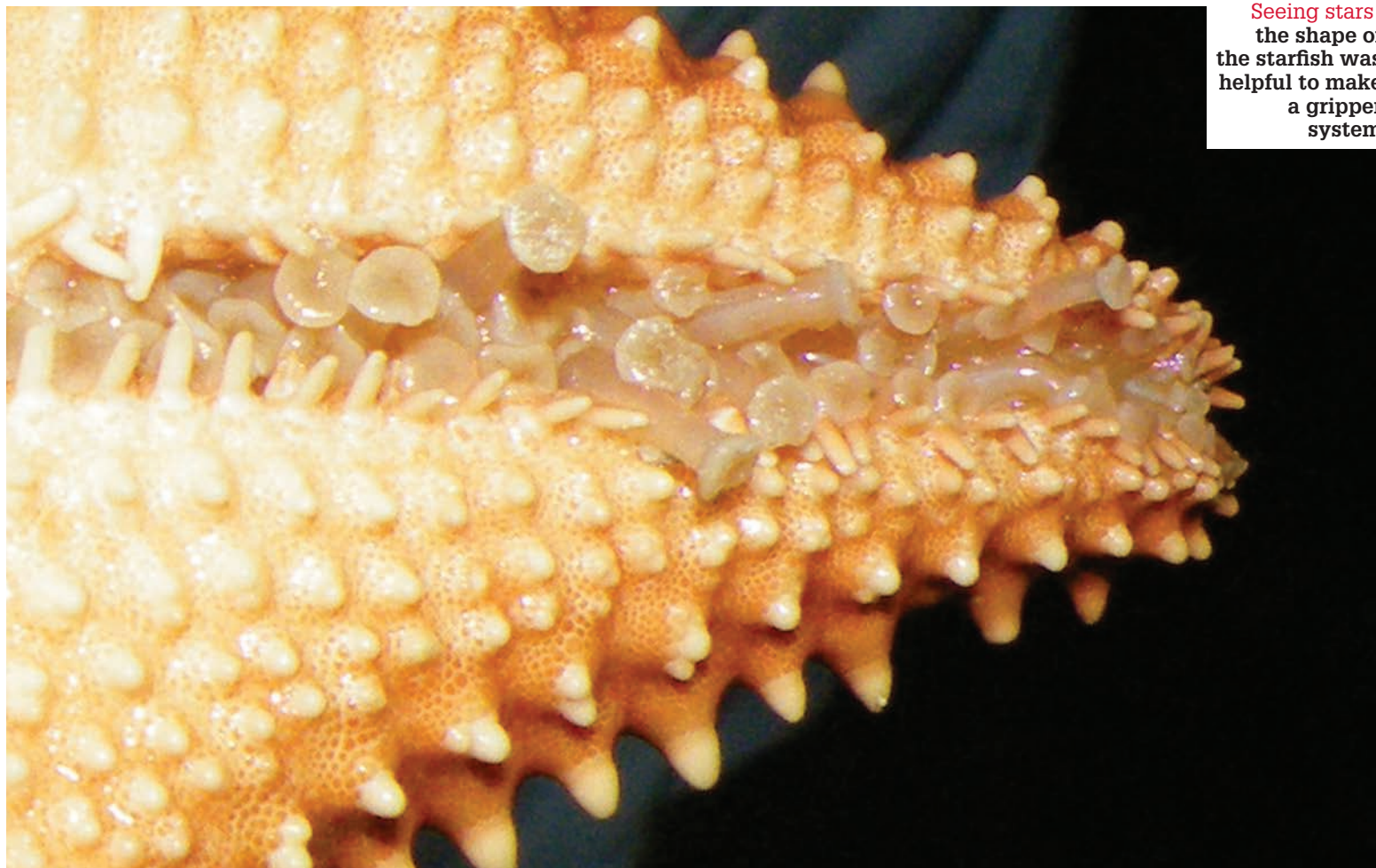
[pressing the foot into the wall] and shear force [pulling along the wall to seat the spatulae] towards the origin of the plot and allowing it to detach its foot with almost no detachment force. "In practice, adopting this loading and unloading strategy was essential for getting the Stickybot robot to climb smoothly and reliably."

This is where model building and study come in. If a gecko climbs a wall, intuition might say that it presses equally hard with both sets of feet, or presses harder with the feet that are lower down the wall. This is how humans climb, exerting more force with their legs than their arms to gain height. "But this is precisely the wrong strategy," Cutkosky said. "Instead, the gecko or robot should pull harder with its front limbs, so that it has more adhesion with which to work."

One way this is now being applied has nothing to do with climbing robots at all; instead, it is being used with micro-UAVs (MAVs) so they can perch on vertical walls, windows and ceilings. This gets around an inevitable limitation of micro-vehicles; they are too small to carry enough power to fly for long. Perching means that they can carry out surveillance or sample the atmosphere without needing to expend too much power. But because gecko-mimicking adhesive is directional, the UAV has to land in such a way that it loads its 'gecko panel' to create adhesion – that is, initially face on – then dragging its 'setae' along slightly to create the van der Waals interaction.

"The vehicle normally flies at speeds of up to 10m/sec and pitches upward to reduce its speed to 1–2m/sec for landing," said Cutkosky. "This is still rather fast, but is desirable because it makes the MAV much less vulnerable to air currents than a vehicle hovering adjacent to a wall." The flying philosophy is like flying the MAV through a funnels in space, where at each stage the goal is to get the craft to the mouth of its next funnel. To make it even more complex, the landing sequence has to incorporate enough time for the setae to bend over.

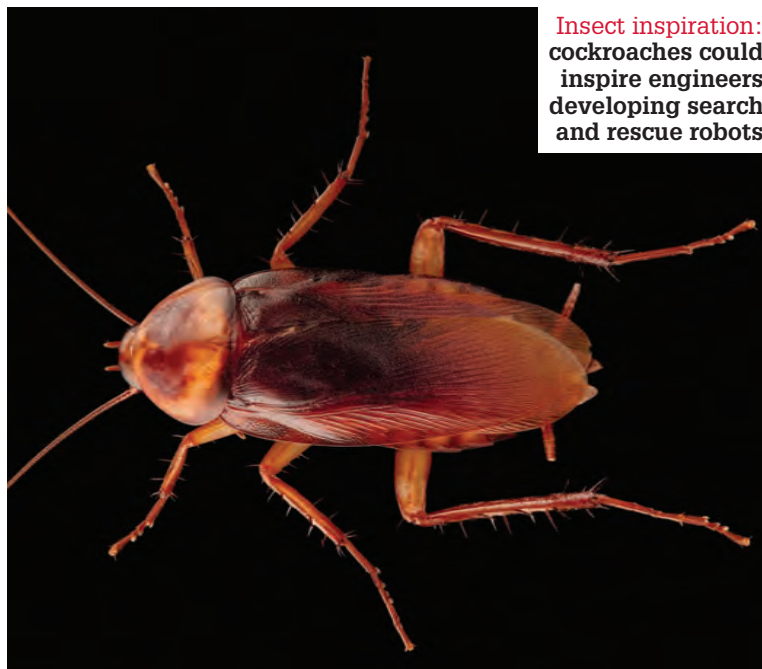
One way to get around this is to design a gripper system with two tiles, each equipped with a gecko-like dry adhesive surface, but arranged so that the adhesive works in the opposite direction: that is, the tiles stick when they are pulled towards each other, and disengages when ->



Seeing stars: the shape of the starfish was helpful to make a gripper system

they are pushed apart. These are linked at the top by a triangular truss made from a spring material, with another linkage acting as a tensioning tendon between the two tiles. As the MAV lands, it collapses the triangular truss and the tensioning tendon pulls the tiles towards each other. To take off, it first has to press into the surface slightly to disengage the adhesive.

There are many differences between natural and engineered gecko adhesives, Cutkosky said – not least the ways the various mechanisms are made. “When making synthetic gecko adhesives, we use bulk manufacturing processes such as lithographic patterning and micro-



Insect inspiration: cockroaches could inspire engineers developing search and rescue robots

As we progress from microscopic to macroscopic features, we typically need to employ entirely different processes

Mark Cutkosky, Stanford University

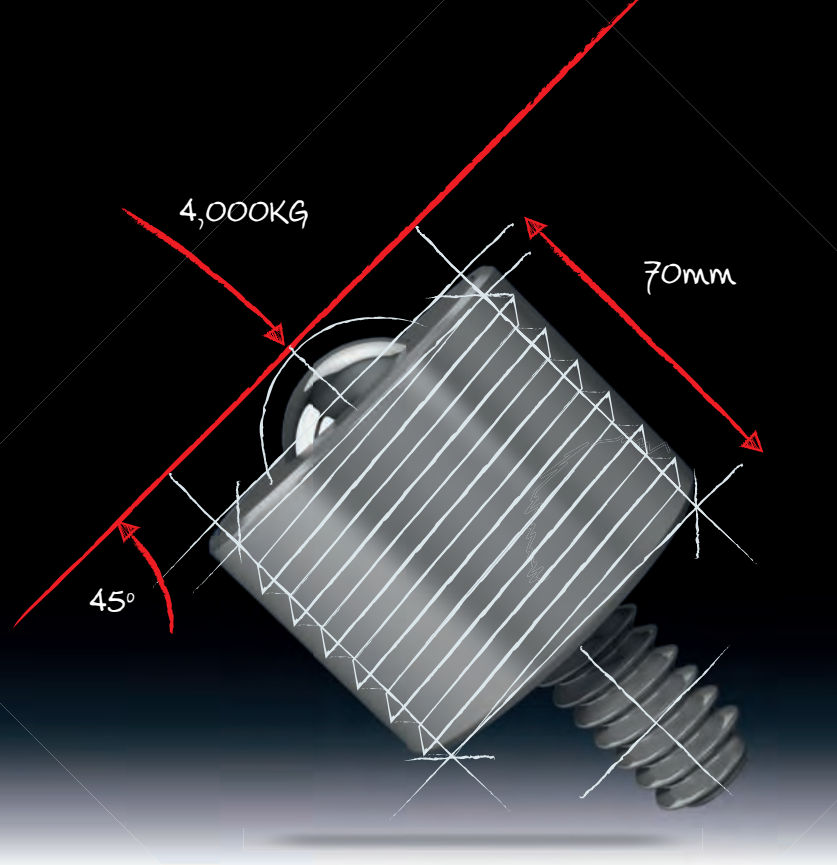
machining. As we progress from microscopic to macroscopic features, we typically need to employ entirely different processes and machines,” he explained. “New manufacturing and prototyping processes such as micro-machining and shape deposition manufacturing expand our repertoire of materials, dimensional scales and geometries, but do not overcome the limitation that each additional level of hierarchy and complexity is costly.”

Whitesides suggested some more areas where bioinspiration might be fruitful. Cockroaches, for example, might be an even better source of inspiration than geckos, especially in search and rescue; they can manoeuvre over a variety of rough terrain, glide into small spaces and even sprint on two legs.

Energy use is another area where nature may have much to teach us: “A pony-sized hard robot, for example, uses about 100 times more energy than a pony to do fewer functions,” he said. “Why? We do not understand the constraints to efficiency in biological systems in the detail we understand the thermodynamics of work carried out by mechanical, human-made heat engines.”

The way living cells set up energy networks – metabolism – is also beyond us, he added. “These networks are like nothing we can rationally construct. The central element is the ability of individual reactions to ‘talk to one another’ through environmentally sensitive catalysts [especially enzymes]. How do these networks work, and why are they stable?” This question is, Whitesides concluded, really another way of asking: “What is life?” ©

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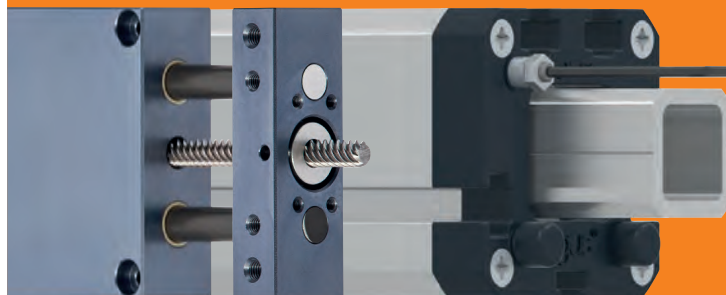
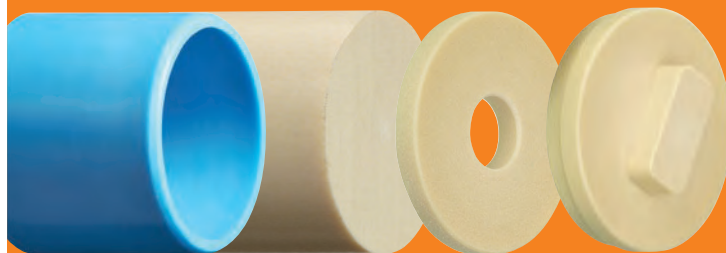
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UK spinout company Heliex Power has found a way to help industry address one of its most enduring waste issues. *Will Sterling reports*



Installation at Vetrobalsamo in Italy

Prof Dan Wright explains how wet steam compression works with the clarity of a man who has convinced board directors, MPs and apprentices alike how high-value engineering works and how it can make money. “I learnt early on that anything you make has to make money,” he said, quoting ex-Ford vice-president Murray Reichenstein, who said that it was money, not cars, that Ford made. Wright hopes to do that with Heliex Power, his latest company in an engineering career that spans four decades. Indeed, figures suggest there are more than one million customers for this clever energy reclaim technology in China alone.

