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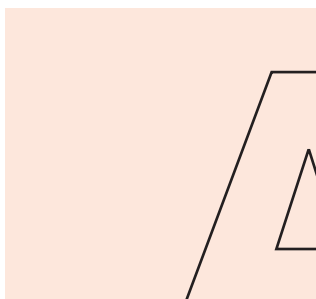
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## our opinion

# Relief in sight



At the time of writing, the European referendum campaign is entering the final, painful strait. And, amid all of the uncertainty, if there's one thing that 'Remainers' and 'Brexiters' alike can all look forward to, it's that an increasingly ill-tempered, ill-informed, and divisive debate will be over.

Over the past several months, *The Engineer* has attempted to give equal weight to both sides of the argument. But based on what we've heard over the course of the campaign it's fair to say that should voters choose to stay in on 23 June, industry's main response will be one of relief. Repeatedly, and with increasing volume, the movers and shakers of UK engineering have made the case for remaining.

The trade bodies and institutes – the mouthpieces of the engineering firms and individuals that help drive the economy – are convinced that we're better off in Europe. Seventy-seven per cent of members of the SMMT, the trade body for UK's automotive sector, favour remaining, while 86 per cent of members of the ADS Group, the industry body for the UK's world-leading aerospace and defence sectors, believe their interests are better served by staying in. And, according to surveys carried out by the MTA and EEF – the UK's two big manufacturing organisations, almost 90 per cent of members want to stay in Europe. Meanwhile, the big institutes, IMechE, ICE, and IET, have all

## "Repeatedly, the movers and shakers of UK engineering have made the case for remaining"

warned that a 'Brexit' will harm business and deepen industry's worsening skills gap. Engineering firms have been no less forthright, with a veritable A to Z of big-hitters such as Airbus, BAE, GE, Ford, GKN, Nissan, Rolls-Royce, and Toyota sounding dire warnings about the consequences of a Brexit. This caution appears to extend to the SME community, with surveys suggesting that at least half are in favour of remaining.

We're sure that there will be some organisations for whom leaving Europe makes sense. In our previous issue, Reid Steel's Simon Boyd made some valid points about the damage caused to engineering SMEs by EU red tape. But it's an argument that few organisations of note seem prepared to make and, at this stage, it seems clear which way the manufacturing sector is leaning. Whether that's indicative of a broader trend remains to be seen. ©

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## MANUFACTURING

# Mountain bike has the missing links

## Bespoke bike frames made with the help of additive manufacturing

JASON FORD REPORTS

**A** Monmouth-based company hopes to break the mould with a bespoke mountain-bike frame that has come to fruition with Altair, HiETA, and Renishaw.

For £4,395 the Robot Bike Co (RBC) will build customers a bespoke frame with carbon-fibre components and tubing bonded into the double lap joints of additive manufactured lugs made from powdered titanium.

Despite the price tag, RBC maintains that the R160 fulfils criteria missing in today's mountain bikes, with AM parts allowing for customisation in a market more used to moulding carbon-fibre frames in three sizes. RBC partner Ed Haythornthwaite added that technology developments would eventually bring bespoke bikes to a wider market.

To order a frame, customers use RBC's website to input their height, inside-leg measurements and arm span, from which the size of the frame

is then calculated. A CAD model of the entire bike frame is quickly generated to ensure the optimum fit, with 11 titanium lugs built around the customers' exact requirements.

Bath-based HiETA, a specialist AM development and project engineering company, introduced RBC to project partners Altair and Renishaw, and also provided the frame's parametric CAD model. It said that 225,720 geometries are possible.

RBC said it has placed high-strength-to-weight ratio titanium in areas of maximum stress and connected them with high stiffness-to-weight carbon composite tubes.

"One of the key things is those double lap joints," according to Haythornthwaite. "We've seen bonded frames in the past and where they fail. [By using AM] it not only reduces peel loads, but also the way we fill... the double lap joint with adhesive. When we push the joint in the tube it splurges out any excess, ensuring the [Henkel] adhesive is absolutely covered, [ensuring] the best-possible joint."

"We couldn't produce that shape by any other sculpt, basically 1mm wall thickness, [and] a very fine gap going down 25mm."

The lugs – titanium-grade Ti6Al4V – are batch processed by Renishaw with SLS (selective laser sintering) of Ti particles in the 10-45µm range prior to heat treatment and CNC machining for bearing, headset, and bottom bracket fit.

Double lap shear joints are used to avoid so-called out of plane loads and AM allows RBC to produce parts with higher aspect ratios, thinner walls and more control over wall thickness tapering compared to a cast or machined parts.

Altair was pivotal to AM part optimisation with SolidThinking Inspire helping to identify where material in the connectors could be removed to save weight and reduce the number of parts used. The simulation experts took the original three-piece chain-stay lug design to a single, hollow-walled component that is lighter, strong and requires minimal support structure during AM build.

According to Haythornthwaite, Altair's input into the R160 ensures there'll be no fatigue issues, adding that RBC would have struggled to get it to ascertain correct weight and strength ratios without Altair's topology optimisation software.

RBC said it would take around four weeks to produce a frame with the finished bike fitted with a suspension system that was designed and developed by David Weagle. 🍌

To order a frame, customers use RBC's website to enter their measurements



## AEROSPACE

# Get a grip on the waste in space

Programme works on removal of old satellites from the Earth's orbit

JASON FORD REPORTS

**T**echnology to remove satellites from space – and prevent the further build-up of man-made space debris – is currently being investigated

by a team of researchers at Strathclyde University.

The team has been awarded some €116,700 of EU funding as part of the two-year TeSeR (Technology for Self-Removal of Spacecraft) programme that is being led by Airbus Defence and Space.

According to NASA, over 500,000 pieces of space debris – made up of items including non-functioning spacecraft and abandoned launch vehicle stages – are currently being tracked as they orbit Earth at speeds of up to 17,500mph.

With a total of €2.8m in funding from the Horizon 2020 programme, TeSeR will carry out initial research for the development of a prototype of a cost-efficient but highly reliable removal module.

Dr Malcolm Macdonald, director of the Strathclyde-based Scottish Centre of Excellence in Satellite Applications,

explained that parts of large spacecraft can survive re-entry and therefore need to be de-orbited more carefully than small satellites that burn up in the atmosphere.

"So large spacecraft may require a propulsion-based system, while small

category that would need a non-propulsion based system.

An additional element to the project is to investigate any future platform's function as a removal back-up in the event of loss of control of the spacecraft.

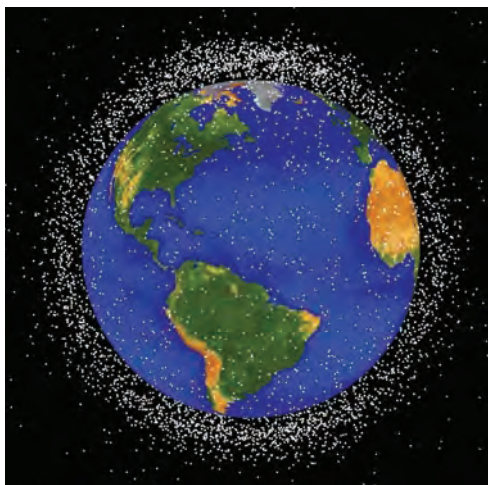
Macdonald added that the most efficient means of removing a functional spacecraft is to use its own propulsion system, and that for the equivalent amount of fuel (or less) it would be challenging to develop a new system that duplicates this function.

"However, anomalies happen and spacecraft fail before the end of life, in this case even if the propellant tank is full it is of no use if you can't command the spacecraft to use it," he said. "In

such a case it is desirable to have a fail-safe system that can, in effect, remove the otherwise dead spacecraft. Such a fail-safe system will have a mass – and cost – impact on the spacecraft but it could be argued that by not installing such a system you would be at fault following a debris event involving your spacecraft."

Macdonald said the project will seek to develop at least one, but up to three, of the identified modular concepts to a prototype stage.

Partners in the project are: Aalborg University; Beazley Furlonge; D-orbit; GomSpace; HTG (Hyperschall Technologie Göttingen); PHS Space; Universität der Bundeswehr München; University of Surrey; and Weber-Steinhaus & Smith. The University of Glasgow is also participating on a sub-contract to Strathclyde. ©



Man-made debris surrounds the Earth

spacecraft may be able to use something else," he said, adding that the programme will prioritise solutions for sub-500kg spacecraft that operate in low-Earth orbit; the

perhaps to be expected, a worrying 12.2 per cent of those we spoke to are considering leaving industry altogether.

Unsurprisingly, the majority of those considering a change of job were primarily motivated by money (73.4 per cent), closely followed by a desire for a new challenge (69.7 per cent).

Interestingly, more than half of those surveyed said they would consider taking a position overseas – with almost 80 per cent indicating that North America and mainland Europe would be attractive destinations.

Many of the other key findings of this year's salary were roughly in line with those of last year: average salaries continue to hover around the £45,000 mark; the oil and gas sector – despite

its well-publicised troubles – continues to offer the highest levels of pay; and industry's gender gap still remains pronounced (just 6.5 per cent of respondents were female).

This year's survey is published in partnership with technical recruitment specialist Matchtech. Commenting on the results, Keith Lewis, Matchtech managing director, said that with 40 per cent of respondents aged 50 or above, the survey highlights the growing need for concerted action on the sector's skills gap.

This year's survey attracted replies from 3,698 engineers working across a variety of sectors – one of the largest surveys of its kind in the UK. ©

Turn to p32 for the full results

## Newsinbrief

### Rotherham advances

Sajid Javid, secretary of state for business, innovation and skills, has officially opened a new 32,000-square-foot facility at the 100-acre Advanced Manufacturing Park in Rotherham. The new building offers specialist office and workshop spaces for growing advanced manufacturing and technology companies.

### Off to the Moon

Airbus Defence and Space is to develop and supply a guidance system for the Russian Luna-Resource lander, scheduled to land on the Moon around 2024. PILOT (Precise and Intelligent Landing using Onboard Technologies) is an autonomous autopilot that will guide the robotic lander into a safe landing spot. Luna-Resource will survey the effects of solar wind on the Moon's surface and determine the composition of lunar soil.

### Flight of autonomy

Sikorsky has undertaken a 30-mile autonomous flight using an S-76 helicopter controlled by a tablet device. The flight is said to complete Phase 1 of an \$8m award from the US Defense Advanced Research Projects Agency's Aircrew Labor In-Cockpit Automation System (ALIAS) programme.

### On the launchpad

GKN Aerospace is to develop and manufacture advanced rocket engine subsystems for the Ariane 6 launch vehicle. The contracts cover subsystems for the main (VULCAIN 2.1) and upper (VINCI) stage engines for the European Space Agency-led rocket launcher. GKN Aerospace will provide five subsystems for each Ariane 6 rocket, including four turbine assemblies for the two engines, generating power for the hydrogen and oxygen fuel systems.

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## SALARY SURVEY

## Change is on the horizon for UK engineers

Survey results suggest sense of dissatisfaction

JON EXCELL REPORTS

Nearly half of UK engineers are considering a change of job, according to *The Engineer's* 2016 Salary Survey (see p32). While high levels of mobility between engineering sectors is

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## MEDICAL

# Prosthetic limbs walk and talk

**Sensors that allow joints to 'communicate' have revolutionised movement** HELEN KNIGHT REPORTS

**A** robotic limb equipped with knee and ankle joints that constantly 'talk' to each other, allowing the leg to adapt to its environment, has been nominated for the 2016 MacRobert Award.

Dubbed Linx, the prosthetic limb is one of three finalists for the £50,000 prize, awarded by the Royal Academy of Engineering.

The Linx, developed by prosthetics specialist Blatchford, is the first limb to be equipped with integrated robotic control of the knee and foot, in which the two joints work together in the same way as a human leg.

An array of sensors across the knee and ankle continuously collect data on their surrounding environment, and the terrain on which the wearer is walking or standing.

A central processor collects this information and uses Mi<sup>2</sup> (Motion integrated intelligence) software to adapt the position of the knee and ankle in response, according to Prof Saeed Zahedi, technical director at Blatchford.

"We use a whole array of sensors to sense the environment, whether the person is standing, sitting, walking on

the flat, going up or down a ramp, or up or downstairs," he said. "We can then use information from those sensors that are measuring the ankle function to instruct the knee, and use the knee sensors to instruct the ankle, so there is a continuous dialogue between the two joints."

Prosthetic limb wearers use a considerable amount of concentration and energy in just keeping steady while standing still, leading to lower-back pain and hip problems, according to Zahedi.

Linx senses when the wearer comes to a standstill, and automatically locks in position. Then, when the user wants to move on, the sensors unlock the joints again. By redistributing the load more evenly at the point at which the prosthesis meets the leg, the system also helps to increase comfort, Zahedi said.

To fit a patient with the Linx, a clinician calibrates the limb's central processor using a specially developed algorithm. This process allows the limb to learn and adapt to its wearer's natural walking speed and style.

The calibration process is quicker than those for previous robotic limbs; the ankle and knee are able to communicate, allowing the smart algorithm to adjust both joints simultaneously. ©

Communication between the joints mean Linx acts more like a human limb



## COMMUNICATION

## Sailing away with BAE

**Bone conduction technology will allow America's Cup team to communicate more effectively**

BAE Systems is supporting the Ben Ainslie Racing (BAR) team in its attempt to win the America's Cup by providing it with a version of its bone-conduction communications technology.

Initially developed for the defence sector to enable soldiers to communicate on the battlefield, the technology uses the body's natural ability to transmit sound through bone. BAE Systems has now adapted the system for Land Rover BAR, allowing the sailors to keep both their ears free for external sounds, while at the same time enabling clear communication in the harsh conditions frequently experienced on board.

"We've heard from Land Rover



System combats background noise

BAR how clear and accurate communication is essential to a winning sailing team," said Mohammed Akhmad, principal scientist at BAE Systems.

"The system we have developed is able to deal with the large amount of background noise, which can affect the clarity of the speech being transmitted, and is also rugged enough to operate in the extreme conditions that sailors are regularly put through." **AW**

## AEROSPACE

## Service module for Orion takes shape in Bremen

**After completion, capsule heads to Cape Canaveral**

STUART NATHAN REPORTS

The service module for the first flight of Nasa's Orion capsule is now being assembled at Airbus Defence & Space's Bremen site.

The primary structure for the European Service Module (ESM) – the framework onto which all of the module's functional components will be attached – is now at the Bremen site, and the integration process is beginning. The first phase is the attachment of "a very large number of brackets", said Bart Reijnen, who leads the Airbus team on the module. The ESM will then be transferred to Bremen's cleanroom for the installation of propulsion systems, tanks for fuel, air and water, and systems to interface with the guidance, avionics and other computers in the crew module.

The ESM is scheduled to be completed by January 2017, and it will be shipped

to the Kennedy Space Center at Cape Canaveral in Florida soon after, where it will be attached to the crew module built by Lockheed Martin. Further testing will be carried out on the whole spacecraft before its scheduled launch on the first mission, EM-1, which will see the uncrewed module sent on a flight around the moon and back. Designed to shake down all the systems that would be needed on a crewed Lunar mission, EM-1 will take Orion further from Earth than any crew-rated spacecraft has ever been, breaking Apollo-13's record.

EM-1 is a significant mission for the European Space Agency (ESA) and Nasa, as it marks the first time that any other agency has been involved on the so-called 'critical path' of a crew-rated mission. This means that the mission cannot proceed without ESA's contribution. Although ESA has been involved with other crewed missions, none of them would have stopped the mission if it was not present. ©



Module under construction at Bremen site



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MATERIALS

# Organic hybrids boost energy flow

**Metals connected by organic ligands improve conductivity of charge** HELEN KNIGHT REPORTS

**M**ore efficient fuel cells for transportation could be developed thanks to efforts to investigate the movement of charge through a new type of material.

Researchers at Manchester and Nottingham universities have mapped the structure of a metal-organic framework (MOF) and how charge flows through it.

The performance of polymer electrolyte membrane fuel cells, used in transportation, depends on the efficiency of the electrolyte material at their centre, which controls the flow of charge between the positive and negative electrodes.

Researchers are attempting to improve the efficiency of the devices by developing smart electrolyte membranes based on materials that can facilitate the charge transfer more smoothly.

MOFs are hybrid materials made up of metals that are connected by

organic ligands. They have a number of advantages that make them potential candidates for use as smart electrolyte materials, according to Dr Sihai Yang, a group leader from Manchester University.

First, the organic ligands can be modified by adding groups of atoms, known as functional groups, such as those containing hydrogen donors, to improve the conductivity of the material, he said.

Second, since the materials have a porous structure, different small molecules that act as proton carriers can also be loaded into their pores, to further improve their conductivity.

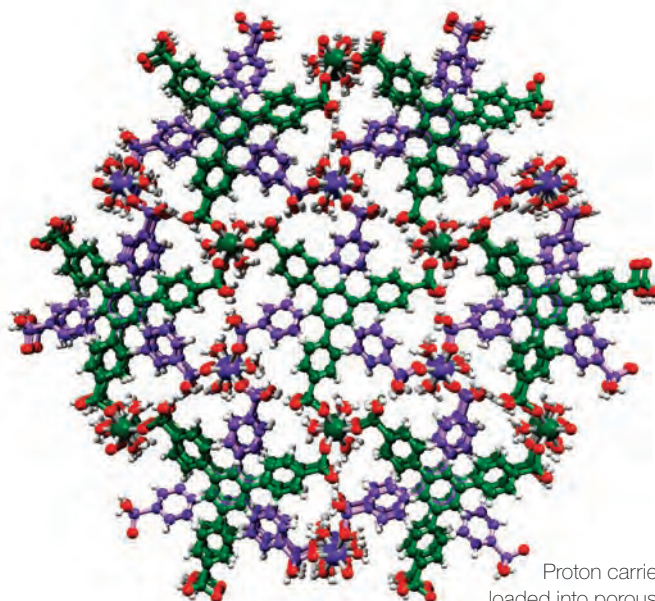
But perhaps most importantly, the crystalline nature of the materials also makes it possible for researchers to study the structure and conductivity of MOFs in precise detail, to gain a better understanding of how to improve their efficiency even further.

To this end, the research team used the powerful x-rays at Diamond Light Source, the UK's synchrotron science facility, to study the atomic structure and workings of one type of MOF material, known as MFM-500(Ni).

They then used neutrons at the Science and Technology Facilities Council's ISIS Neutron and Muon Source to map the movement of protons through the material.

They found that, contrary to previous predictions that protons moved through the material by jumping between different sites, they in fact move freely within spheres.

Within the structure of the material are a number of these spheres overlapping each other, which allows the protons to simply hop between them, said Yang. "This gives them a three-dimensional continuous diffusion pathway," he said. ☐



Proton carriers can be loaded into porous materials

"Protons can hop between spheres giving them a three-dimensional continuous pathway"

Dr Sihai Yang,  
Manchester University

AERONAUTICS

## Dry run for drone detector

**A system developed by UK firms seeks out UAVs from distances of 10km and is set for tests in the US**

The US Federal Aviation Administration is conducting airport trials of a counter-drone system developed jointly by three UK companies.

Anti-UAV Defence System (AUDS) is able to detect drones up to 10km away using Ku band electronic scanning radar provided by Essex-based Bligher

Surveillance Systems. Once detected, the UAV is tracked with infrared and daylight cameras, and specialist video tracking software. This part of the system is delivered by Chess Dynamics of West Sussex. Finally, a directional radio frequency (RF) inhibitor from Northamptonshire's Enterprise Control Systems disables the UAV.

"AUDS is able to operate effectively in complex airport environments night and day whatever the weather and without disrupting other airport equipment," said AUDS spokesman Mark Radford.

The AUDS partners said the operation, from threat detection to grounding, typically takes 8-15 seconds. **AW**

MANUFACTURING

# Waterjets cut impact on environment

**High-pressure water cutting saves energy**

GLYNN GARLICK REPORTS

Technologies and techniques that could reduce the cost and environmental impact of using composites are entering production following the completion of a European research project.

The Reform project focused on the forming, machining, assembly and recycling of composites.

The University of Sheffield Advanced Manufacturing Research Centre (AMRC) with Boeing coordinated the €7m (£5.5m) four-year project and led research into waterjet cutting and milling of composite components.

Waterjets use high-pressure water containing abrasive particles to erode materials, effectively cutting them.

AMRC designed a new cutting head and a small nozzle to increase accuracy and cutting power. CAM modules were created to optimise cutting and milling parameters.

Reform coordinator Dr Rosemary Gault, from the AMRC, said: "Manufacturing the new cutting head was really difficult. We did the design quite early on before we figured out how to actually make it.

"It's all about the geometry and the assembly. All the bits have to be assembled so that it doesn't all fly apart when the high-pressure water goes through it," she added.

The research resulted in up to 95 per cent recovery of water and abrasives, a reduction of up to 75 per cent in machine and delivery times, and less scrap.

"It's cheaper because they found 60 per cent of the cost of jet cutting is actually abrasive, so you are saving quite a lot of money," Gault said.

Nine companies and four research organisations took part in the project, funded by the European 7th Framework Factory of the Future Programme in response to the increasing use of composites in the transport and construction industries.

Work on forming using laser-assisted tape lay-up and augmented reality led to reductions in energy requirements, scrap, time and labour costs. ☐



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## MATERIALS

# A larger scope for 3D printing

**Libraries will list combinations of materials that can be used** HELEN KNIGHT REPORTS

**T**he range of materials used in 3D printing could be expanded dramatically by a UK project aiming to create a library of new formulations.

Researchers at Nottingham University, led by Prof Ricky Wildman, have been awarded a £3.5m grant by EPSRC to investigate the formulation of new 3D printing materials. As part of the project, they will also establish a series of libraries listing combinations of materials that could be used by industry in different printing techniques.

The project, one of seven EPSRC-funded research efforts investigating complex formulation processes, will attempt to expand the use of 3D printing, according to Wildman.

"It is all about widening the portfolio of materials and making it easier for people to use 3D printing," he said.