A born engineer and petrol head, inventor and businessman Wright founded Heliex in 2009, based on a technology he had investigated while at Howden Compressors, in Glasgow and Johannesburg, in the mid-1970s with technical support from City University London. His resumé before Heliex reads like a British engineering almanac. A degree in aeronautical engineering from Glasgow University was followed by senior engineering and management positions at Ford, Formula

One, Fleming Thermodynamics, Ogle Design, Johnston Sweepers, GKN Wheels, consultancy, government advisory and more.

In 1993, he established Albion Auto Industries from the Leyland DAF bankruptcy, saving 450 jobs in the process. He raised £24m to buy out the shareholders and found new customers. By 1996 he had taken turnover to £85m with £3m profit. He was awarded

“ The rotors are positive displacement and are able to take in wet steam without suffering any erosion

Prof Dan Wright, Heliex

an MBE for services to engineering and is a visiting professor of City University, London.

Wright’s current company, Heliex, was spun out from City University in 2010 after City had

developed screw expander technology that allowed the recovery of energy from waste heat and low-pressure steam. Investment came from BP and AEL, with a further chunk from Greencoat Capital in 2012.

The core technology is in the rotary screw expanders, which recover medium-grade energy from industrial processes and engine exhausts and convert this to clean electricity and thermal power via a simple thermodynamic cycle.

While high-pressure steam energy recovery is common in gas turbines, Heliex’s technology has a unique selling point, explained Wright: “Normally when power is generated from steam it is superheated – more high temperature than high pressure and therefore dry. You can put dry steam through turbines and have no ill effects. But if you put steam from lower-temperature sources into a turbine, it erodes the blades and causes failure.”

It may look fairly simple but these screw expanders are packed with technology. “The trick is that the rotors are positive displacement and, due to the design of the profile, they are able to take in wet steam without suffering any erosion,” said Wright. So the Heliex expander ->



The rotors use the steam as a lubricant

generators can operate in lower-temperature, lower-quality steam regimes than are required for turbines. The design also eliminates timing gears – because the screws do not need to reduce to the speed of an alternator as in a turbine – and other costly components. “We don’t need a gearbox; in fact we have a belt drive that reduces the 4,500rev/min down to 3,000rev/min, and it runs the alternator at

synchronous speed – it is a constant-speed machine; this lowers the cost,” he added.

While industry has known about the wet steam conundrum for many years, no one has come up with a satisfactory solution – until the specific profile of the rotors were developed contained within the expander body, which can range in size from 160kW to 400kW.

The N profile of the rotors permit the rotors to touch each other, using steam as the lubricant, a capability discovered by City University, without any significant wear, again reducing the cost and size of the machine. Other advantages are that their weight and comparative simplicity means they are robust and low maintenance compared with some power reclaim technologies.

The applications include waste heat recovery (WHR) and machines used in parallel with existing pressure-reduction valves (PRV) in a plant. Wright articulates the business case for the machines, showing the electrical output generated, annual revenue and carbon emissions saved.

For the PRV application, additional gas is burned to power the machine, but there is still a significant net annual saving from the electricity it produces.

Is the process efficiency reduced? Sometimes a company wants the thermal energy used by the generator replaced for its

process. “It might look like we’re just extracting energy from the steam line when this energy is needed for the customer’s process, which is a flaw,” said Wright. “But we find that in 90 per cent of cases with this equipment, the amount of energy we extract and convert to electricity, the resulting energy reduction in the steam has almost no effect on the customer’s process. If the company want the steam energy restored to the levels before we installed, he [or she] has to burn more gas.”

Figures show this conversion rate is very efficient. An HP 145 generator extracts 119kWm (the gross shaft power output), provided to the customer as electricity but removed as thermal input to his or her process. If the customer needs this to be returned, the extra gas required in the boiler to create this energy is 132.9kW. The small difference in this enthalpy is very efficient compared with a thermal power station, Wright said.

The estimated payback period is from two to five years. “In Italy, not only does [one of our customers] get paid for electricity and the thermal energy; they get tradable carbon certificates too, which is why they have fast payback,” he said.

The potential markets are head turning. Heliex claims that every type of industrial process – from chemicals to food and from power generation to chicken manure – produces steam that could have energy regenerated by these expanders. The company has customers in Ireland, Italy and the UK and a healthy order book. Many of the parts are sourced in Scotland and the UK.

Heliex is enjoying a ‘global niche’, but it needs to move fast. Spirax Sarco, which collaborated with Heliex for a couple of years, is supposedly developing a competitor machine, and further imitation always follows success. For now, Heliex has some protection: a patent on the screw rotor profiles that allows it to work with the steam as a lubricant, and patents on the thermodynamic, wet steam cycle.

This proper engineer is hoping screw technology will provide the late twist that his illustrious career deserves, while building an exporting green British engineering company to be proud of. ☺

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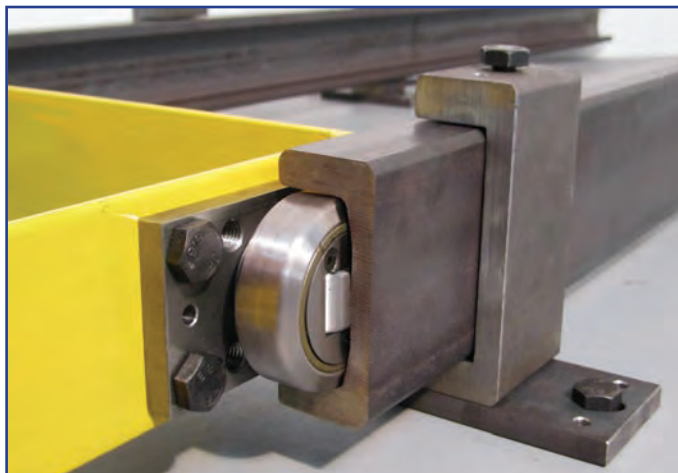
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Carbon cutter

peter emery

Executive group operations director, Drax Group



Education

1980–81: Pre-university work experience – Johannesburg Consolidated Investment Co
1981–84: University of Nottingham BSc (Hons) Mining Engineering, 1st Class

Career

1984–2004: Esso Petroleum Company/ExxonMobil
1984–91: Industrial sales, strategic planning, distribution operations (plant manager, Avonmouth and Terminal Manager, Purfleet)
1991–92: Exxon Company International, New Jersey, US, downstream marketing capital budget co-ordinator (Far East, then global)
1992–2004: Fawley Refinery, leadership positions in zonal operations, refinery maintenance manager, refinery operations manager
2004–15: Drax Power/Group
2004–05: Drax Power, production director and member of executive team that floated Drax on the LSE
2005–15: Drax Group, executive production director
2009: Fellow of Institute of Materials, Minerals and Mining
2015–present: Drax Group, executive group operations director

Drax Group's operations director talks to **Stuart Nathan** about the technical challenges behind Europe's biggest decarbonisation project

Drax Power Station dominates the skyline around the North Yorkshire town of Selby. Its 3,960MW of generating capacity is the largest of any power station in western Europe; alone it supplies some seven per cent of the UK's electricity; it has six energy-generating units, each with a nameplate capacity of 667MW – the largest in the UK.

And because energy generation is always a double-edged sword, Drax is also the UK's largest single source of CO₂ and its largest consumer of coal: when running on coal alone, it burns 250,000 tonnes per week in the winter, and emits 22 million tonnes per year of CO₂ – about four per cent of the UK total. But its profile is changing, and a clue to this can be found in a cluster of shining-white ovoid domes in a large area in the south west of the site. These hold a different fuel from the pulverised coal the plant was originally designed to burn. While it is probably still best known as a coal-fired power station, Drax is also Britain's largest generator of renewable power, because it is also the largest burner of biomass. Two of the station's six turbines have been converted to run solely by biomass firing, with the conversion of a third currently under way.

"We should have all six units up and running by the beginning of the autumn," said Drax operations director Peter Emery. "Initially, the idea was that the furnaces would all co-fire coal and biomass, but the government decided it didn't like the idea of 'half-green, half-black' units."

He added: "The decision was made that having half of the turbines fired by coal and the other half by biomass would be a better idea, and that's now a requirement."

Most of the biomass Drax burns are pellets of fast-growing coniferous wood, sourced from



Higher power: the Drax facility provides seven per cent of the UK's electricity

sustainably managed forestry in the US, where Drax Power Group, the company that owns and runs the power station, has built and manages plants to convert the felled trees into suitable pellet form for transportation and burning. In addition, it also burns what it calls 'residual agricultural products' – straw and the husks of sunflower seeds and peanuts processed for edible oil production – and specifically grown 'energy crops' such as miscanthus, a fast-growing, low-mineral, fibrous grass that can flourish on poor-quality land unsuitable for food crop cultivation.

As policy, Drax's wood pellets do not contribute to a net increase in carbon emissions across the entire process of growing the trees, processing the timber, transporting the finished pellets, storing them or burning them.

Drax is also keen to stress that the trees it processes into pellets are generally not large, straight, mature trees. Instead, pellets tend to come from prunings and thinnings taken to keep the trees and forests healthy.

"In the past, the biggest customer for this kind of wood would have been the pulp and paper industry, which didn't care



Left: biomass storage domes



Right: coal bucket wheel machine



was some in Europe, mostly for heating, but nothing in the US. We've built two pelletising plants in the US where pulp, paper and fibre-board plants had closed down because of lack of demand."

The situation is similar in parts of Europe, such as Scandinavia, where pulp and paper had previously been large industries. "But we've found it easier to gain access to the market in the US, partly because the infrastructure, railheads and other facilities we need are already there at scale, and it's easier to be sure of the sustainability credentials, which is absolutely vital for us to meet our mandated targets," Emery said.

Moreover, the south-west US is a more suitable location to grow pine. "It takes about 25 years for them to mature; whereas in Scandinavia it takes 75 years," he explained. "That higher productivity again drives down the cost of fuel and reduces the resources needed to grow them. Our view is that we need these global supply chains because we can go to the most efficient, low-cost producer; they might not be the closest, but when you ship 50,000 tonnes at a time, the cost of shipping and the carbon footprint aren't huge."

Drax became a biomass user because it was felt there was a need for a business case to reduce its carbon emissions, Emery said. "We were among the largest carbon emitters in Europe," he added. "So we came up with a three-part strategy in 2005 to make the station as efficient as possible, so we started with a £100m turbine upgrade and we looked at all the heat transfer and heat integration systems, and that in itself saved a million tonnes a year of CO₂. But we got to the point where we started to get diminishing returns, so biomass was the next vehicle, and the third, which is our next target,

is to explore carbon capture and storage. But where we are today is the culmination of 10 years' work."

The initial efficiency improvements were all made with no change to the station's input, so substituting some of the coal for combustible biomass seemed an obvious step to take, Emery said. "This project saves between 11 and 12 million tonnes of carbon per year; it's Europe's largest single decarbonisation project."

Converting a coal system to run on biomass requires several things to be changed, mainly around the way the materials are handled. "With the fuel itself, it's about two thirds as dense as coal and you need twice as much volume to produce the same amount of heat," Emery explained. "So the materials-handling equipment has to be changed, and you also need to keep biomass dry. When you cut a tree down it's 50 per cent moisture, but in pellets that's down to five to 10 per cent. So it's quite dusty, and that needs to be controlled, for employee health and fire and explosion risk. Also, biomass is self-heating, so that has to be managed or it can ignite. So we've had to control dust, extract

“One byproduct of the rise of the internet is that demand for paper has declined in the past few years

it and minimise exposure of people to dust. Plus we've installed the storage domes, and designed a new rail car to handle the biomass pellets. Coal cars are constrained by weight, but pellet cars are constrained by volume, so we've

made a car with 30 per cent more capacity, and that significantly reduces the carbon profile of transporting biomass." The rail cars come in from the ports of Tyne, Hull and Immingham; only the UK-sourced agricultural waste fuels do not come into Drax by train.