The materials available for use in 3D printing are quite limited, and are often restricted to a particular additive manufacturing technique, he added. "If you want a certain material, then you have to use a particular 3D printing process," said Wildman.

The researchers now hope to break this link between process and materials. The team is working with Morgan Alexander in the university's School of Pharmacy, to apply a high-throughput biomaterials screening technology Alexander has

developed for the study of potential materials suitable for ink-jet printing.

Materials used in ink-jet printing have particular requirements on their viscosity and surface tension, so the team needed to rapidly test physical properties of different formulations.

The screening technique rapidly prints an array of materials onto a surface. These can then be subjected to physical tests, such as atomic-force microscopy, to characterise their mechanical properties.

This should make the process

"We will very quickly be able to get a snapshot if the material is printable"

Ricky Wildman

Nottingham University

much faster than the technique of printing out an object in each new material and testing them individually.

"We will very quickly be able to get a snapshot of whether the material is printable and what its properties are, many hundreds of times faster," said Wildman.

The team plans to investigate the formulation of materials for ink-jet printing, paste extrusion and hot-melt extrusion (HME) techniques. ©

The libraries will aid 3D printing



## AVIATION

## Put the drones on alert

**Software will be able to specify 'alert regions' for the operators of drones**

Cloud-based software offering real-time air-traffic control for drones could help address safety concerns prompted by recent 'near-misses', its developers have claimed.

Airspace Alerts from UK start-up Altitude Angel enable drone operators to specify 'alert regions' that the Cloud platform monitors for low-flying manned aircraft, proactively sending a push notification via email or SMS to drone operators to ensure they have time to move out of the way safely.

The technology watches global aviation traffic, aggregating data from multiple sources. It receives around 12 million messages every minute, which are filtered to provide



Drones could be alerted to danger

updates on low-altitude air traffic flying below 800m.

"Once we have a filtered set of aircraft data, we perform analysis to determine if the aircraft's trajectory is likely to encroach on an area our users are flying within, and can tell the drone operator where to look – and when – to help them avoid being in the wrong place at the wrong time," said Richard Parker, founder and CEO of Altitude Angel. **JE**

## ROBOTICS

## Generating a buzz around flight control

**Model attempts to explain how bees use their vision**

STUART NATHAN REPORTS



Bees use optic flow to control flight

An attempt to model the way bees navigate during flight could unlock new ways of controlling the flight of autonomous aircraft and other robotic systems.

The model, created by engineers at Sheffield University, attempts to explain how bees use their vision to detect movement in the world around them and avoid crashing into objects.

It's already known that bees use optic flow – monitoring how objects appear to be moving in their field of vision – to control their flight, but precisely how they do this has always been a mystery. Study of bees' brains has only identified structures that can determine the direction of an object's motion as the bees see it, but not its speed.

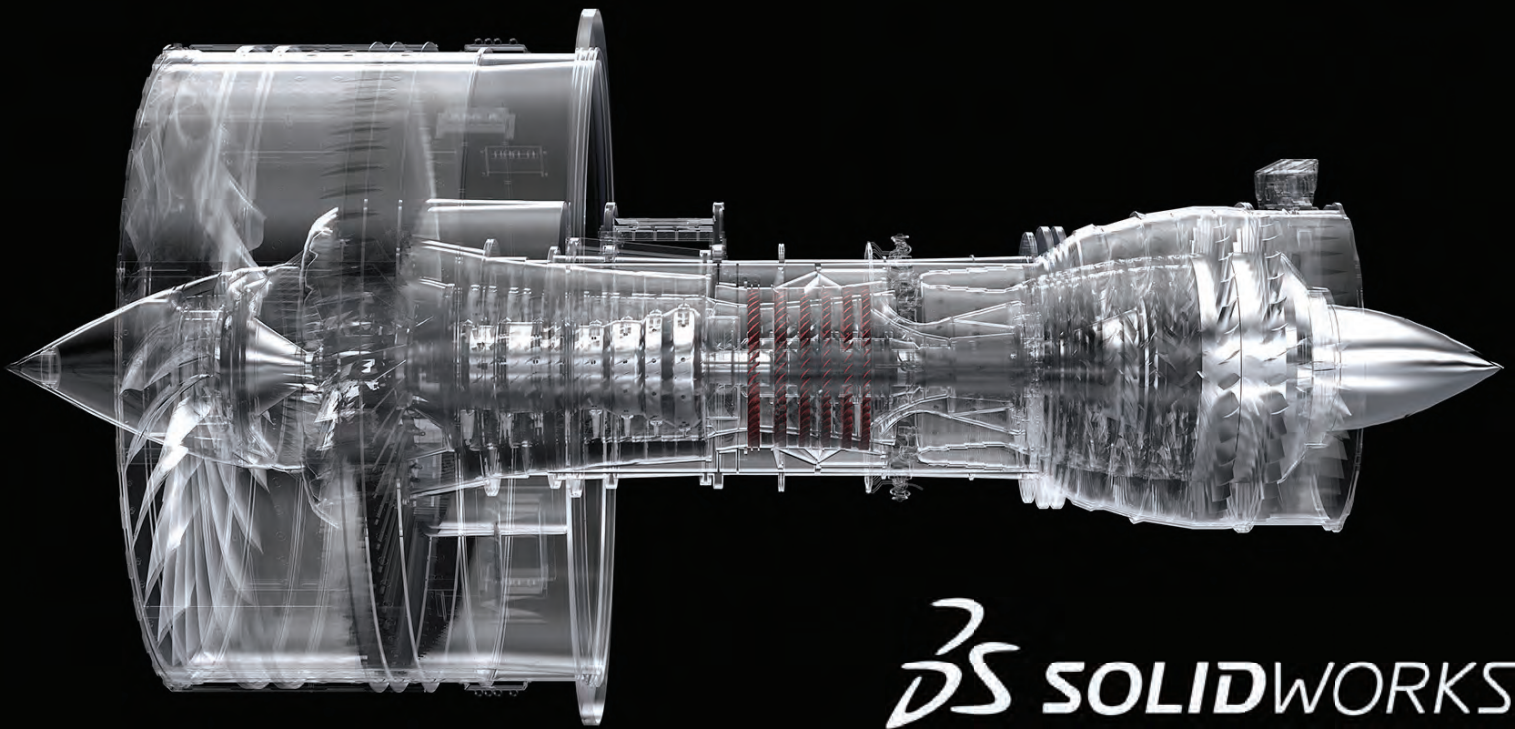
"Honeybees are excellent navigators and explorers, using vision extensively in these tasks, despite having a brain of only one million neurons," said Alex Cope, lead

researcher on the team's paper in the *Journal of Computational Biology*. "Understanding how bees avoid walls, and what information they can use to navigate, moves us closer to the development of efficient algorithms for navigation and routing – which would greatly enhance the performance of autonomous flying robotics."

Cope and his colleagues have discovered that combining the feedback of these 'motion-direction' sensing brain structures could allow the bees to sense 'motion speed'.

The team tested the theory by creating a virtual corridor whose walls were made up from a series of objects connected together. Sensing these objects as they pass through the virtual bee's field of vision on both sides guided the insect along the corridor.

Using this approach in robotics could allow a navigation system to be built up from relatively simple, low-cost and low-power sensors. ©



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## MEDICAL

# Smartphones used for in vitro testing

Technology could replace expensive customised readers

JASON FORD REPORTS

**T**echnology embedded in smartphones is being exploited to develop an in vitro diagnostic testing solution that bridges the gap between

multi-step manual lab tests and automated test-specific readers.

42 Technology's inVi concept – an app that works in tandem with a smartphone or tablet's accelerometer, touchscreen, camera or location details – could allow diagnostics companies to develop a new generation of accurate, repeatable 'point of care' tests without the expense of dedicated reading equipment.

The Cambridgeshire-based company adds that inVi could also give patients and their healthcare

"Experts picked up that the inVi could be a key tool in epidemic tracking"

Andrew Chapman  
42 Technology

providers access to tests that previously may have been too costly for routine use because they needed an expensive customised reader.

"Most industry experts who have seen the inVi demonstrator picked up that it could be a key tool in epidemic tracking, where the tests

could be of a lower fidelity but still prove useful," said Andrew Chapman, head of 42 Technology's healthcare business. "Especially if they were correlated with – for example – location data from the smartphone. An example question that inVi could address was 'What about the next H1N1 or Zika virus? How would we test a population en masse?'"

42 Technology envisages scenarios where the smartphone touchscreen detects when a user has successfully positioned a test cartridge, or actuated

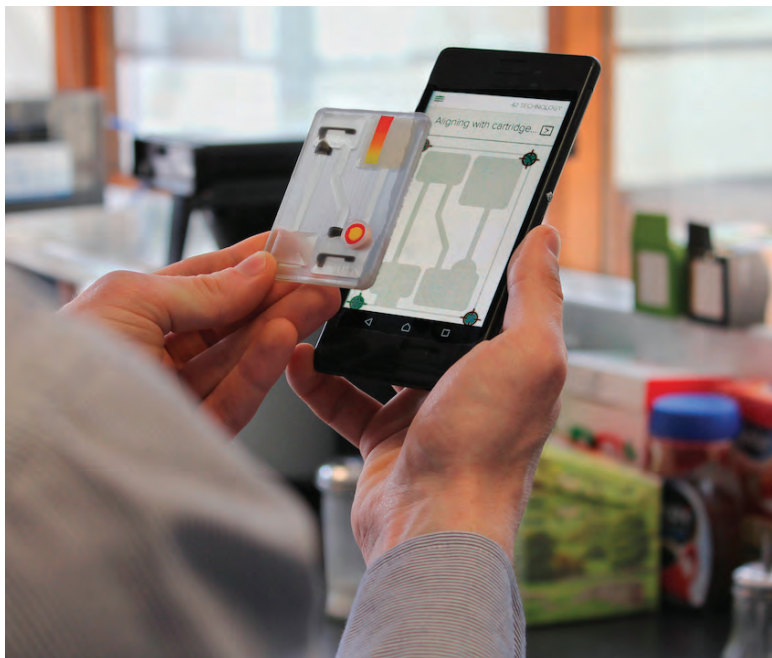
valves or pumping elements within the cartridge; or using the phone's accelerometer to verify that the user has performed adequate shaking to mix the reagent.

In similar, existing systems, a diagnostic test cartridge contains the necessary reagents alongside elements that can be activated by and/or interact with the reading instrument, such as plungers that act on physical elements within the cartridge.

Although sharing a similar architecture, inVi requires the user to provide the actuation, with their smartphone instructing and verifying steps as they happen.

Chapman added that inVi is being designed to work with a relatively low-resolution camera although the more important aspect is the camera's ability to be calibrated and to recognise colours.

The consultancy is now looking for commercial partners to develop the technology for a market estimated to be worth \$50bn per year. ☐



Smartphones could facilitate a new generation of 'point of care' tests

## TRANSPORT

## Rolls-Royce propels yachts into the future

Thrusters are lightweight and easy to steer

HELEN KNIGHT REPORTS

Lighter, more environmentally friendly yachts are under currently construction, thanks to a new steerable carbon-fibre thruster developed by Rolls-Royce.

The company has signed an agreement with Italian yacht maker Benetti to produce the lightweight thrusters, which are built using advanced carbon-fibre epoxy composites in load-carrying parts, for use in its megayachts.

The new thruster, which has been dubbed Azipull Carbon 65, is said to have high propulsion efficiency, be easy to maintain, and to provide good manoeuvrability.

As well as fast yachts, the thrusters could also be used in passenger vessels and workboats.

The first thruster in the series, the AZP C65, is designed for vessels with a power rating of 2MW, and is fitted with a fixed pitch, pulling-type propeller, or one that faces forward.

Since the propeller faces forward, the way in which water flows into it is only determined by the hull itself. This makes it possible to obtain a more uniform water flow to the propeller, thereby avoiding unsteady cavitation. This, in turn, minimises propeller noise and vibration.

The driveline is designed with two spiral bevel gear sets, which are installed in a supporting structure that ensures it has the best load carrying capacity under all operating conditions. Power is transferred from the input shaft in the upper unit down the steerable underwater parts to the propeller shaft and pulling propeller itself.

The thruster can be steered using a hydraulic system. An automation and control system has also been developed for the new thrusters, which each weigh only 2,800kg when dry.

The first yacht covered by the agreement, called *Ironman*, has already been delivered, while the second and third hulls are under construction, and should be completed within months. ☐

## COMMUNICATIONS

## Shape of things to come

Engineers at Bristol University have developed a handheld computer that can change its shape

A handheld, shape-shifting computer could pave the way for a new generation of multi-functional devices, its developers have claimed.

Cubimorph, created by engineers at Bristol University, in collaboration with academics at the universities of Purdue, Lancaster and Sussex, holds touchscreens on

each of its six module faces and uses a hinge-mounted turntable mechanism to self-reconfigure in the user's hand. It can for instance, instantly transform itself from a phone into a games console.

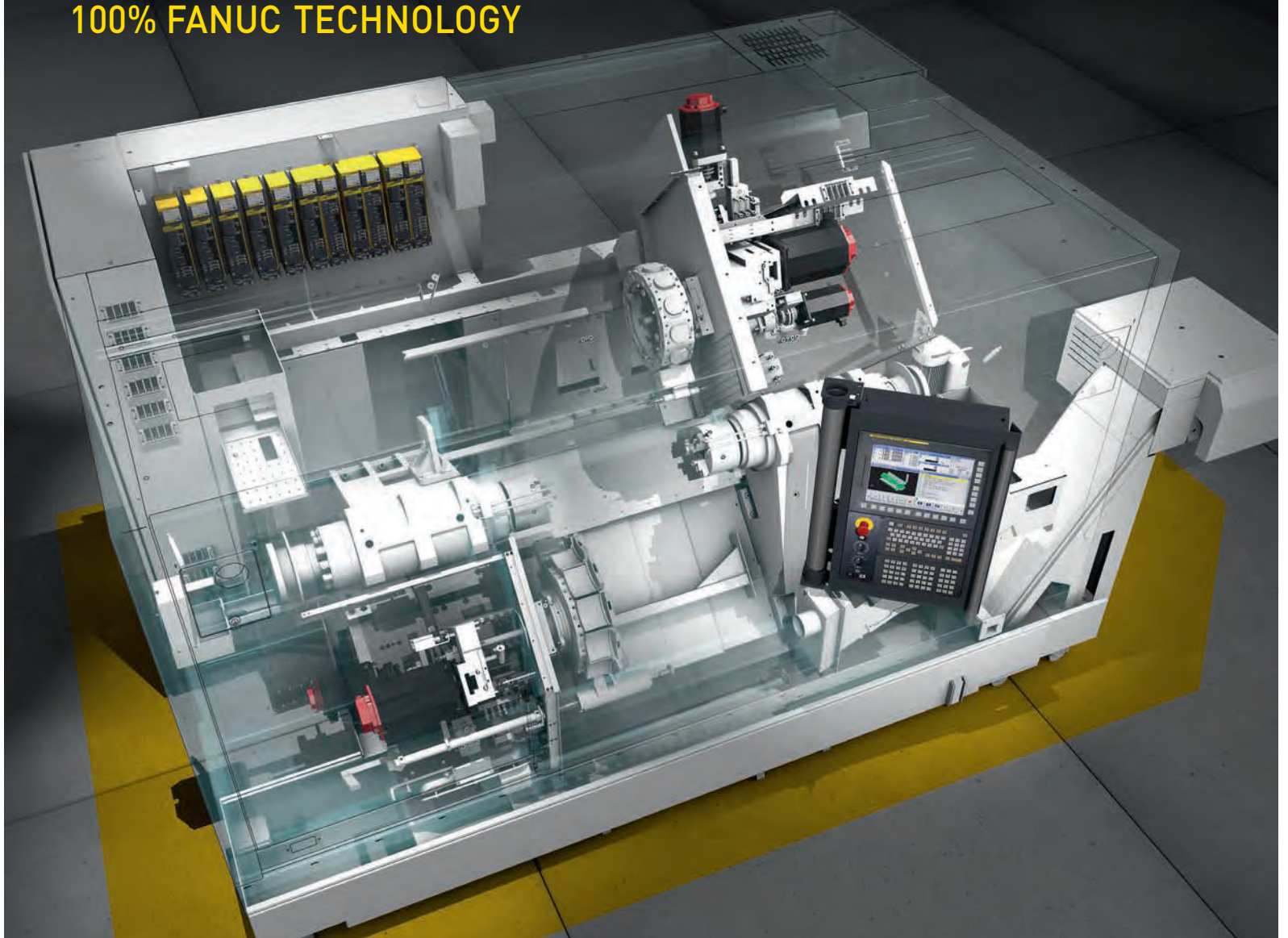
Made out of a chain of cubes, the device is one of the latest developments in the emerging field of programmable matter – where interactive devices change shape to fit functionalities required by end-users. For instance, one example is a mobile phone that can transform into a console when a user launches a game.

Until now, devices have consisted of folding displays and barely reach high shape resolution. **JE**

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# Don't reinvent the wheel for girls

Attracting more teenage girls into engineering should be a matter of using tried-and-tested techniques

**T**he good news is that more women than ever before are choosing to work in engineering. There were 12,000 more women working as professional engineers in the UK in 2015 compared to the year before. We hope when *Labour Force Survey*

data from 2016 is published in August to see a further increase. Slowly but surely, the message is getting out to girls and their families about the opportunities that engineering can offer.

Opportunities are in terms of pay and prospects, which are better than in many more traditionally female sectors, as well as opportunities for a varied, interesting and meaningful career.

The bad news is that we are starting from a very low base and women still make up less than 10 per cent of the UK's professional engineering workforce. Engineering is a more popular choice for women in other parts of the world such as Mexico, Eastern Europe and the Middle East, proving that barriers are cultural rather than genetic. WISE research, commissioned by Network Rail, found

that psychological barriers get in the way of girls choosing engineering. There is a conflict between how teenage girls identify themselves and what they perceive to be the identity of 'an engineer'. Engineering outreach programmes based on hands-on activity are not enough to convince most girls to choose engineering — they may enjoy the activity but they don't see themselves as an engineer.

The WISE People Like Me campaign gets girls to select adjectives to describe themselves, matches these to two or three 'types of scientist' and shows them roles in engineering for people with a similar personality type. Don't re-invent the wheel — use tried-and-tested techniques, based on robust evidence about what works with girls.

"Engineering outreach programmes based on hands-on activity are not enough to convince most girls to choose a career in engineering"

Helen Wollaston

A similar approach can be used in recruitment campaigns to attract more female applicants to engineering roles. If you include adjectives to describe the type of person you are looking for, women are more likely to be interested. It also helps if you describe the bigger picture — what the organisation or project does and how this supports a wider social or environmental purpose. This will attract interest from women (and men) who want to make a difference to the world they live in. Network Rail used our research to refresh the marketing of its graduate recruitment programme. It was delighted with the volume and quality of applicants, as well as the diversity. Simple steps make a big difference.

Recruitment isn't the only challenge, however. We also need to get better at keeping women in the profession, which means giving them the same encouragement and opportunities as their male colleagues to rise to the top. This doesn't mean positive discrimination. Most of us prefer to get jobs on merit, not simply because of our gender. There isn't a magic bullet that will fix things in one go. We are talking about cultural change, which requires concerted and consistent action on a number of fronts, led from the top. Leaders of 49 companies have signed up to the Ten Steps, a framework to improve women's representation at senior levels in science, technology and engineering. We share good practice so that they can learn from each other and be inspired to do more. Like any cultural change, it will take time to reap the business benefits.

There is a growing body of evidence to support a business case for change. Global research by McKinsey found companies with three or more women in the leadership team are 15 per cent more likely to have financial returns above average for their sector. Engineering firms that learn how to hire and keep women at all levels of the business will stay ahead of the competition in other respects.

If you think that is you or your firm, why not put yourself forward for a WISE Award (closing date 8 July). The awards are designed to flush out new role models and champions who will help us get a positive message about women and engineering out to girls, women, their families, teachers and employers in communities up and down the land. Our vision is that it is as natural for a girl to show interest in engineering as it is for her brother. Work with WISE to make that dream come true. ©

**Helen Wollaston, chief executive, WISE**

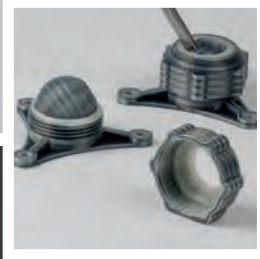
There is a conflict between how teenage girls identify themselves and what they perceive an engineer to be





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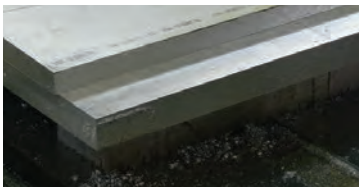
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# Mailbox

## Thehotopic

### Frack to the future

#### Approval for fracking near the village of Kirby Misperton sparked a heated debate



The fact that the process of hydraulic fracturing has been banned in a significant number of regions across the globe due to the disastrous effects it has had on the environment should tell us a lot. Safe in theory but not in practice.

**Rob**

I'm satisfied that enough is known about the process that it is technically feasible and potentially safe, but actual safety must be demonstrated on a case-by-case basis because not all local rock formations are the same. The

question of economic practicality then depends on whether extraction can be achieved safely with any additional safeguards, which includes surface logistics of accessing potentially remote sites, removing spoil and getting the gas out.

**Wallace**

Fracking can be both safe and unsafe. It all depends on how it's done. The argument should not be frack or not frack; it should be how do we regulate fracking to make sure it's safe.

**Stewart Barker**

It's time that we got the opportunity to attempt to exploit this wealth of resources sitting under our feet. The first trials will tell us much that we don't already know. Fracking in the US and more recently elsewhere has proven the process is safe and can be profitable when done under most recently established technical conditions. Our energy dependence demands that we find our own sources of natural gas. We are too dependent on Eastern European gas at present.

**Phil**

Concerned parties will always say that fracking is safe because it's in their interest to. For decades,

tobacco, asbestos, radium and DDT were entirely safe – beneficial even – until one day it was determined that, actually, they weren't. I suspect that fracking falls into this category.