Chemical composition is also an issue; alkali metal and chlorine residues from the biomass can cause fouling and corrosion, which must be monitored and countered.

Using small pellets allows the furnaces to operate with little conversion. "When you burn coal you grind it to powder so it burns almost instantaneously; pellets have similar properties," Emery said. "Also pellets are easier to handle and transport than logs and chips."

Emery sees Drax as helping with the general decarbonisation of the UK, largely because its output is variable. "The generating units are very flexible and can run from about 200–667MW, which helps the National Grid manage supply and also means that we're very complementary to variable renewables. The efficiency losses in turning down a coal plant are actually less marked than turning down a gas-fired plant, contrary to the impression that's often given. One of our business cases for biomass was that it helps us retain the flexibility of coal, to help the National Grid balancing."

While Drax itself might be a one-off in terms of its sheer scale and the effort needed to convert its units, it has in a way single-handedly kickstarted the biomass industry in the UK, Emery claimed. "We've built port facilities, the rail setup and so on, so the question is now what else can you do with biomass? Could we use more of it in home heat instead of oil and gas, or in CHP [combined heat and power] systems? If you used more of it in power generation, what might it look like? It probably wouldn't look like Drax. You'd probably burn at a lower temperature to avoid fouling problems, but that would mean you could vary the input more, with more straw, miscanthus, leaves and bark as well as white wood. But you have to start it off so you can start that process of optimisation." ©

about the quality of the wood; as long as it was cellulose it was fine," Emery explained. "But one of the byproducts of the rise of the internet and of e-readers is that demand for paper has declined massively in the past few years, and the market for that lower-quality wood has suffered badly. Biomass for energy is providing a market for this material, which would otherwise just be unwanted. And having that market makes it economically viable for the forests to be cultivated."

Emery continued: "We actually pretty much set up this large-scale industry for making pellets. There

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An alternative to autonomy

Jaguar Land Rover is focusing on developing systems that assist drivers rather than replace them. **Andrew Wade reports**

There's little doubt at this stage that the driverless car is just around the corner. In fact, in many respects, it is already here – you just can't wander into your local dealership and buy one yet. Huge progress has been made with autonomous vehicles in recent years, with Google in particular making big strides in the US. In May, the tech giant revealed figures on collisions that have occurred during the initial stages of its driverless programme, claiming that the handful of minor incidents have been the result of third parties and/or driver error.

According to Google, its autonomous vehicles have not been responsible for a single fender bender. "I guess our biggest learning from the accidents has been that people don't pay attention, even trained drivers," said Google co-founder Sergey Brin at the company's recent shareholder meeting.

What is the future then for human beings behind the wheel? Brin, who heads up Google's driverless project, seems to imply that people simply cannot be trusted to drive to the same level that computers can, and the figures so far support him. Computers do not get tired, or angry, or distracted by the latest billboard advertising on the drive home from work.

But fully autonomous vehicles are a little way off yet. Google's cars can navigate the California highways with ease, but they are not being let loose on the winding streets of San Francisco during rush hour just yet. The ability to navigate complex and constantly evolving traffic situations remains solely with us – for now at least.

If Dr Wolfgang Epple has anything to do with it, it will remain that way as well. Jaguar Land Rover's (JLR's) director of Research and Technology said he is not interested in driverless



Wellness monitoring: a seat-mounted sensor measures heart and respiratory rate

cars, and wants the driver to be at the centre of technological change. Speaking last month at JLR's technology showcase in Gaydon, Epple outlined his vision for autonomous vehicles, and the role of human agency in the future of driving. "Autonomy is not going to appear as a revolution overnight," he said. "From our point of view, it is a journey that increases, over time, the complexity and the capability of the various features."

For Epple, car autonomy is something that should be there to assist drivers, not replace them. He said JLR has no intention of developing a driverless car, and the notion is not one that appeals to the many employees at JLR for whom driving is not simply a way to get from A to B.

This sentiment is one many drivers around the country will undoubtedly relate to. Cars are more than simply a method of transport for some people, and driving can be enjoyable when roadworks and traffic are not around to spoil the fun. Lots of people find driving relaxing, and the idea of handing over the controls to a computer and essentially being taxied around is not something everyone finds appealing.

That's not to say technology doesn't have a role to play; just that it should develop to assist drivers rather than push them aside. The programmes JLR is focusing on are intended to do just that. Mind Sense (pictured, left) is an ambitious project investigating if brainwaves can

be used to gauge driver alertness, monitoring brain activity through the steering wheel and delivering prompts when concentration slips.

Elsewhere, *The Engineer* recently covered JLR's progress with Pothole Alert, a system designed to map hazards on the road surface.

Other technologies on display in Gaydon included the Predictive Infotainment Screen, a system that uses cameras and path-tracking filters on the central control panel to predict where fingers are aiming. JLR claims this increases the speed of successful button selection by 22 per cent, reducing the amount of time drivers have their eyes off the road. The system is being trialled in conjunction with Mid-Air Touch, which provides haptic feedback to the fingertips using ultrasonic sensors.

The common aim across these projects is to make life easier for drivers, improving safety and comfort rather than working towards driverless cars. As technology evolves, however, and companies such as Google continue to push the boundaries of vehicle autonomy, it will be interesting to see if JLR can remain true to the values of Epple. In the future, there will certainly be a market for fully autonomous cars, capable of operating in all environments. But for now, JLR's focus remains firmly on the driver. Humans still appear have a future behind the wheel. For how long, we shall have to wait and see. ©



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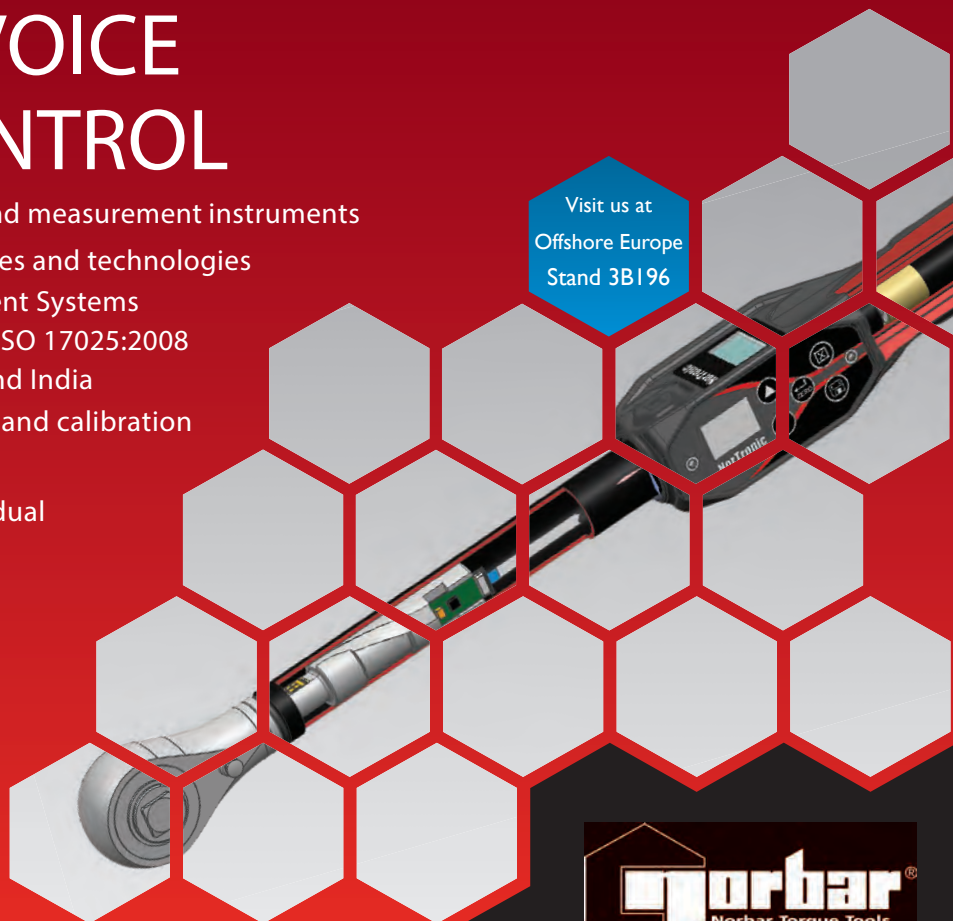
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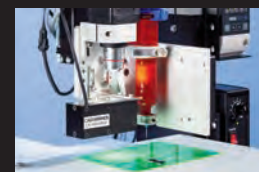


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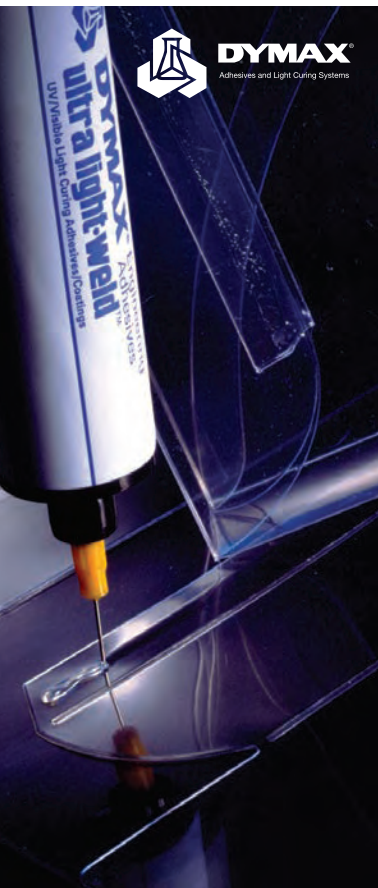
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All together now

Various joining methods are being developed to help manufacturers of composite products save weight, time and cost. Will Sterling reports



On the up: robotic fastening on an advanced winglet

If a company can reduce the time and materials used to stick multiple composite components together, it will reduce total production time and cost. So all users of composite structures – manufacturers of aircraft, wind turbine blades, motorsport technology and, increasingly, mainstream automotive equipment – are eager to perfect the bonding process. But relying purely on adhesives is not easy.

“Because we are always chasing weight and cost, bonding parts together is an efficient way of doing that and it could lead to lower-weight structures,” said John Cornforth, head of airframe and special product technologies at GKN Aerospace. “In both metals and composites, we often make individual

piece parts, drill holes in them, and then we countersink them, remove the burrs and fasten them together. If you bond it in one hit, it is likely to be a cheaper process.”

But aerospace is a naturally conservative industry and the adoption of adhesive-only joining techniques is slow.

Some aerospace components today, including critical parts, are bonded with adhesives only, such as stiffeners onto panels on winglets. The intent to do more of this is there, but the industry is still nervous about bonding for highly loaded parts. The field where the industry needs a shove, Cornforth suggested, is to design these processes into a manufacturing standard; how to co-cure and marry two components quickly that meet all

the regulations. “If you want to design a part for co-cured structures, then those kinds of methods are not in the textbooks,” Cornforth said. “We would like to get to more generic methods that allow you to size a joint that is sufficiently reliable.”

In the aircraft industry, the maximum load factor during authorised flight is the limit load.

Mechanical fasteners and adhesives are applied, where the fasteners alone could carry the limit load. “Fasteners tend to be used in places where two components are bonded just to stop the initiation of a disbond, where components will come apart,” added Cornforth. The ultimate load to which the aircraft is tested is one-and-a-half times the limit load, ->

feature: fasteners and adhesives

so aerospace is truly “belt and braces” on safety and there is little sign of more bonding only in critical parts.

There are three principle types of bonding two or more composite components:

1. Co-cured – where both parts have not been cured yet (as supplied, known as ‘green material’) and are cured in the oven together.

2. Co-bonded – where one part is pre-cured and another part is not, for example the skin of a winglet and a stiffener where the latter settles into the skin’s shape easily. This would be done in order to achieve aerospace conformance.

3. Secondary bonding – two composite parts that are fully cured and joined. The challenge here is they need to be tooled very accurately to ensure they come together at the right bond line on its whole surface area, especially on large parts.

The main types of bonding adhesive for composites are thermosets and thermoplastics. Among thermosets are epoxy resins, modified polyesters and methyl methacrylates (MMAs). There are some other newer compounds such as bismaleimide resins.