**Phil Stannard**

What has to be remembered, is that with all engineering production processes, the safety aspects will improve over time. Therefore, we shouldn't throw this technology in the bin at this early stage of its development. As we all know, most engineering developments and evolutionary processes do not happen overnight. Also, the people who object because of the CO<sub>2</sub> emissions, should think about where we're going to get our energy from during the many years it's going to take to develop sustainable environmentally friendly energy sources.

**John**

Surely it goes without saying that fracking must be closely regulated, the risks are negligible, but must be managed properly. The UK is hurtling into an energy abyss with power cuts/expensive electricity guaranteed in the next few years: fracking offers some mitigation of our self-induced energy stupidity. I suppose that the same objectors will be worried by the massive increase in LNG imports that are planned to meet the coming gas shortages. It just needs the right level of press hysteria and LNG will become the next threat, all opportunities being ignored... as seems to be the case with fracking.

**Jack Broughton**

We should be looking to natural gas as a long-term chemical feedstock, rather than as an energy source. It is nice to know the country has this resource untapped for when we need it but in the meantime we should be continuing to research and develop other forms of energy production, such as nuclear, renewables such as wind and solar, tidal schemes and wave and energy efficiency where feasible (i.e. not playing to the 'profits-next-quarter' brigade).

**Anonymous**

## Inyour opinion

### Better together?

#### Our poll on international space collaboration prompted a range of responses

Much as I would hope for collaboration, I think it more likely that, say, the Chinese will go it alone.

**Mike Burrows**

You have to wonder, in the context of aircraft development, whether the cost of collaboration hasn't been higher than going it alone.

**Mike West**

India has demonstrated that individual approaches can be the best: it learned from the low-cost success of the Russian sputniks in the 1960s.

Collaboration obviously has an important place, but cannot dominate or it will sink in bureaucracy.

**Jack Broughton**

National interests will always override joint efforts when talking about defence. Perhaps there might be a 'space NATO' vying for influence against another such organisation, and several countries have developed Earth-launched anti-satellite missiles that surely point to the extension of military capability into space.

**Phil Stannard**

### Bring back the duck

#### Calls to reinstate the bronze duck at the feet of the statue of legendary locomotive designer Nigel Gresley provoked a surprisingly sensible discussion

Although the wishes of Sir Nigel's family have to be considered, I have always thought it a real shame

that the Mallard was removed. Not only humour and whimsy – it also has an air of the visually poetic to it. Of course, there is also the precedent for such oblique references set by the celebratory telegram sent by Lady Wedgwood to Sir Nigel when the record was gained: "Three cheers for the Mallard, LMS out for a duck."

**Stephen Mosley**

The duck should be kept. It might get people interested who otherwise wouldn't give a normal statue a second glance. Before you know it there will be a new enthusiast.

**David**

I thought the ducks were an interesting and informative part of the statue. Unfortunately engineers are often thought of by some as being mechanical and humourless. What a shame such a ridiculous canard has been perpetuated. Put the duck back – any thing else would be quackers.

**Mike Patching**





## The **secret** engineer

Our anonymous blogger asks whether the driverless vehicle will make our roads safer



There are times when those of us in the engineering community get to see new developments marching inexorably over the horizon. It starts with odd reports in trade journals about imagined future developments of nascent technology. Such things become talked about and speculation starts. Then ragged prototypes appear with the air of barely understood wizardry, followed by initially disappointing first products and refinements until that first idea is finally – fully – realised.

The example that springs most clearly to mind for me is the whole telecommunications thing. As for the more exciting stuff – flying cars, robotic housemaids (the gender assignment being an indicator of just how long these promises have been around) and so on – well, these remain hinted at but are still no closer to reality.

By comparison, the idea of a wristwatch that allows you to talk to someone across the planet is now here and does an awful lot more as well.

We now seem to be on the cusp of the widespread application of yet another long-promised technological leap. After many years

of ever more sophisticated (yet still 'controlled environment'-bound) prototypes, there has been a sudden leap forward with various trials now taking place in the real world. It would appear we are about to enter the age of the autonomous car.

There have been a few articles in the wider media but I wonder how many people outside of our profession realise the great advances that have been recently made? Given that one of the biggest stories to hit the headlines revolved around a Google car crashing into a bus, if anything, they are probably even more convinced that this is just a mad boffin's rabid fantasy. Make no mistake though, it is fast approaching.

For example, Google's fleet of autonomous cars has already logged around 700,000 miles of autonomous driving.

I have to say that this is not a development I relish. I understand the reasoning behind the statements that our roads will become safer, but I cannot get excited. First, I don't know if I'd trust it. I remember being told, while learning to drive, that there are two ways to escape an accident – either slow down or speed up. I wonder if this is even an option with the self-driving car? It would certainly make for an interesting lawsuit should a crash be unavoidable and the car actually sped up just before impact.

For me though, to remove the pleasure of driving, the thrill of control and skill, would be to lose a little of the value in life. Think of it as the automotive equivalent of the slow food movement. Safety can be improved in various ways, this way panders to the lazy. Technology should not seek solutions by merely removing us from the loop – instead it should enhance our experience.

If ever I find myself packing for a journey to King's Cross I will undoubtedly be adding a few yellow rubber ducks. If enough people do it perhaps the family will cave in. I mean no one has tried to exorcise the mice from Cuneo's paintings and they are just as twee.

**David**

Why not another bronze statue alongside the one of Gresley of a single Mallard. No comment, no plaque – we shall all appreciate the significance. Should keep everyone happy.

**Mervyn Edwards**

I've never seen the statue but seeing your photo and the name, it was British engineering at its best. No need for a plaque – the little duck said it all. I don't think the grandsons did their grandfather's memory any favours. After all, the great man called his best-known creation after a wet feathered friend, which sort of implies his approval.

**Brian**

While I appreciate the wish of people to add some whimsy to draw attention to the statue I do think that a duck is an irrelevance. Gresley is known to the general public as the man who designed a steam engine called Mallard not for any great interest in our web-footed avian friends. If the statue had been of Sir Peter Scott then a duck is relevant. Why not have an angel in a kilt as a representation of the Flying Scotsman, it's just as appropriate? A model of Mallard the locomotive would be better as it provides a link that most people will know about to a man they may well have no knowledge of at all, rather than a steam-buff in-joke.

**Nick Green**

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# Not just the referendum

**The day of the referendum vote in the UK is also an important date for shaping the aspirations of many future engineers**

“Diversity shouldn’t be a shorthand for gender balance. We want young people, whatever their gender, ethnicity or socio-economic background”

Paul Jackson



rather busy day looms on 23 June. As in the past couple of years it marks National Women in Engineering Day, which gives the industry the opportunity to celebrate great female engineers past and present, and to encourage more young women to consider an engineering career. That’s part of what Tomorrow’s Engineers does all year round, not with anything specifically targeted at girls, but by creating a context and environment in which young people can picture their future selves. We want to address the

gender balance within the industry and look to do that by supporting companies to deliver inclusive schools outreach, work experience and recruitment.

While this month sees a focus on women for which WES should be congratulated, strategies and policies to attract a more diverse workforce need to be more inclusive overall. As an industry we are making some inroads but there is still much to do. Diversity shouldn’t be a shorthand for gender balance. Yes, we want to see more female engineers but more importantly we want young people, whatever their gender, ethnicity or socio-economic background, to know that, with the right skills, the industry is open to them.

There are several ways to achieve that. Positive role models that young people can relate to are key, which is why we’re always on the look-out for inspiring stories from technicians and engineers. The opportunity to see engineering in action is another, so a strategic approach to schools engagement and an inclusive work experience policy are really important for diversity. Tomorrow’s Engineers can support on both counts.

Of course, the EU referendum is the day’s main event. Many of the major organisations have expressed a view, as a corporate and/or through polling membership. I’m not sure that we have previously seen a coordination of government, EEF, CBI, IOD, IET, Unite the Union and corporates such as Airbus and Siemens expressing a strong view that remaining in the EU is the best choice. That’s quite a coordination.

In another coordinated effort The Big Bang West Midlands also takes place that day, bringing together businesses and education. One of several regional fairs taking place

Positive role models for the engineering sector that young people can relate to are key

in the summer term, the event will give 3,000 local schoolchildren the chance to see classroom learning brought to life and to speak to STEM professionals about their jobs. But it’s not just the professionals that are sharing their experience; there will be some fantastic projects competing for a place at the finals of The Big Bang Competition (previously the National Science and Engineering Competition).

There will also be fierce competition in the form of Lego space missions as teams compete in the national final of the Tomorrow’s Engineers EEP Robotics Challenge. In its first year the challenge has seen 100 student teams introduced to real-world engineering as they worked together to build and program Lego robots to take on a series of missions developed with NASA. Not only does the final crown the champion but it gives other would-be engineers the chance to see what they could be doing.

This will be an important day in shaping the future of the UK and in shaping the aspirations of many future engineers. ©

**Paul Jackson**  
**Chief executive EngineeringUK**





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# Bombs away on the ocean floor

**With the seabed around the UK now the site of unprecedented activity, dealing with the explosive legacy of two world wars is firmly on the agenda.** Jon Excell reports

In May 2016 the residents of a quiet street in Oxford became the latest participants in a drama played out somewhere in the UK on an almost monthly basis: a mass evacuation triggered by the discovery of an unexploded Second World War bomb.

The incident – swiftly dealt with by experts – was the latest in an apparently growing number of similar discoveries. Last year, in London alone, more than nine wartime German bombs were discovered. Many of which were still capable of inflicting devastation on a massive scale.

And yet for every item of unexploded ordnance (UXO) that's found on land, experts estimate that there could be tens of thousands more lying on the seabed around the UK: the explosive legacy of two world wars, decades of test-firing and dubious munitions-dumping practices that only ended in the 1990s.

For most of the 20th century this wasn't an issue. Engineers working in the oil and gas sector would occasionally encounter the odd item, and fishing trawlers would sometimes land an unexpectedly hazardous catch, but the bottom of the sea was generally seen as the safest place for it.

However, thanks to the relatively recent and rapid growth of the UK's offshore renewables sector this is no longer the case.

Today, the seabed around the UK, home to some of the world's biggest offshore energy projects, is the site of unprecedented levels of subsea activity.

And the pressure to ensure that these projects are completed safely and on time is driving ever more innovative solutions to the challenge of detecting, identifying and dealing with subsea UXO.

One person at the sharp end of this growth industry is Dave Welch, a former Royal Navy bomb-disposal expert, who now runs one of the UK's leading Explosive Ordnance Disposal (EOD) consultancies, Ramora UK.

While Ramora regularly carries out bomb disposal on land, offshore UXO accounts for an increasing amount of the company's work, said Welch. "There are more and more wind farms going in and they're all finding items. Since 2009, as a company, we've seen a steady increase from four or five a year to the point where last year, on one job alone over a three-week period, we did 40."

According to Welch, many items that are found are inert or empty, others are live – i.e. they haven't yet been fired and therefore aren't prepared for detonation. Some, however, are what is termed as 'blind'. In other words they've been dropped or fired and for some reason haven't detonated. A stray nudge, knock or sudden increase in temperature could, in theory, set them off.

Unsurprisingly, wind farm developers, ever wary of fickle investor confidence in what's still a relatively young sector, are reluctant to discuss the issue.

And when they do, they tend to steer well clear of suggesting that this is anything other than a problem that can easily be dealt with. "It very much depends on the area and even then I would put it on to the category of precautionary," said Matthew Green, a project director at energy giant Vattenfall.

Nevertheless, managing the UXO risk is increasingly seen as a critical part of the development process and has become one of the biggest drivers of subsea innovation today.

The process begins with some good old-fashioned detective work, in which a UXO consultant will pore over historical data relating to sunken ships, firing ranges and so on to provide developers with a risk assessment of what, if anything, they

might find in a particular area. Specialist marine contractors will then head out to the site and deploy a range of different techniques to survey the seabed and identify objects of potential interest.

One of the major players around the UK is specialist marine survey contractor Bibby HydroMap. "Today, 60 per cent of our renewables work is UXO-related," said geophysicist Caroline Tweedle.

Much of the surveying work involves the use of magnetometers: sensors that are able to detect the

**01** Bibby HydroMap's dROP system



01



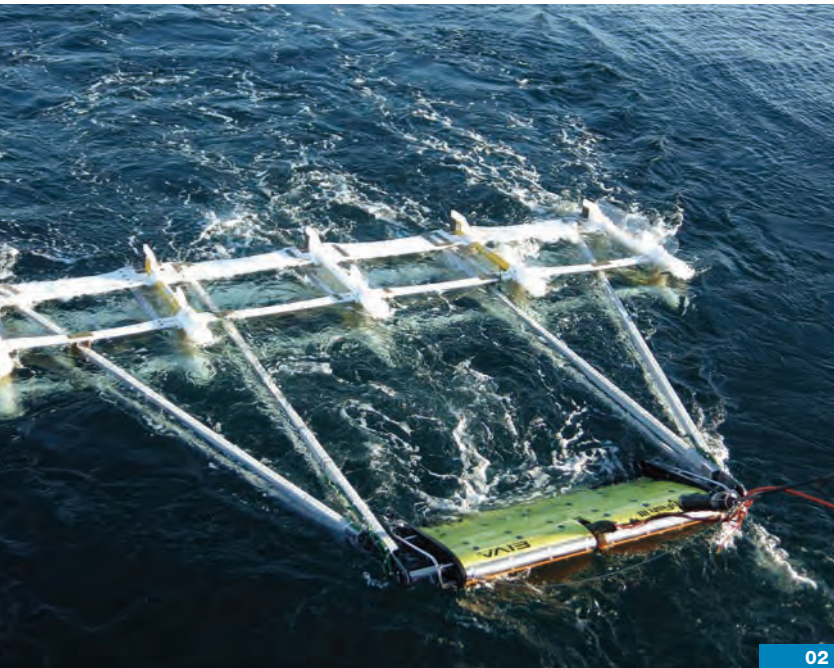
telltale magnetic signature of ferrous objects on, or even below, the seabed. These are typically towed by surface vessels, often in groups or arrays, which are able to measure the gradient of the magnetic field in order to provide a high-resolution image of anomalies at the survey site.

Time is of the essence and the energy industry's demand for quick results is a major driver of innovation. "The competition comes down to who can put the most magnetometers out the back the quickest," said Tweedle, "innovation is focused on trying to cover more ground, in more detail, more quickly than has been possible in the past."

With this in mind, Bibby HydroMap is currently trialling a system in the North Sea that will have a three-winged towed array of magnetometers designed to fly just 3m above the seabed. "This has a detection range of about 12m and huge swathes of ground can be covered quickly," said Tweedle.

Another major innovator in this area is Fugro, which is currently making waves with the Geowing: a fixed gradiometer array consisting of five magnetometers that are effectively able to tune out the magnetic signature from background geology, thereby reducing the number of false positives. The system is currently being used on a number of projects through Europe, the Baltic and the North Sea.

The choice of technology used also varies according to the environment. For instance, one of Fugro's specialist areas is carrying out surveys in near-shore



02

environments where mobile sand and shallow waters create a range of challenges that aren't encountered further out to sea.

"One of the key parameters is altitude above seabed," said Fugro geophysicist Thomas Harris. "When you're in shallow water you've still got to operate the equipment safely in among tides. You're jumping in, doing a bit of surveying; it's quite a dynamic environment."

Around 80 per cent of explosives found on the seabed are air-dropped iron bombs from the Second World War. And for these, magnetometry is the perfect solution. For non-ferrous items, however, such as the particularly dangerous air-dropped German sea-mines (which are made from aluminium), different approaches are required.

One solution to this problem is Bibby HydroMap's dROP system – a compact, remotely operated vehicle (ROV) that receives much of its propulsive power from a surface support vessel and is claimed to represent an easier-to-deploy solution than many larger ROVs.

The advantage of a system such as this, according to Bibby geophysicist David Rider, is that it can be equipped with a variety of different sensors.

05



**02** Fugro's Geowing towed magnetometer array

**03** UXO is a major consideration for all new offshore wind projects

**04** Kongsberg's Hugin AUV represents a different approach to subsea detection

**05** UXO is towed to a safe place and detonated  
*Image: Ramora UK*

04



03



One that's been particularly effective is a so-called Sub-Bottom Imager (SBI) developed by PanGeo Subsea. According to Rider, this advanced acoustic system can provide a real-time 3D view of the ground beneath the seabed down to a depth of up to 5m.

Further into the future, Rider said that dROP could also be the ideal platform for subsea versions of advanced electromagnetic (EM) detection systems that are currently being used on land.

An example of this is MetalMapper, a US-developed system hitherto used on land that's able to distinguish items of ordnance from scrap metal. "This does EM readings in three axes, said Rider, "by comparing the decay curve in each axis they can compare it to a library of known items – and it will reduce the number of false positives. The dROP would be a really good platform to use for this, as you can go really slowly, and even hover."

Whichever technique is deployed there is still a heavy reliance on surface support. However, some believe that continued developments in autonomous underwater vehicle (AUV) technology could change things dramatically in the years ahead.

One firm eyeing up the opportunity in this area is AUV manufacturer Kongsberg Maritime. Indeed, the company's marine robotics sales director Richard Mills claimed that for many applications AUVs could have considerable advantages over existing approaches. "The whole aim of an AUV is that you put a range of sensors together on a >>



>> single platform collecting all of the data at the same time and you get to put it very close to the sea floor, without a tether, without a ship close to it, and without a 3-tonne workhorse ROV. It's a better cost option," he said.

The offshore energy sector is already a major customer for Kongsberg's Hugin vehicle, an unmanned sub originally developed for mine clearance that Mills describes as a "pick-up truck": i.e. much of its real power lies in the payload of sensors and sonar systems that can be bolted onto it.

A good example of this is Kongsberg's HISAS system, a wideband synthetic aperture sonar that combines a number of acoustic pings to form an image that has a much higher resolution than conventional sonars.

"With a traditional sonar you have degradation in resolution the further away it gets from the source," explained Mills. "With this one using some clever processing we actually synthesised more than 30 returns from a single ping, which gives what we call a multi-aspect view of a target and allows us to resolve the resolution right down to, in theory, about 2 x 2cm – regardless of whether it is 5m or 300m from you."

The technology is suitable for detecting and identifying seabed munitions, he claimed. "If you have the tail fin of a Second World War bomb sticking up out of the silt you'll be able to see the tail fin, tell which way it's oriented, and potentially identify not only that there's an object there but also what type of object it is."

But the bomb-hunting capabilities of AUVs could perhaps be even further enhanced by some recent developments in magnetometry.

Fitting magnetometers to AUVs has hitherto been challenging – with electromagnetic interference from the vehicle's systems severely impacting upon the technique's usefulness.

However, thanks to a collaboration with Canadian firm Ocean Floor Geophysics, Kongsberg now offers a system that uses a clever algorithm to tune out all of these variable signals, and collect reliable MAG data from the seabed. This breakthrough could, said Mills, potentially help usher in a new era of AUV-based magnetometry.

In the longer term, while new sensors will continue to emerge, Mills believed that continued developments in autonomy, which will enable AUVs to react in real time to sensor data and even classify specific items of ordnance, will drive the technology's use for UXO detection.

For now, however, these decisions are left to the UXO experts. And once



06

**06** Aluminium sea mines are among the hardest items to detect

*Image: Ramora UK*

**07** Fugro engineers prepare to carry out a survey

anomalies have been detected, it's back to specialists such as Ramora to interpret the data and figure out how to make the site safe.

"We need to determine whether these items are anywhere near an asset," said Ramora's Dave Welch, "can they be destroyed where they are? If they can, we just deploy charges and deal with them or relocate them to a safe area for disposal."

In some respects, dealing with subsea ordnance is simpler than handling items on the land: there are



07

fewer neighbours to worry about, and the seawater is a great blast insulator. What's more, despite a growing number of finds, the risks posed by these items are now very well understood. "We've done a lot now, we're into the hundreds, we've never had an item of ordnance detonate at a point where it was not intended to do so. Generally speaking, treat them with respect and avoid heat shock and friction, and you won't go far wrong," said Welch.

Nevertheless, there has been a high level of technical innovation and development over the years, which has been primarily focused on enabling the job to be performed more quickly and removing the need for human divers.

In Ramora's case this has meant the development of a system known as REODS (Remote Explosive Ordnance Disposal System): a kit of bolt-on components that can be used to rapidly turn any type of ROV into a specially adapted vehicle capable of performing many of the tasks once carried out by divers.

During a typical relocation operation, an ROV equipped with this technology will attach a hydraulic claw mechanism to an item of subsea ordnance before moving away from the explosive and remotely initiating a 'lift bag' system that will raise the item of ordnance from the sea floor. This lift bag can then be connected to a towline, which is used to move the explosive out of harm's way for detonation. Commenting on the capabilities of the system, Welch said: "We can pretty much deal with any subsea explosive disposal now down to any depth."

Vatenfall's Matthew Green echoed Welch's faith in today's processes for dealing with the problem of explosive material on the sea floor. "As we're getting more familiar with performing these surveys, and more comfortable with the methodology and the principles, we've been able to include the UXO campaign into our normal development and construction periods", he said.

But, according to Welch, the sector still has some important lessons to learn if it wants to deal with the issue as smoothly as possible. "If you don't plan ahead you can be tripped by all manner of unexpected regulations," he said, citing a recent incident on the Rampion wind-farm project, where UXO disposal was held up by the fact that the Whiting breeding season was taking place.