Thermosets are more traditional, where a chemical reaction sets the material permanently, but thermoplastics are attractive to industry as a result of their high thermal properties and better damage properties.

“Thermoplastics can reform at the right conditions, with almost viscose-like properties, and the key industry driver is their application in crash situations,” explained Dan Kells, collaborative research manager at the National Composites Centre (NCC) in Bristol.

Among adhesives, while epoxy resins are favoured by many manufacturers because they are compatible with the material of the components they join, some companies prefer alternatives. Plymouth-based Princess Yachts,

which uses glass-reinforced polymer, resin infused and hand laid, now uses modified polyesters and MMAs as its bonding agent due to the expense of epoxies.

“The adhesive is superior to the laminate [epoxy], so there is no point in looking for a more superior adhesive when you are already outperforming your laminate,” explained Julian Spooner, head of composites at Princess Yachts. “We’ve discussed it with epoxy suppliers but they can’t bring their cost down.”

The method of joining components in luxury yachts needs to consider weight but also speed – most models are semi-custom made with a production line that runs to a drum beat. “You want to apply the quickest process; we want the material to go off [set] as quickly as possible to get the yacht to the next process,” said Spooner.

The automotive industry’s use of composite materials has been rising. At the NCC in Bristol, more projects than ever are run for automotive customers today. Tooling company Expert Tooling in Coventry is running research projects examining the best ways to bond carbon fibre to carbon fibre, and carbon fibre to aluminium depending on the zone of the car. This is part of the Varcity project, a programme involving automotive company Jaguar Land Rover, funded by government innovation agency InnovateUK.

“When you bond aluminium or steel parts to composites, because of the different expansion rates when heated, you need adhesives that are either more flexible or stiffer,” said Gavin Osmond, a graduate research engineer at

Expert Tooling. “In places you need traditional mechanical fasteners, for example joining a seat to the carbon-fibre floor.”

The methods they assessed included self-piercing rivets for carbon fibre to carbon fibre and a method using Böllhoff studs that are adhesively bonded onto the carbon, a technique used on the BMW i3 and i8 cars. For the majority of panel-type bonding needs, adhesive-only bonding in the automotive sector is adequate, according to Osmond, but working out which method is best for which car area is the key.

“When you bond aluminium or steel parts to composites, you need adhesives that are either more flexible or stiffer

Gavin Osmond, Expert Tooling

Deploying robots for bonding both composite and metal parts is also increasing. Research and development work is under way at the NCC and the EPSRC Centre for Innovative Manufacturing in Composites (CIMComp). Currently, one of the most practicable applications for robots is in inspection. “At the NCC, we are looking to apply robotics for checking the bonding line is even,” said the NCC’s Dan Kells.

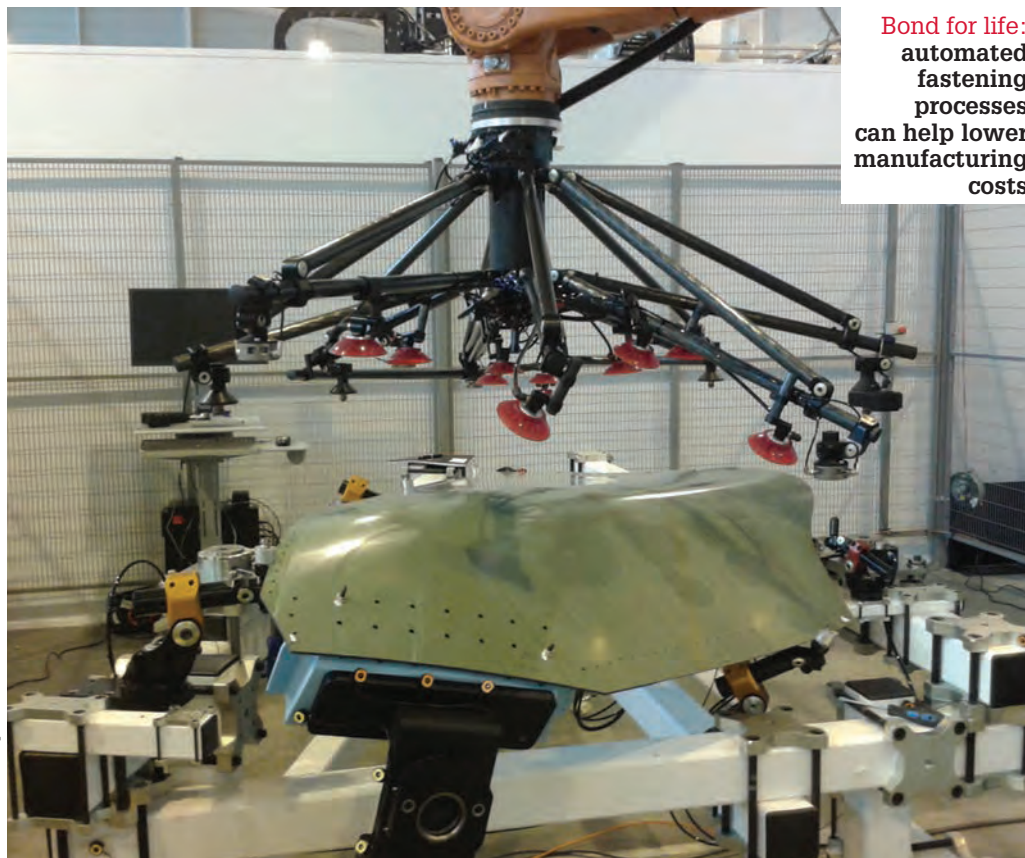
Inspection and the proving of bonds is the elephant in the room, so to speak, for a more mature adhesive-only regime in composite manufacture. “The problem with adhesives is proving,” explained John Cornforth at GKN Aerospace. “You have the difficulty with adhesives in that once you’ve made it all you can do is ensure that you follow a process that leads to a good joint. But you cannot prove that you have a good joint unless you destroy the joint.”

Conversely, with a mechanical joint only, companies incur higher costs, especially with titanium bolts, and components often need stress concentration, or thickening, which adds weight and cost. Recognising these inspection problems for adhesives, and the limitations of fasteners, CIMComp has worked on an EPSRC-funded project to embed titanium and steel in carbon fibre.

“The bonding world is dominated by adhesives or bolts,” explained Andrew Mills, principal research fellow, composites manufacturing, at Cranfield University. “Bolts are heavy and bonding is generally less trusted for life-critical applications. Our ‘spiky’ fittings are one solution.”

With metal pieces with projections or spikes, the joints are tolerant to poor preparation and tend to fail in a pseudo-ductile or safe way, rather than an unsafe total failure. The novel embedded inserts programme is working with a large UK motorsport company and a manufacturer of unmanned aircraft. “It is exciting for industry because attaching carbon-fibre components can be so expensive and heavy,” said Mills. ☉

Bond for life: automated fastening processes can help lower manufacturing costs

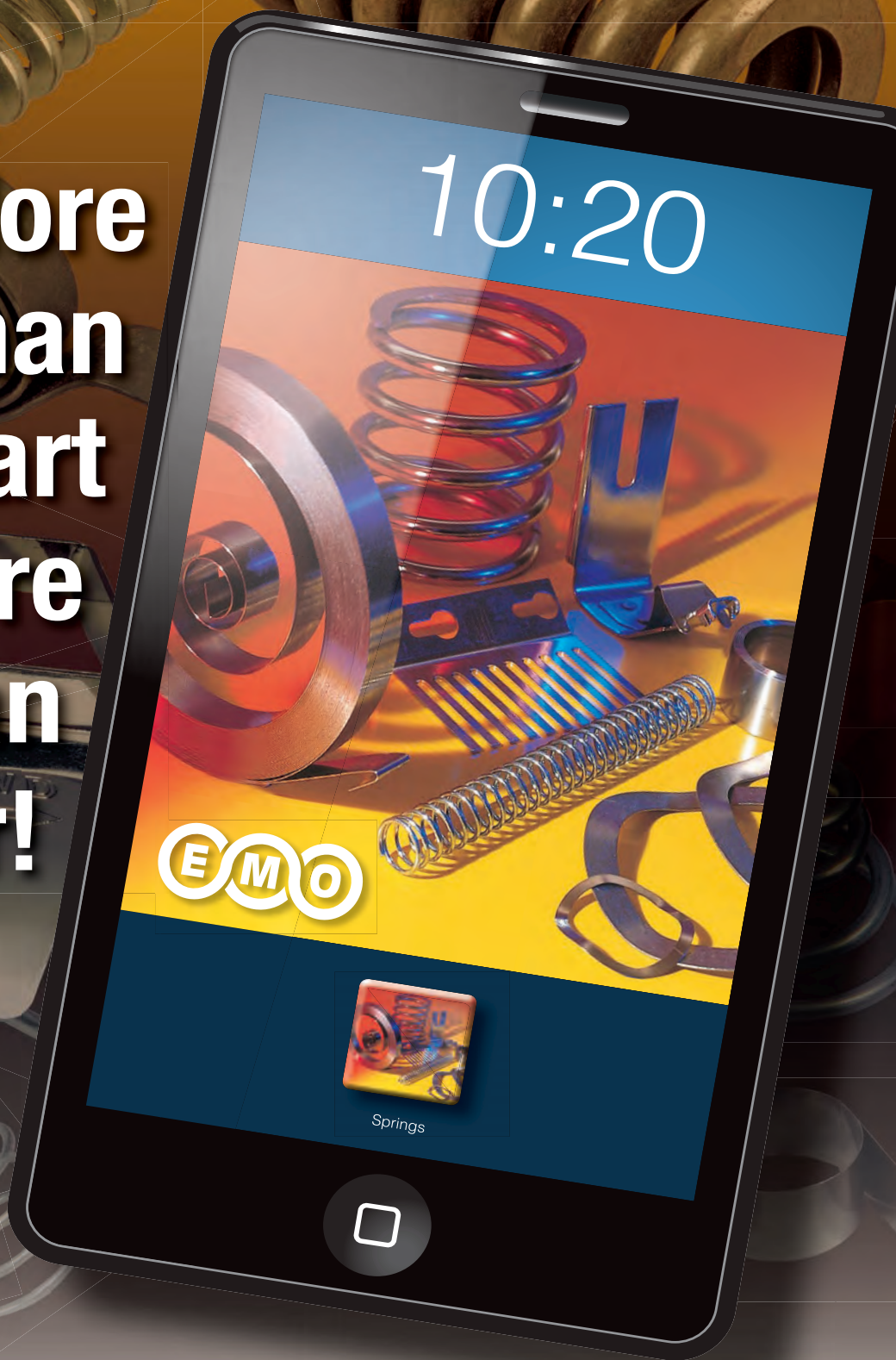


Credit: GKN Aerospace

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DESIGN • DEVELOPMENT • PROTOTYPING • MANUFACTURE

Choosing the right adhesives for aerospace interiors

Strict regulations govern all materials used in aircraft interiors. Here, senior application development engineer **Andrew Marks** of 3M looks at the key product selection criteria

There are three main drivers that govern all materials used in aircraft interiors: passenger safety, weight management and aesthetics. The critical requirements for adhesives are that they ensure the safety and comfort of passengers, deliver durability and performance of individual interior components and ensure compliance with regulations.

Flammability regulations relate to all aspects of aircraft interiors – both visible and invisible. In the process flow for the construction of interior components made from composite panels, adhesives play a key role at all levels, from core splicing to insert potting, edge filling, panel assembly, veneers' application and reinforcement for fixtures and fittings.

From the safety aspect, there is a range of regulations that have an impact on the choice of materials for aircraft interiors designed to ensure passenger safety and reduce environmental risk. The Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA) are responsible for the regulations that cover fire testing requirements for flame retardancy (FR) and fire, smoke and toxicity (FST).

In Europe, there are additional regulations relating to toxicity levels as well as REACH health and safety concerns that have to be taken into account.

REACH places restrictions on the manufacture, placement on the market and use of specific substances known as SVHCs. These regulations mean that some materials

available in the US cannot be used in Europe, and OEMs need to take account of the fact that any aircraft flying into Europe is governed by European legislation, so substances not permitted under REACH regulations cannot be used regardless of their acceptability in other territories.

As a forward-looking industry supplier, 3M follows a strategy of developing solutions that meet both current and future regulatory requirements looking at a 10- to 20-year horizon to take into account chemicals that are likely to be phased out or banned.

From an operational point of view, aircraft weight is a key factor influencing fuel consumption, which has an impact both on airline profitability and the environment. Depending on the specification of the aircraft, the weight of the interior components could be higher than the weight of the airframe.

As one way to drive down weight in aircraft interiors applications, 3M has developed a line

Filling the void: 3M's Glass Bubbles Technology



of lightweight, low-density void fillers designed to fill, close and reinforce honeycomb and sandwich structures. The weight of the void filler can be reduced by effectively 'adding air' in the form of microspheres as an alternative to conventional fillers; this is achieved thanks to the 3M Glass Bubbles Technology, engineered hollow glass microspheres with a high-strength-to-density ratio.

With an increasing demand from airlines for modern fuel-saving craft, there is a huge order backlog across the industry. Heightened demand puts pressure on any organisation within the supply chain to accelerate deliveries to help speed up production. For interiors manufacturers, the choice of adhesives can significantly affect manufacturing efficiency and speed of production, which in turn can significantly add to profitability.

There are a number of factors that affect productivity in bonding/filling operations: speed and flexibility of curing, mix efficiency, filling capability and materials properties. Carefully selecting solutions with the right performance properties is central to having a positive impact on manufacturing efficiency.

Using the right adhesives and choosing the most effective delivery method can substantially simplify many aircraft interior manufacturing tasks. The correct choice allows operators to complete assembly speedily and efficiently while meeting the overriding demand for passenger safety and, of course, meeting the airlines' desire for aircraft interiors that are appealing to their passengers.

Intertronics

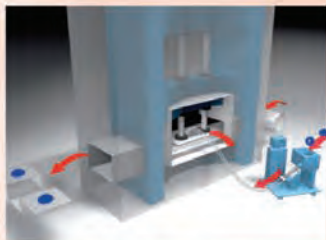
A limiting factor in UV bonding is the curing of the adhesive in shadowed areas. Dymax 3401, a new adhesive from Intertronics that combines UV and moisture curing, cures in seconds using broad-spectrum or LED UV curing lamps, with adhesive in shadowed areas taken care of by an ambient secondary moisture cure. The adhesive features low shrinkage and moisture and thermal resistance and, post process, fluoresces blue under low-intensity black light for easy inline bond inspection. The product is recommended for evaluation in assemblies including substrates such as ABS, PC, PCTG, PEI, PETG, PI, PSDU, PVC, brass and glass and can also be used for sealing and encapsulating, where appropriate.

igus

igus claims that its new iglidur B160 tribo-tape is suitable for reducing friction, noise and abrasion in wear-prone areas. With a thickness of only 0.5mm (including the adhesive back at 0.65mm), the space requirement is very low. Tribo-tape offers complete design flexibility; it is available specially tailored by the metre or in specially designed prefabricated parts. The features of tribo-tape include a low coefficient of friction and a lubricant- and maintenance-free design; it is also easy to cut and glue while being cost effective. The tape comes in a variety of widths and can be ordered with or without an adhesive backing. The company's cutting service can be used to produce products from customers' dxf files.

Scott Bader

Scott Bader has recently become an approved composites materials supplier of moulding and structural adhesive products to all of the production facilities around the world that make up the Daimler AG Group of manufacturing companies. Approved FRP lamination products supplied include Scott Bader's unique technology 'ultra-low styrene content' Crystic Ecogel S1PA spray gelcoat to help reduce styrene emission levels in Daimler factories without any loss of end-use application performance. Closed mould grades of Crystic unsaturated polyester resins are also supplied to the Daimler AG Group and approved subcontract converters fabricating composite vehicle parts.



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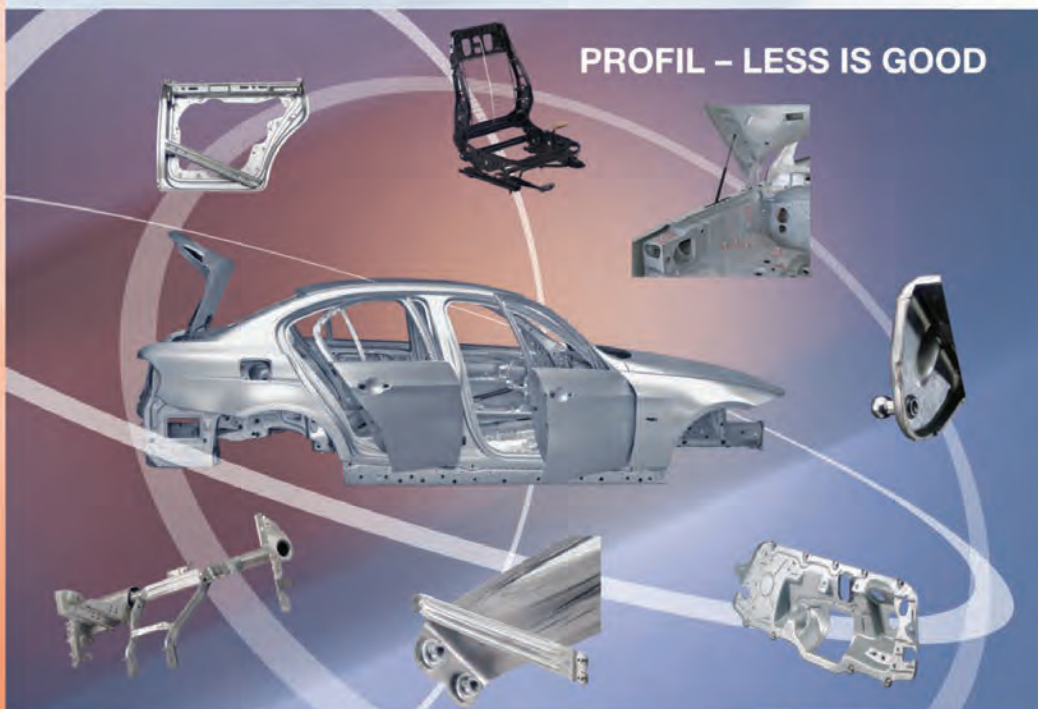
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The race to remanufacture

3D printing is giving old machines a new lease of life. But can the new technology perform as well as the original part? Evelyn Adams reports

The 3D printing industry is 'choking off its own revolution'. Those were the words of designer Francis Bitoniti earlier this summer, as he described how the technology had become associated with toy-like machines and overpriced materials.

The problem is that the promise of 3D printing often can be vastly different from the reality. The technology has been hailed as the solution to everything from self-assembling furniture to custom-made prosthetics. In reality, however, 3D printing has largely been confined to creating prototypes rather than the final product.

But while consumer products have proven difficult for technology, there is one area that is beginning to benefit hugely from 3D printing: remanufacturing. The process involves the disassembly of products, during which parts are cleaned, repaired or replaced then reassembled. It can often be costly, time consuming and labour intensive. But 3D printing could change that.

"Remanufacturing is more efficient than recycling because only a small portion of the part needs to be remade instead of the entire thing," Dr Jason Jones, co-founder and chief executive of Hybrid Manufacturing Technologies, told *The Engineer*.

Remanufacturing recaptures the value given to the product when it was first manufactured. While it is an ideal solution in terms of cost and energy, for older machines it can prove difficult to get the needed parts to replace those that are worn or broken. That is where 3D printing can help.

Jones claims that a specific type of 3D printing based on automated welding, known as directed energy deposition (DED), is the ideal technology for adding back missing, broken or worn portions of metal parts. A directed energy deposition machine is usually made up of a nozzle placed on a multi-axis arm, which deposits melted material onto the surface, where it hardens. In some ways, it is similar to material extrusion, but the nozzle can move, allowing the material to be deposited from any angle.

The DED process is usually used with metals in the form of powder or wire, but it can be used with polymers and ceramics. For remanufacturing, it could help create intricate parts in a fraction of the time, or be used to make custom parts that are no longer in production elsewhere. "The remanufacturing of mechanical



Toolbox: Hybrid's AMBIT system combines traditional and non-traditional techniques

parts that wear out as they rotate are ideal candidates for 3D-printed repair," said Jones. "Often they are manually repaired by welding and grinding. However, 3D printing offers a new level of automation for these activities."

Examples of these parts include the bearing surfaces on shafts, impellers for turbochargers, and blades, vanes and blisks for various types of turbines. Normally these rotating parts are associated with power generation and transport, particularly aerospace.

DED is not ideal for highly detailed internal complexity that is commonplace in other types of 3D printing

Dr Jason Jones, Hybrid

But directed energy deposition (DED) is not a perfect solution. "The DED approach is not ideal for highly detailed internal complexity that is commonplace in some of the other types

of 3D printing, such as powder bed fusion," warns Jones. "There is also a limit to how hot you can get a part before it begins to deform. For that reason, DED is most successful right now where only a small portion of the part is hot at any given time; nevertheless there is a desire to increase the rate of deposition."

These technical limits are being addressed by a growing number of projects. For instance, the creation of software that anticipates the hotspots and high stress points and compensates for them is an area of research at Lawrence Livermore National Labs in the US as well as start-up 3DSIM. Lawrence Livermore National Labs is currently using its computer modelling expertise to predict component performance of 3D-printed parts over time, particularly those created using novel techniques.

Meanwhile, Darpa's Open Manufacturing project is attempting to assess how 3D-printing technologies change the performance of the final product. Its project will address the technical challenge of 3D printing for remanufacturing, among other things, by building computer models and 3D-printing technologies that they say will be able to capture, analyse and control variability in the manufacturing process to predict the properties of the final part. ->

inbrief

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Airbus uses Stratasys FDM systems

Airbus has produced more than 1,000 flight parts on Stratasys FDM 3D production systems for use in the first-of-type A350 XWB aircraft. The 3D-printed parts were used in place of traditionally manufactured parts to increase supply chain flexibility. Airbus initiated development of 3D printing with Stratasys in 2013 as a schedule risk-reduction activity that proved valuable for the A350 XWB programme. The parts are 3D printed using ULTEM 9085 resin for FDM. ULTEM 9085 resin provides a high-strength-to-weight ratio and is flame, smoke and toxicity compliant for aircraft interior applications. This enables Airbus to manufacture strong, lighter-weight parts while reducing costs.

Windform materials reach space

Components produced by 3D printing specialist CRP have made it into orbit aboard KySat-2, a CubeSat developed by students at Kentucky University and Morehead State University. CRP produced five parts that are incorporated into the deployable solar panels on KySat-2: camera annulus, lens cover, deployable extensions, antenna clips and battery holders. The parts were made from Windform XT 2.0, a material filled with carbon fibre that offers maximum mechanical performance for 3D-printed parts. The material is said to combine maximum toughness and robustness, yet it produces a light, final part that does not affect the overall production weight of the KySat-2 unit.

UK team set to '3D print' optical fibre

Southampton University researchers are exploring the use of 3D-printing technology to produce optical fibre. It is claimed that the technique, which is being developed at the Zepler Institute, could enable the production of complex structures and unlock fresh applications for fibre optics. Current techniques used to produce optical-fibre preforms give a consistent structure along the length of the preform but make it difficult to control the shape and composition of the fibre in 3D. This limits the degree of flexibility engineers can exercise in the design of the fibre and, as a result, the capabilities the fibres can offer. However, the new technique, being developed by Prof Jayanta Sahu, could allow engineers to manufacture preforms with more complex structures and different features along their lengths.



Quick fix: a resurfaced vane section

"Open Manufacturing is fundamentally about capturing and understanding the physics and process parameters of additive and other novel production concepts, so we can rapidly predict with high confidence how the finished part will perform," said Mick Maher, programme manager in Darpa's Defense Sciences Office. According to Maher, the approach is an alternative to "a blunt and repetitive 'test and retest' approach that is inevitably expensive and time consuming, ultimately undermining incentives for innovation".

The biggest challenge with 3D-printed parts made for remanufacturing is that they are usually made up of tiny, micron-scale weld beads that are placed on top of each other. As these beads create a different microstructure, the 3D-printed part can have radically different properties than one created with the same material using traditional manufacturing techniques. Darpa believes that knowing how different materials behave when they are 3D printed could help counteract this effect.

To achieve this enhanced manufacturing control, Open Manufacturing is looking at 'rapid low-cost additive manufacturing' (RLCAM), which will use computer modelling to predict materials performance for direct metal laser sintering (DMLS) on a nickel-based superalloy powder. In DMLS, a laser melts the metal powder to additively build a 3D product. A separate project will combine physics- and data-based informatics models to study what might affect the quality of large manufactured structures, such as aircraft wings.

"There are a variety of sensing and other adaptive software options to help make repairing easier, since when it comes to used parts no two are exactly the same," said Jones. As well as software, Jones's company, Hybrid Manufacturing Technologies, earlier this year revealed millGrind, the world's first hybrid grinding machine. The technology could help make parts for remanufacturing stronger and more complex.