One thing's for sure. With offshore development showing little sign of slowing down, the problem of subsea UXO isn't going to go away. And with developers targeting an increasing range of locations – from far out to sea, to much closer to land – this unique challenge will continue to drive subsea innovation for many years to come. "It's only going to get more challenging," said Bibby HydroMap's David Rider, "and at the moment it's really the driving force in an awful lot of innovation." ©



08

**08** Air-dropped Second World War bombs account for around 80 per cent of the items that are found

"We can pretty much deal with any subsea explosive disposal now down to any depth"

Dave Welch, Ramora UK



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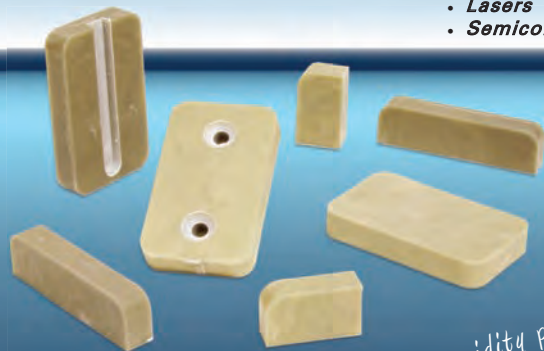
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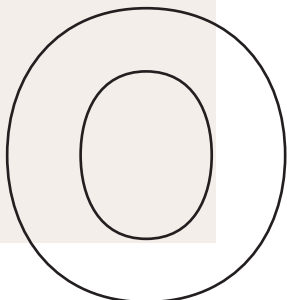
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# Moving in from the fast lane

**Sectors such as retail and the emergency services are proving to be the unexpected beneficiaries of technologies developed in motorsport.** Stuart Nathan reports



One of the main points of motorsport, we're often told, is that it's an R&D project and proving ground for the automotive industry. Racing cars are prototypes, and the technologies developed in the sport — anti-lock braking systems, traction control, safety cells, regenerative

braking and, more recently, high-performance hybrid technologies — filter down to road cars some 15-20 years after their debut on Grand Prix circuits.

But automotive isn't the only sector that benefits from the expertise of motorsport's engineers. A recent event at the Institute of Engineering and Technology saw the Motorsport Industry Association showcase some of the more unexpected examples of what it refers to as 'horizontal innovation'; the transfer of its sector's technologies into other industries.

Some of these can be highly unexpected. Take, for example, your local supermarket. The reason it's blessedly chilly on a hot day isn't just down to air-conditioning. It's because many of the aisles are lined by open-fronted fridges holding dairy products, drinks, meat and other chilled items; and while they certainly keep their contents cold, they also leak chilled air out into the shop.

This is a major source of losses. Supermarkets are estimated to consume 5 per cent of all the electricity generated in the UK, and 60 per cent of the energy they use is consumed by fridges; so that's 3 per cent of all the UK's energy that isn't being used efficiently. The cost of that goes onto our supermarket bills, and the carbon generated goes into the atmosphere.

Loss of cold air is essentially an aerodynamic problem, so in trying to reduce its energy costs, Sainsbury's consulted with Williams Advanced Engineering (WAE) to bring its experience of solving aerodynamics problems into the cold. Paul McNamara, technical director at WAE explains that the challenge was to design an aerofoil to direct the chilled airflow primarily into the fridge cabinet, so as little as possible spilled out. "This means we can design a passive component that can be retrofitted at relatively low cost and can have a significant impact on energy usage," he said.

Senior aerodynamicist Ian Turner explained that the most important tool for this was computational fluid dynamics. "It's a massive part of Formula One aero development and we've been able to harness it for this problem," he said. "We started by putting a fridge into our virtual aerodynamic simulation tool to understand the airflow in and around the fridge.

We have the ability to run very large aerodynamic simulations very quickly and to very high accuracy, and we also have in-house rapid prototyping capability so we can design, make and test components very quickly as well."

The resulting aerofoil design has been tested by Sainsbury's in several real branches, and early indications are that it can deliver energy savings of up to 20 per cent in fridge operation.

Switching from hardware to personnel, motorsport has developed much knowledge about how to measure the effects of motion at

speed on the human body, and this has been brought to bear onto an issue facing rather smaller human beings than the adult racing drivers it usually applies to; namely, premature and seriously ill babies. The Greater Manchester Neonatal Transport Team worked with Race Technology, a Nottingham-based firm specialising in dataloggers used in motorsport, to develop a system to evaluate the effects of putting a premature baby in a fast ambulance so that they can reach specialist care facilities.

While speed is very important in these cases, babies are always vulnerable and particularly so if premature. "The unit wanted to see how things such as speed, acceleration, deceleration and cornering *g*-forces were affecting the health of the babies as they're taken from hospital to hospital," explained Race's operations director, Lorne Winborn.





This is a case of balancing risk; very often, leaving the babies where they are isn't an option, but with premature babies, moving them in any way can affect their blood pressure. The Manchester team linked tools used in Race Technology's equipment, such as accelerometers and GPS, mounted on one of its specialised transport indicators, with its own equipment that monitors the babies' heart rate and blood pressure so that it could map any changes in their vital signs to the profile of their journey, and the forces incurred on the way due to acceleration, deceleration, cornering and vibration.

Race Technology, like many in the motorsport sector, is a small company well versed in customisation. "If any customers come to us with a specific requirement, we're always interested in trying to turn our hand and adapt our technology to that, but in this case we didn't really have to

adapt our technology at all," Winborn said. The results of the exercise are now being used in the design of improved ambulances and incubators for this special application. "I can't think of a better use of our technologies," Winborn said.

Vehicle design is, of course, the main strength of motorsport, but it tends to be for vehicles that are as fast as possible and as safe as possible for a single driver. Similar requirements but for a rather larger number of people faced automotive technology consultancy Ricardo when it worked with General Dynamics on a new armoured vehicle called the Foxhound. This came from a conversation with the MoD, where as General Dynamic Land Systems' customer, it needed to find a vehicle with the capabilities and protective capacity of GD's Mastiff vehicle, but the size of a Land Rover. "But the Mastiff is a very large vehicle, with drive to

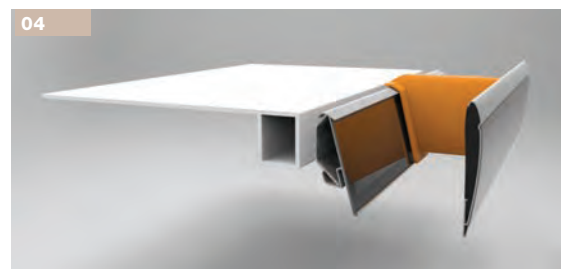
**01** Ricardo's race-honed ability to meet a tight deadline helped shape the Foxhound

**02/04** Williams aerodynamics' expertise led to a supermarket chiller redesign

**03** Race Technology helped develop a system for transporting premature babies



02



04



03

all six wheels, weighing 12-15 tonnes," said David Hinds, executive director for strategy at GD Land Systems. The Mastiff is "fantastically survivable" he added: if it's attacked, or drives over a mine, its occupants stand a very good chance of walking away alive, but it's too big and heavy to manoeuvre around tight city streets in the Middle East.

Andy North, chief engineer of Ricardo's defence division, explained that the project combined General Dynamics' expertise in protection technologies with the motorsport company's ability to meet a strict mechanical brief in a short time, honed by the tight between-race and between-season timescales of the race circuits. "There were only five requirements: the small turning circle and width of the vehicle; it had to comply with the MoD's new generic vehicle architecture, which means it had to be able to have the ability to plug in new subsystems without lots of wiring; we were the first vehicle in this class," Hinds said. "It had to be a composite vehicle in terms of the crew pod; and it had to be mine, blast and IED survivable."

North said: "We would normally start with a commercial vehicle and add armour, but we couldn't do that here; we had to start with a clean sheet of paper. We brought in our systems engineering modelling approach and people from our lightweighting and motorsports teams." Foxhound is now in theatre, replacing the old Snatch Land Rover vehicles that proved tragically vulnerable to IEDs; it has a v-shaped armoured hull to deflect blasts at ground level away from its crew pod and, while its 70mph top speed won't challenge the rally and motorsport vehicles that are Ricardo's more usual products, it will keep its occupants safe in some of the world's most dangerous places. ©

"The unit wanted to see how things such as speed and acceleration were affecting the health of babies taken from hospital to hospital"

Lorne Winborn, Race Technology





# Man on a mission

**ESA's director of human spaceflight and robotic exploration talks to Andrew Wade about his deep space ambitions**

When David Parker

joined ESA in April, he did so at an exciting time for European, and particularly UK, space operations. The former head of the UK Space Agency moved to its European

counterpart to become director of human spaceflight and robotic exploration, a role that means he is heavily involved in Tim Peake's ISS mission, as well as programmes such as ExoMars.

Speaking recently with Parker, *The Engineer* asked about the progress of Major Peake, the various ESA astronaut missions in the pipeline, and how the future of manned spaceflight is shaping up.

"He's got less than a month now to go," Parker said about Peake in May. "He's still extremely busy with the science programme, and I was just talking to him about some of the experiments he's been involved with: the life-science ones, and the air-breathing experiments to do with the effects of the space environment on the lungs of the astronauts, which is all really interesting stuff."

With Peake due to return to Earth on a Russian Soyuz craft in mid-June, Parker has one eye on ESA's upcoming missions to the ISS. French astronaut Thomas Pesquet is due to begin his six-month mission aboard the station later this year, and Paolo Nespoli is scheduled to return to the ISS in May 2017, a month after the Italian celebrates his 60th birthday.

"For Thomas Pesquet's mission, the very detailed planning is now underway, with launch somewhere around the beginning of November," said Parker. "He's the last of that group of astronauts that were selected in 2009 to get his first mission, so he's very much looking forward to that."

"Paulo Nespoli will be returning to the station. He's one of the more senior astronauts, so it's going to be interesting, the science around how he performs and how he reacts to the space environment again, having done missions before."

Just days before we spoke to Parker, it was announced that 40-year-old German Alexander Gerst will become only the second ESA astronaut to command the ISS. Having first spent time on the station two years ago, Gerst will return in 2018 for another six-month tour.

"It's early days of planning for Alex's mission, but he was presenting his first mission to us at the programme board last week, and he's still massively enthusiastic. I remember he was out supporting the families in Baikonur for Tim's



"You'd assemble a habitation module and a propulsion module in Earth orbit, then start to fly out on voyages of exploration into deep space for the first time"

launch, and I was having a drink with him, and I think he would have pushed [Peake] out of the way to get back on board the rocket."

Those sentiments were echoed recently by Helen Sharman, Britain's first astronaut. Speaking on the 25th anniversary of her mission to Mir, Sharman said she had yet to meet an astronaut that wouldn't return to space, and she was no exception. She also warned that Peake could be the last UK astronaut for the foreseeable future unless more funding was forthcoming.

Later this year Parker and his ESA colleagues will be making the case for Europe to continue its involvement with the ISS until 2024. If agreement can be reached to join the other partners in the station's operation, that would translate roughly to one ESA astronaut mission to the ISS each year.

"The opportunities are there for future missions for this group of astronauts," said Parker. "We probably wouldn't start a new selection, but that's not definite. It would be more about taking the





02



**01** Major Tim Peake – the first British ESA astronaut

**02** ESA is a key partner in the Orion programme

maximum experience out of the astronaut group that we have now, who have all proved to be excellent.”

If the ESA member states can agree a funding package, that could open the door for Tim Peake to return to the ISS at some point. Failing that, UK space activity in the near future may be restricted to manufacturing, something the country has traditionally excelled in.

ESA is a key partner with NASA in the Orion programme, supplying the service module that will provide propulsion and life support for the US-built crew module, as humanity once again looks to explore deep space. Manufacturing so far has been based on the continent, but future iterations of the service module could see the UK play a role in the supply chain.