The millGrind is a continuous-dress creep-feed grinding machine that comes with laser

cladding and milling capabilities. This system lets users perform grinding with additive manufacturing in a single setup. It aims to offer flexibility so manufacturers can reduce the number of setups needed to get to finished parts, particularly in aerospace and marine applications. This will aid organisations such as the navy, which is considering using rapid prototyping for applications to repair parts aboard ships.

It isn't just Earth-bound applications that will benefit from better-performing 3D-printing technologies for remanufacturing. Last year, an astronaut on the International Space Station

“A blunt and repetitive ‘test and retest’ approach that is expensive and time consuming, undermining incentives for innovation

Mick Maher, Darpa

used a 3D printer to make a socket wrench in space. Eventually, space agencies are hoping that digital code will replace the need to send tools and spare parts into orbit.

"For the space station even, [3D printing] will decrease risk, decrease cost and increase efficiency," Niki Werkheiser, 3D print project manager at Nasa's Marshall Space Flight Center, said late last year. "But for longer-term missions, for space exploration, this is absolutely a critical technology."

Jones is hopeful the limits of technologies such as DED will soon be overcome using smart software tools and hybrid machines. Whether in space or on the factory floor, 3D printing, he said, may have just found the niche its needs to finally deliver on its promises. ©

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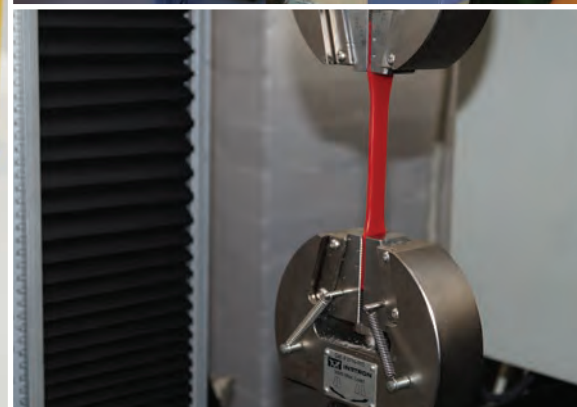
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KySat-2: Small Sat successfully launched into orbit - Image courtesy of Kentucky Space LLC.

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The northern way

This year's free-to-attend industrial technology and electronics show will highlight the region's major supply chain strengths

Northern Manufacturing & Electronics, a free-to-attend industrial technology and electronics show, returns to EventCity, Manchester, from 30 September to 1 October 2015. This year's event is expected to be significantly larger than last year, and will present a new feature, called RoadRailAir, highlighting the region's major supply chain strengths to the automotive, public transport and aerospace manufacturing sectors.

The event has quickly become established as one of the most important shows in the north for engineering and manufacturing. Further growth in the size of the show this year means that visitors to Northern Manufacturing 2015 can expect to meet an even broader selection of suppliers, ranging from local specialist firms to major international companies. Companies including Amada, BAE Systems, LCL Electronics, igus UK, Kuka Robotics, Olympus, Nikon Metrology, Yamazaki Mazak and TRUMPF are among the more familiar names represented. The show follows the format of the extremely successful Southern Manufacturing & Electronics Show, which now ranks as the top annual engineering show in

the UK, attended by many hundreds of companies, including some of the largest machinery and industrial equipment manufacturers in the world.

A new feature for Northern Manufacturing 2015, RoadRailAir, will highlight the region's major supply chain strengths to the automotive, public transport and aerospace manufacturing sectors. The show's regional focus allows easy access from across the north, the Midlands, Scotland and Northern Ireland – areas where these key activities are strongly represented.

But thanks to its unique exhibitor mix of machinery and production equipment, components, electronics and subcontract services, the Northern Manufacturing show has proven itself to be immensely popular with visitors from across the entire spectrum of manufacturing enterprise.

Technology trails guide delegates around the event, making it possible for them to make the most effective use of time at the show. Subcontract services presented include 3D design, electronic assembly, subcontract manufacturing, tool making and production equipment. The show is also set to feature



many big-name machinery manufacturers such as Amada, Bystronic and Haas Automation giving live demonstrations throughout the two-day event.

Business services are also widely available at this year's show. STEGTA, the training and apprenticeships facilitator, will be on hand to discuss visitors' apprenticeship and training needs. Trade bodies, such as the North West Aerospace Alliance, will be available to give information on subjects such as funding and project delivery support. Financial support companies covering issues such as asset finance and tax will be available along with numerous other experts in fields such as barcode solutions, waste management, electronic design and manufacturing software, patent and trademark advice and 3D printers. Companies delivering industrial cleaning, industrial consumables, machine services, stock control products and consumables are exhibiting at the show in the works management and maintenance category.

The free seminar programme is an additional incentive to head to EventCity. During a busy two-day programme, presenters from various notable organisations will speak on a wide variety of technical and operational topics in a series of hour-long sessions running over both days of the show.

As with the show itself, entry to the seminar sessions is free, making this an outstanding opportunity to listen to world-class presenters illustrate the latest ideas in manufacturing, engineering and industrial management.

Entry to Northern Manufacturing & Electronics 2015 is completely free to business visitors, and EventCity offers 3,000 free on-site car parking spaces, with easy access by road, rail or air. To register online for tickets, or to find out about exhibiting at this unique event, simply visit www.industrynorth.co.uk.



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The hidden value of patents

Those who read the technology or business sections of the newspapers will likely be familiar with the "mobile phone wars" taking place between major mobile phone and software manufacturers around the world.

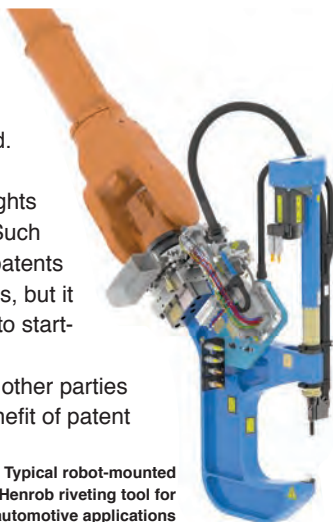
In a series of high-stakes legal battles, these companies have asserted their own patent rights and challenged the patents held by others. Such high profile cases make it easy to think that patents are the preserve of billion-dollar multinationals, but it is important not to underestimate their value to start-ups and SMEs as well.

A patent gives an inventor the right to stop other parties from stealing their idea, and an important benefit of patent protection is the ability to claim damages if a competitor uses your invention.

However, in many cases the true value of a patent lies in the battles that you do not have to fight – the existence of a granted patent, or even a pending patent application, is often enough to dissuade another party from seeking to capitalise on your hard work.

One company that uses patent protection to great effect is Henrob Limited, an engineering company in Flintshire, North Wales. Henrob is a pioneer in self-pierce riveting, a cold joining process used extensively in the automotive sector. Marks & Clerk has worked closely with Henrob for over two decades, protecting their products and inventions so that competitors cannot exploit Henrob's extensive R&D investment by copying their ideas.

Typical robot-mounted
Henrob riveting tool for
automotive applications



Henrob has also generated direct revenue from its patent portfolio. After patenting key improvements in the field, it licensed this technology to third parties. The company has therefore made a profit not only from the equipment that it sells, but also from equipment sold by other companies. Henrob's patent portfolio was also a positive factor in the discussions that led to the company winning a multi-million pound contract with a major automotive manufacturer, and in negotiations over Henrob's recent acquisition by Atlas Copco AB, based in Stockholm, Sweden.

Other Marks & Clerk clients have used their patents to secure investment, as collateral on a loan, to establish the rightful owner of an invention after departure of an employee, and to secure a lower rate of corporation tax through HMRC's Patent Box scheme. Filing a patent application also establishes a date on which an invention was known, preventing other parties from seeing the idea and seeking to patent it themselves.

There are a great many ways in which patents and other intellectual property rights can be beneficial. In order to make the most of these rights, a business should follow a carefully planned strategy which ensures that new ideas are identified early on, and that the protection obtained is in tune with the organisation's commercial objectives.



Tom Warner is a mechanical engineer who now works as a patent attorney in Marks & Clerk's Manchester office. Marks & Clerk works with organisations of all sizes, and offers services covering every aspect of patents, trade marks, designs, domain names and copyright. If you would like more information, Tom can be reached at twarner@marks-clerk.com or on +44 161 233 5800.

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Making a stand

Exhibitors will showcase a variety of new products and services

Kabelschlepp Metool

Kabelschlepp Metool will be showcasing Robotrax, a durable cable carrier designed to ensure maximum freedom of movement for industrial robots. Together with the quick-release brackets, it forms a robust and durable system that is claimed to meet all requirements of this special application. The cable carrier itself consists of individual plastic links with spherical clips attached to both sides, which support the three-dimensional swivel and circular movements of the machines. The forces are transmitted via a steel cable at the centre, making it suitable for extremely high towing forces and accelerations.

Minitab

Quality improvement software specialist Minitab will be demonstrating a range of statistical analysis tools that are used worldwide to decrease waste, improve products and increase customer satisfaction. Minitab products are used extensively in quality initiatives such as Lean and Six Sigma. Products on show will include Minitab Statistical Software, which according to the company has been used in virtually every major Six Sigma initiative around the world, and Devize, which is claimed to be one of the most useful, intuitive and usable Monte Carlo simulation software tools on the market.

Quickgrind

At this year's show, Quickgrind will demonstrate its innovative high-speed machining (HSM) techniques and its unique remanufacturing approach. As a world leader in industrial carbide cutting tool manufacturing, Quickgrind's expertise in HSM, remanufacture and tool management can greatly reduce machining cycle times, cut costs and ensure process stability. This is among the improvements recently demonstrated by OPEN MIND Technologies and Quickgrind at their joint hyperDAYS events at Mazak, through which the partners heralded 'a new dawn of milling innovation'.

ECi Software Solutions

ECi will be demonstrating how its M1 software can be used to improve processes and maximise profitability. Designed to meet the rapidly changing needs of manufacturers, ECi M1 is an intuitive software solution designed for SME manufacturers who need flexibility as well as functionality. Visitors to ECi Software's stand will learn about the latest new features, mobile apps and customer self-service portal and get to see the powerful product configurator in action. Visitors will also learn how it will minimise pricing challenges, save time and reduce potential errors.

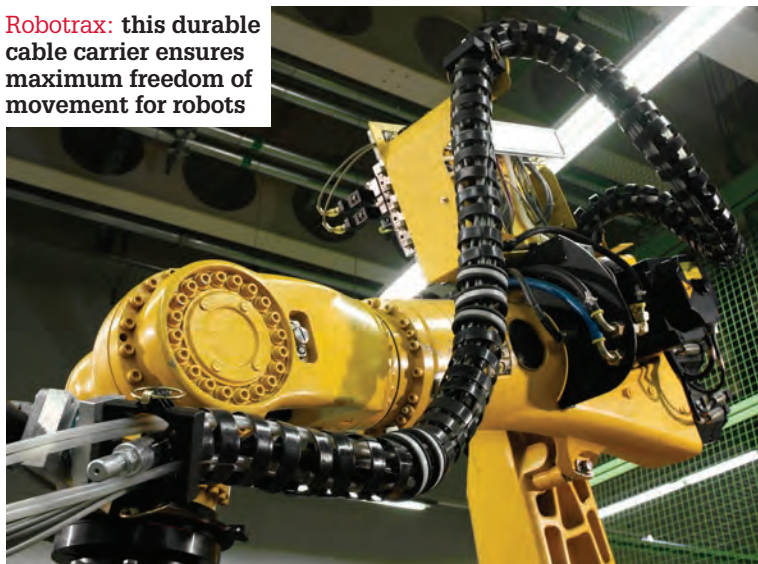
Marks & Clerk

The protection of intellectual property (IP) is of critical importance to maintain a competitive advantage, and advisers from Marks & Clerk will be on hand throughout the event to offer practical advice on patent issues. Patent attorney Peter Roberts will be presenting a special session entitled 'How to adopt a successful IP strategy to harness your competitive advantage', while visitors to the Marks & Clerk stand (D31) will be able to book complementary one-to-one IP sessions and discuss any issues or challenges with regards to IP-related matters.

Blue Diamond Technologies

Blue Diamond Technologies offers a complete design, engineering and manufacturing service for a wide range of mechanical components and assemblies, including machined components, cast parts and components in plastic and rubber. On its stand (F27), the company will have examples of many parts currently in production together with working engineers able to discuss how a visitor may take advantage of its expertise.

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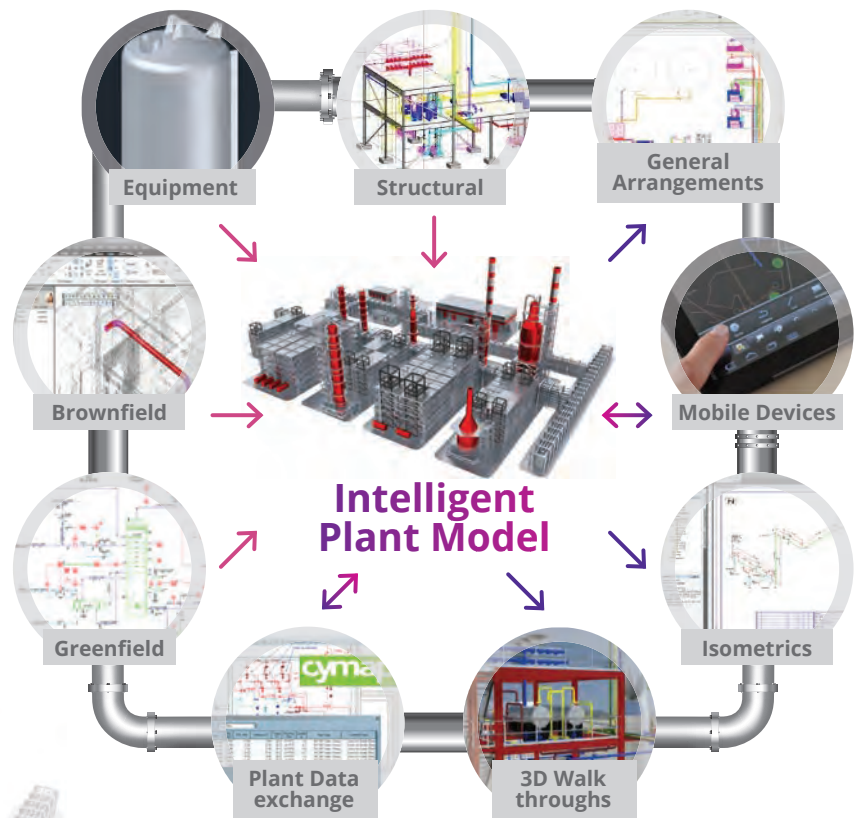
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CONSULTANCY

The right environment

With environmental engineers in high demand, several UK universities are now offering short courses to help deliver key skills. Evelyn Adams reports



High fliers: Cranfield is set to offer a short course on UAVs for environmental monitoring

Environmental engineers need to keep up with rapid changes in technology, legislation and policy. The sector is increasingly multi-disciplinary and many professional bodies now expect their members to keep continuing professional development (CPD) records to show they have current knowledge in the field. To meet that demand, a number of UK universities have begun increasing their environmental engineering CPD short-course offering.

For instance, Cranfield University's upcoming 'Unmanned Aerial Vehicles (UAVs) for Environmental Monitoring' short course will look at the main principles behind UAV flight control, data capture, image processing and environmental applications. Running from 27–31 July, the course is targeted particularly at governmental organisations, researchers and environmental consultants. Theoretical concepts will be covered in the first two days, and the remainder of the time will cover case studies based on environmental applications.

Cranfield University is offering courses this year in 'Principles of Sustainability', 'Risk and Reliability Engineering' and 'Environmental Valuation'. It also offers an online course named 'Principles of Cost Engineering', which aims to give students an understanding of cost in the context of the business of environmental engineering. The course is delivered through Blackboard, an online learning system, in the form of a narrated PowerPoint presentation and video.

Surrey University's Centre for Environmental Strategy is running several CPD short courses in environmental engineering this year. They will provide both a theoretical and practical understanding of environmental problems, such as lifecycle assessment and waste management. There are three CES programmes that can be taken full or part time, and are taught through intensive, week-long modules.

Students will also complete a dissertation, and have the option of a placement in industry.

In the past, several high-profile guest lecturers have assisted with the delivery of modules. For example, Jonathon Porritt, former chairman of the Sustainable Development Commission, usually acts as a guest lecturer on the Sustainable Development Applications module.

Nicki Ledger is a former student in Corporate Environmental Management and is now working as a sustainability officer for the city of Melville. "I originally completed a degree in Biology, but found it very hard to get into the environmental industry without specialised knowledge," she explained.

Studying the MSc in Corporate Environmental Management provided me with a mix of skills

Nicki Ledger

"Studying the MSc in Corporate Environmental Management at Surrey provided me with a mix of theory and practical skills."

At Newcastle University, students have the option of taking nine different short courses, including 'Core Concepts in Environmental Engineering', 'Groundwater Contamination and Remediation' and 'Environmental Engineering for Developing Countries'. "We have designed courses that involve typically one to five days away from the workplace," the university said. The courses are taught on site, and many are modules on taught Masters programmes in Environmental Engineering.

The Faculty of Engineering at Leeds University has a dedicated CPD unit that offers

a range of short courses designed for people in industry. Within environmental engineering, it offers five short courses in subjects covering carbon capture and storage and industrial air pollution. The university is also offering a new course named 'Industrial Liquid Mixing'. The two-day short course outlines the fundamentals and technologies of liquid mixing.

At Imperial College London, the range of environmental engineering CPD short courses includes 'Chemistry for Environmental Engineering', 'Environmental Fluid Mechanics', 'Hydrological Processes' and 'Irrigation'. The 'Chemistry for Environmental Engineering' course forms a part of the core teaching delivered to Masters degree students taking the Environmental Engineering, Environmental Engineering and Business Management and Environmental Engineering and Sustainable Development programmes. The course is delivered in the autumn term as a set of 10 lectures.

The UK continues to have a shortage of engineers and scientists, particularly in the environmental engineering sector. Students on these courses can expect to be highly sought after by employers. And you could be rewarded for the extra time spent on CPD courses.

According to government figures, starting salaries for environmental engineers range from £20,000 to £30,000 a year. With experience this can rise to between £35,000 and £60,000 a year. With extensive experience, senior energy engineers can earn around £80,000. Joining a professional engineering body such as the Energy Institute may help your career prospects. As well as professional development support, benefits could include events, seminars and conferences to help keep you up to date in the sector. ©

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Job security

The growing threat of cyber crime is creating a wide range of career opportunities for engineers. **Helen Knight reports**



The cyber attack on Sony Pictures late last year revealed not only the lengths that determined hackers will go to in targeting a company, but also the devastating impact they can have.

The aggressive attack, by the hacker group Guardians of the Peace, was intended to damage and publicly shame the company. It resulted in the publication of millions of private emails, as well as personal information about the company's executives, and stars such as Ben Affleck.

Such attacks also reveal weaknesses in corporate cyber security, and the way in which companies and governments respond to the threat presented by today's sophisticated breed of hackers.

Engineers working in the cyber security field are at the front line of efforts to protect countries and private companies from attacks by hackers and digital criminals.

Cyber-security engineers can be involved in anything including managing networks to keep hackers out, testing networks to assess their vulnerabilities and forensic analysis of attacks and new malware to understand the nature of a threat. They can also be involved in advising

“ Elements of cyber-security divisions are becoming the norm where world-class R&D is being carried out

Jim Wheeler, Protection Group International

companies and government departments on the latest threats, as well as how to better protect themselves.

Unfortunately, every organisation has something worth stealing, particularly if it has great ideas, according to Jim Wheeler, director of cyber operations for Protection Group International (PGI), a UK-based risk management specialist.

“Elements of cyber-security divisions are beginning to become the norm in the areas where world-class R&D [research and development] is being carried out,” he said. “The most efficient deep-sea drill bit, the strongest engine, the lightest battery, the best compression algorithm: they all need their future revenue streams protecting.”

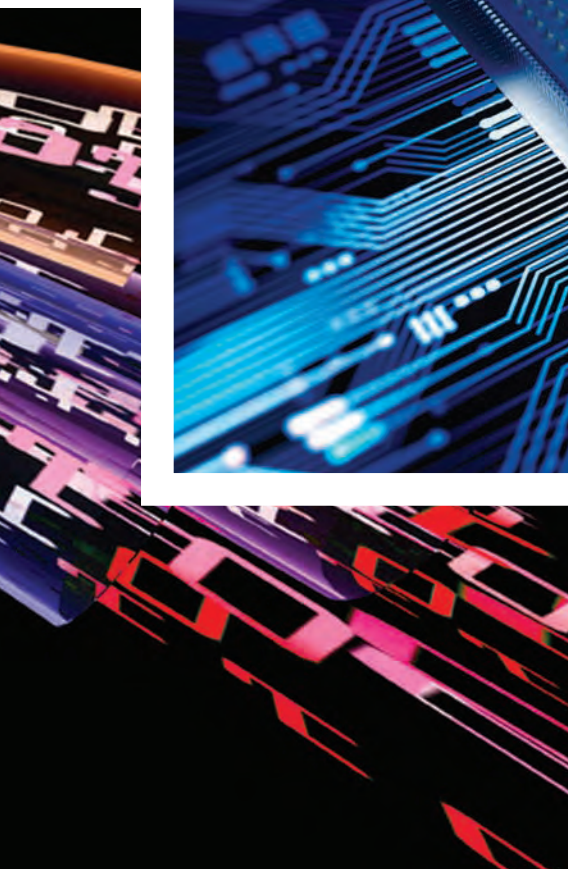
Countries can be attacked via their financial systems, utilities or ability to process and deliver information, including through both governmental and commercial organisations,

according to Elaine Baker, engineering director at BAE Systems Applied Intelligence.

“We protect a lot of companies across a variety of industries, starting with what might be termed ‘critical national infrastructure’,” she said.

“We protect against all kinds of threats, including insider trading at banks and financial institutions, fraud, money laundering, hacking, phishing and the like – what might generally be termed old-fashioned cyber crime or cyber terrorism.”

Increasingly, cyber-security firms such as BAE Systems are also looking at digital criminality, or the perpetration of major crimes using modern tools, said Baker. “It's easier and far safer for career criminals to commission malware writers and hackers to build a tool that lets them skim a tiny amount from hundreds of thousands of bank accounts than it is to run, armed, through the door



of a bank branch – but the end results are often the same,” she said.

The company’s cyber-security team helps its customers guard against advanced cyber attacks. These are often extremely targeted hacks specifically tailored to that organisation – as was the case in the Guardians of the Peace attack on Sony.

However, unlike the Sony attack, in many cases the intent is not to humiliate the targeted organisation, but to steal valuable intellectual property or other information, or to disrupt their operations.

Engineers working at BAE Systems Applied Intelligence develop advanced technology-led security systems, according to Baker. This includes protecting an organisation’s email systems.

Email is one of the most widely targeted systems, and 70–90 per cent of malware is designed specifically to attack a given organisation, Baker added.

“That means so-called ‘Zero Day Attacks’ – attacks that are entirely new and that haven’t been seen before – are being made against a much wider variety of organisations,” she explained.

On an average day, engineers working in cyber security could be designing and building sensors to identify malware signatures, or handling and analysing data. In particular, cyber-security engineers need to be able to understand the movement of data and the mechanisms used to move and act on it, and then understand and analyse its impact, according to Baker. “In essence, the skills needed are core engineering skills,” she said.

Engineers working in the sector need detailed information and analysis skills, with experience in understanding data and spotting patterns within that data.

“Another important skillset is the ability to predict outcomes based on information we review and enhance,” Baker added.

More and more graduates are finding the idea of working in cyber security appealing, and as a result BAE Systems has seen a high level of interest in roles at its Applied Intelligence arm, she said.

The company recruits professionals at all levels, including software engineers and design specialists, who work with client organisations and within the Applied Intelligence research laboratories, she explained.

Across the industry as a whole, however, there is a significant shortfall in the number of properly qualified cyber-security professionals both in the UK and globally, and many top

companies are struggling to recruit the staff they need, according to Stephanie Daman, the chief executive officer of the Cyber Security Challenge – a programme of national competitions and education and networking initiatives designed to encourage people to enter the profession.

That is not because the UK does not have talented individuals who could do these jobs, but rather because many of those with the right skills are self-taught and do not therefore have formal qualifications, she said.

“As cyber security is now fundamental in ensuring that we trust the online services that have become so much part of our lives, the disconnect between the talent we know is out there and the right number of properly qualified individuals in cyber security roles is hugely worrying,” added Daman.

Academia is helping to address this need, with graduates in ethical hacking, information security and cyber security beginning to enter the workplace, according to PGI’s Wheeler.

But specialists are also moving across from IT roles, network engineering and software design into the cyber-security field, he said.

In 2014, PGI also launched its own Cyber Academy, in a bid to help bridge the skills gap. Good cyber-security engineers need knowledge, attention to detail and integrity, according to Wheeler.

Ultimately, though, all engineers will need to be aware of the dangers of cyber crime, he said.

“Both cyber crime – crime committed purely on computers – and cyber-enabled crime – crime that is helped by the use of computers, such as illegal-substance logistics, fraudulent purchases and credit-card detail theft – have grown exponentially,” he explained. “So much so that we all need to become more aware of the risks and have an embedded cyber-security strategy.” ©

“ Another important skillset is the ability to predict outcomes based on information we review and enhance
Elaine Baker, BAE Systems



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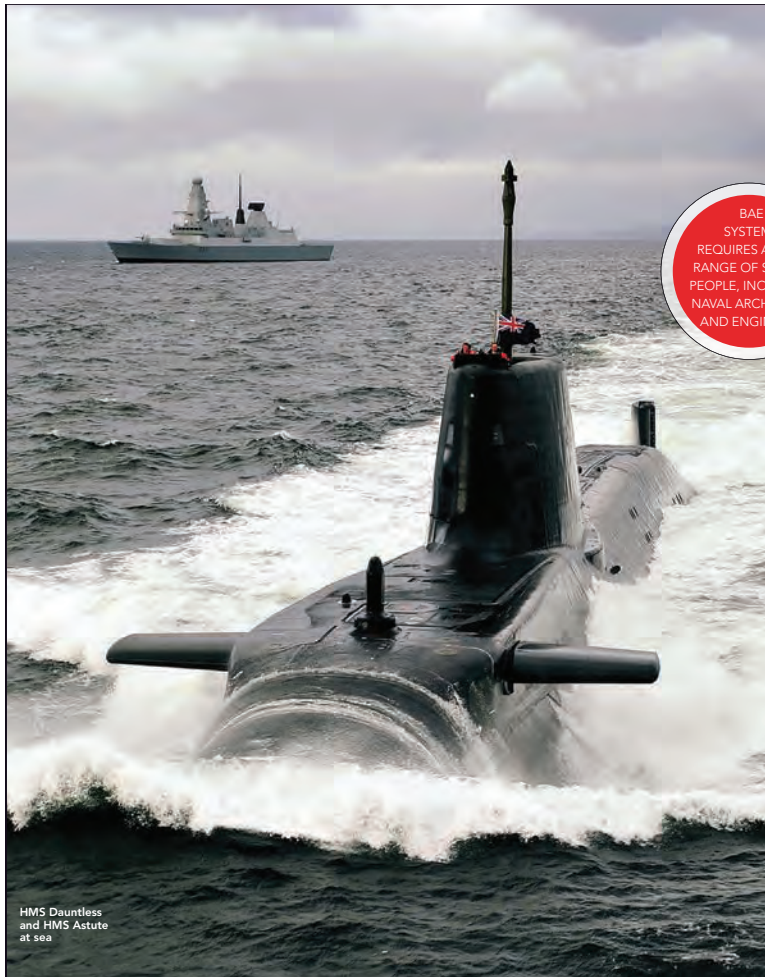
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- Mentoring and developing the senior staff in sales techniques
- Achieving and surpassing revenue targets
- Up-selling and cross selling additional services and solutions
- Bid presentation at board level
- Creation of management reports

Technical Skills/ Experience

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- Experience managing multiple bids simultaneously within the engineering field
- Word and PowerPoint at an intermediate to advanced level
- A good standard of literacy and numeracy is essential

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Role requires UK based travel on a regular basis. The successful candidate must expect to be off site 2/3 days per week.



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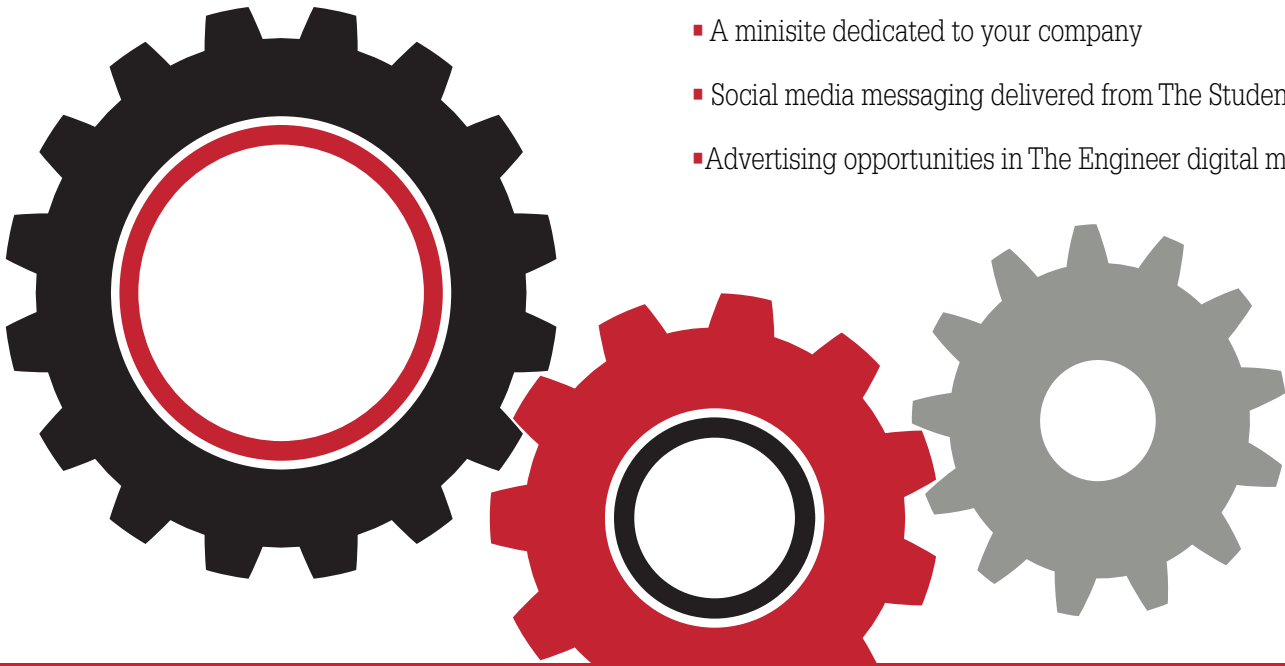
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july 1909

The Engineer reported on Hubert Latham's unsuccessful attempt to cross the Channel

The early 20th century was awash with milestone aeronautical achievements, but in July 1909 *The Engineer* reported on one of the sector's more ill-fated landmarks: Hubert Latham's attempt to make the first cross-channel aircraft crossing.

Latham attempted his crossing in a monoplane dubbed Antoinette IV that had been designed by French inventor Leon Levavasseur. The aircraft was equipped with a 50hp eight-cylinder petrol motor equipped with a novel cooling system that used the radiator as part of the structure of the aircraft.

"Sangatte, the French terminus of the abandoned Channel Tunnel, was chosen as the starting point, the aeroplane intending to land at Dover," wrote *The Engineer*. "At a quarter to seven, having made all the necessary preparations, Mr Latham ascended in his machine, and after executing a wide circle round Sangatte headed for Dover."



The article reports that, after travelling around eight miles, the "machine was seen to be gradually descending in a long straight line to the surface of the water", where it eventually

landed and was rescued by a torpedo boat that was following Latham's progress.

The Engineer wrote that, despite ultimately being unsuccessful, "sufficient was done to demonstrate the possibility of success

“The machine was seen to be gradually descending to the surface of the water

and the suitability of Mr Latham's type of machine for this particular purpose."

What's more, Latham did at least earn the distinction of becoming the first

person to land an aircraft on a body of water.

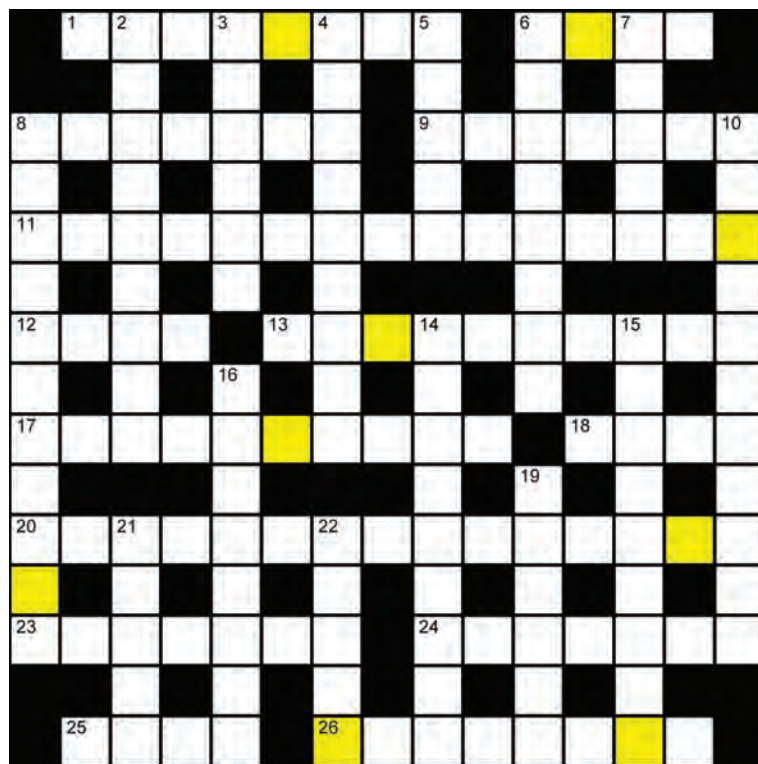
The article said: "There are more or less always, over any large stretch of water, vertical currents of air that must naturally render the condition of the problem of flight somewhat more complicated than in their absence." As for the cause of the accident, Latham put it down to the effect of salt in the air on the carburettor.

Latham made a second unsuccessful attempt a few days later, but had by then been pipped to the post by Louis Bleriot, who made the first successful crossing of the channel just days after Latham's initial attempt. **JE**

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

prize crossword

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



ACROSS

- 1 Expanded and contracted rhythmically (8)
- 6 Total spent for goods or services (4)
- 8 Order imposing a trade barrier (7)
- 9 Device that produces light when current flows between two electrodes (3,4)
- 11 Worker on the train lines (7,8)
- 12 Large and imposing house (4)
- 13 Fraught with danger (5-3-2)
- 17 Protect by insurance (10)
- 18 Flat surface that rotates and pushes against air or water (4)
- 20 Colliding with an obstacle (8,7)
- 23 Hole from which a fine coarse material is removed (7)
- 24 In a cheap manner (7)
- 25 Replace a broken part (4)
- 26 Unit of area equal to 100 acres (8)

DOWN

- 2 Not restrained or controlled (9)
- 3 Marked by practical hard-headed intelligence (6)
- 4 Common measure of timber (3-2-4)
- 5 Empty of liquid (5)
- 6 Recurring in oscillations (8)
- 7 Sturdy hand shovel (5)
- 8 Violent natural tremors (11)
- 10 Important dock with customs officials (4,2,5)
- 14 Emotionally purging (9)
- 15 Tube through which liquid is carried away (9)
- 16 Equipment used to help slow a vehicle (5,3)
- 19 Commonly repeated word or phrase (6)
- 21 Unit of weight equal to 28.349g (5)
- 22 A V-shaped indentation (5)

Last issue's highlighted solution was **PALISADE**. The winner is **Anthony Lee**.

originengineering

Anthony Poulton-Smith explores the origins of everyday engineering terms

When it comes to engineering, the **piston** is one of the fundamental parts of an engine. During the Industrial Revolution, the piston carried the water away when it performed as a pump. Today we mostly associate the piston with the internal combustion engine.

The first known use in English dates from 1704. This is a Middle French word, where piston described 'a large pestle'. Today the pestle, which always comes with a mortar, is used for grinding up herbs and spices. Traditionally, chemists used the same to grind up

ingredients for medicines. Yet, working back deeper into history, we find the Old Italian 'pistone', which came from 'pestare'. Earlier still in Latin, we find 'pistare' and 'pistus', which mean 'to pound'.

Interesting to note that 'piston' has come into use, for it could just as easily have been 'embolus'. Seen a little earlier (1660), this is derived from the Latin 'embolus' ('piston of a pump') and ultimately from the Greek 'embolus' ('peg, stopper') and a line that has given us the medical term 'embolism' when referring to an arterial blockage.

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