“There will be some need for further development of the service module, so the possibilities are there,” Parker explained. “Alongside that, we want to participate in other elements of the future exploration programme. The thing we’re talking to member states about is the Deep Space Habitat.”

This is a concept proposed by NASA to house astronauts beyond low-Earth orbit for periods up to 500 days. With the ISS approaching the end of its service, and nations unable to commit to lunar or Martian landings yet, the Deep Space Habitat would act as something of a testing ground for more ambitious missions of the future.

“Think of a mini space station, but with an electric propulsion system that would go towards the Moon, either into a lunar orbit or a Lagrangian point – one of the balance points between the Earth and Moon’s gravity – where you could have a stable place and basically operate there for weeks and eventually months, learning how to operate far more independently from planet Earth, so a thousand times further away than the space station is.”

“We’d use the Orion vehicle to take the astronauts there. You’d assemble a habitation module and a propulsion module in Earth orbit, then start to fly out on voyages of exploration into deep space for the first time. The Apollo missions only went to the Moon for a few days at a time. This would be weeks or months in deep space.”

## CareerCV

### David Parker

Director of human spaceflight and robotic exploration, ESA

#### Education

- 1984** BSc Hons in aeronautics and astronautics at Southampton University
- 1989** PhD in wind tunnel magnetic suspension technology at Southampton University

#### Career

- 1990** Joined British Aerospace Space Systems as a guidance, navigation and control engineer
- 1991** Promoted to head of liquid propulsion systems
- 1995** Appointed head of guidance navigation and control department at Matra Marconi Space, Bristol
- 1997** Selected for a two-year secondment as assistant director at the British National Space Centre, London
- 2002** Key account manager for space science, EADS Astrium
- 2004** Director of space science and exploration at the UK Space Agency
- 2012** Appointed chief executive of UK Space Agency
- 2016** Appointed director of human spaceflight and robotic exploration at ESA

For these lengths of time and at that distance, the environment becomes more hostile, and life-support infrastructure becomes complicated. Radiation shielding, in particular, is a major concern. The Deep Space Habitat would be operating beyond the magnetic field protection of the Van Allen belts, and astronauts would therefore potentially be exposed to lethal doses of radiation if not properly equipped.

Studies for the Deep Space Habitat are still in the early stages and ESA is waiting to see how NASA intends to proceed. It’s being led by the US agency, with European participation dependent on a number of factors, not least if NASA decides to actually ‘green light’ the programme. If it does go ahead, ESA’s contribution to the project could include both technology and personnel.

“That would be our aspiration,” Parker said. “The idea is we make contributions to the Deep Space Habitat as part of offsetting our responsibilities on the space station programme, and then perhaps providing service modules... that would essentially entitle the possibility of European astronauts to be on board. All of that is subject to negotiation, none of it has been agreed, but it’s clearly the aspiration to not just be building things, but also to have European astronauts setting out on voyages into deep space.”

So, dependent on the funding, the future for European astronauts looks bright. Perhaps one day Tim Peake might be the first UK astronaut to venture into deep space. Probably best to let him get reacquainted with gravity before anyone from ESA suggests it though. ©

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# Nanotech: the final frontier

**Novelist Jon Wallace considers the science fiction implications of engineering stories that have caught his eye. This month: will nanobots build better people?**

**L**egions of microscopic robots fascinate sci-fi writers, from *Star Trek*'s Borg nanoprobes to the power-outage swarm of *Revolution*. In each case, nanotech is a tyrant, reducing people to little more than slavery – to a soulless, technological 'hive mind' in the first; to a brutal, pre-electric dictatorship in the second. Our primitive understanding of microbiology hardwires us, it seems, to view artificial microscopic agents with suspicion – as contaminating fifth columnists, or agents of chaos.

Engineers have brighter ambitions for nanotechnology. Barriers to developing effective nanorobots are enormous, but babysteps are being taken. *The Engineer* reported this month on a miniature robot formed of a layer of biodegradable 'Biolefin' that, once swallowed, expands in the stomach, taking on a rectangular shape with accordion folds. It's thought embedded magnets could allow it to be controlled externally, employed to remove foreign objects from the stomach, patch wounds, or deliver medication to a specific point in the digestive system.

This is only the beginning of engineers' hopes for nanotech healthcare. Researchers plan magnetically charged nanobots controlled via MRI technology, used to dredge clogged arteries of fatty deposits, and diagnostic nanobots that float about our bodies, detecting cancer nodes and delivering targeted treatment – ending carpet-bombing solutions such as chemotherapy. Even the materials by which such nanobots might be made is mind-boggling; atom-thick graphene strips folded in complex origami patterns; DNA strand shoestrings that untie to release antibody payloads.

To the sci-fi mind these plans feed our conception of the human body as a kind of alien landscape, a frontier that we are exploring and taming; in stories such as *Inner Space* and *Futurama*'s 'Parasites Lost' episode, nanobots are really shrunken spacecraft, vessels for miniaturised people – atom-sized pilots on fantastic voyages, where heart, lungs and orifices are vast geological features. Often our plucky explorers learn to manipulate their hosts – playing with their senses, appearance, and intelligence.



The human body can be conceived of as an alien landscape, a new frontier to be explored

As writers we might be tempted to explore this notion of man exploring man a little further. In the age of dying privacy it's easy to imagine nanobots used as the agents of the surveillance state – what better way to follow your target than to have him carry his own spies inside him? In fact, what better way to assassinate him? We could follow the adventures of some nano spook whose adapted bots destroy enemies of the state from within, stimulating cancer, furring up arteries and provoking strokes. They are so successful that enemies are vanquished entirely and our hero is turfed out of a job. Good for nothing but snooping, he turns his toys to the freelance service of gossip media, discovering an enormous market for nanobot photography of celebrity breast implants, tumours and bloodclots shot from within.

Even the most utopian visions of nanotech can be given a gloomier twist. Futurist Ray Kurzweil posits a nanobot future of godlike intelligence and immortality; nanotech will allow our minds direct access to the

**"Even the most utopian visions of nanotech can be given a gloomier twist"**

Jon Wallace

Cloud, he believes, feeding knowledge directly into our brains. The same tech, he states, will back up our memories and thoughts, allowing us to live on as electronic reproductions.

But really, how godlike would someone plugged into the world's Cloud of free 'information' be? Could nanotech overcome our own confirmation bias? Research shows that we tend to find ourselves in 'echo chambers' online, which reinforce our existing worldviews, true or not. A story could trace the fortunes of a tribe of technologically advanced but terminally misinformed conspiracy

buffs – certain in their 'knowledge' that the Moon landings were faked. By being permanently plugged into the feedback loop of misinformation, they become radicalised, burning NASA installations and butchering rocket scientists in frenzied revenge attacks, setting back space exploration by 50 years, but confident in their utterly clueless cause.

As for immortality, isn't death part of what drives us to seize life? Besides, who would really want their loved ones around forever? A story could follow one poor wretch condemned to live with the bot memory of her parents for all eternity, a kind of endless Christmas dinner of criticism, embarrassing anecdotes and arguments about politics.

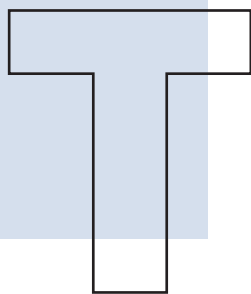
Money distorts most of our visions of the future, and with nanotech it's no different. Sci-fi has plenty of *Gattaca*-like worlds, where the wealthy are near immortal bot-maintained cyborgs, sealed in a perfect tyranny. Perhaps our best hope lies in the nanobots taking the initiative themselves; ensuring an equitable spread of appropriate enhancements to mankind, and filtering the information we access.

This chimes with Kurzweil's most optimistic vision, of using bots to expand the neocortex, creating more profound means of expression. Or perhaps, becoming equally exquisite examples of humanity, we'll become so unbearably self-satisfied we'll have no need of such distractions. ☉

**Jon Wallace is a science fiction author living and working in England. His new novel, *Rig*, is out this month from Gollancz. Check out his website [jonwallace.co](http://jonwallace.co)**

# Taking a snapshot of the salary scene

**The Engineer's 2016 Salary Survey asked engineers from across the different sectors of UK industry about their role and earnings**



The past 12 months have been dominated by headlines about the impact of the economic slowdown in China, particularly on traditional sectors such as the steel industry, the drop in oil prices, and uncertainty over the UK's future in Europe.

But how has the weak international trade market and domestic uncertainty affected

life for the UK's engineers? Have earnings in engineering suffered as a result, or has there been an overall rise in salaries despite the difficulties in some sectors?

In our 2016 Salary Survey we have once again asked engineers from across the different sectors of UK industry to tell us about themselves, including their earnings, what they do, and where they work.

With 3,698 engineers from across the UK and from 18 sectors of industry taking part, this year's survey has provided us with an illuminating picture of life in engineering today, from levels of job satisfaction and how pay and benefits in some sectors differ to others, to the number of women in the profession and how

**"The energy sector remains the place to be if you are looking for the highest salaries"**

their earnings compare to those of their male colleagues.

What's more, by comparing these results with those from our 2015 survey, we can see whether and in what way things have changed for engineers over the past year.

The average salary for engineers across all sectors in 2016 is £45,367, a marginal increase on last year's figure of £45,055. Like last year, this compares well with average salaries across other professions in the UK, sitting slightly below the £50,606 and £48,590 earned by qualified accountants and those in banking, respectively, but above the £44,818 earned by professionals in the financial services industry.

Despite well-publicised difficulties in the industry caused by declining oil prices, the energy sector remains the place to be if you are looking for the highest salaries in engineering. The average salary in the oil and gas sector remains at the top of the table for the second year, at £51,370. This,

## £51.3k–£38k

average salary by sector

Oil and gas	£51,370
Energy/renewables/nuclear	£50,132
Chemicals and pharma	£47,506
Automotive	£45,879
Telecoms and utilities/electronics	£44,898
Aerospace	£44,580
Food and drink/consumer goods	£44,196
Defence and security/marine	£43,698
Rail/civil and structural	£43,181
Materials	£39,494
Academia	£38,029



## Keith Lewis managing director, Matchtech



The Engineer Salary Survey 2016 provides valuable insight to the views of the engineering community today. Not only do the responses provide clear indications about job satisfaction, salary expectations and job opportunities across different sectors, but an analysis of the demographics of the people who completed the survey can also unveil an image of the current state of the industry.

In relation to job satisfaction, around half of the engineers surveyed would describe themselves as happy in their jobs and fortunately over 80 per cent expect to remain in the industry for the next five years. Interestingly, salaries did not seem to play a part in levels of job satisfaction, at least not in the way you would expect, with some of the lowest-earning sector engineers actually reporting the highest levels of happiness – 56 per cent of engineers in academia, for example, are satisfied in their jobs despite having the lowest average salary of engineers across 18 sectors. Professionals in the rail, civil and construction industries are also largely satisfied (55.4 per cent) and feel valued in their job compared to professionals in other sectors. Discouragingly, despite ranking highly in the feeling-valued stakes, the number of rail, civil and construction engineers who feel this way is less than half (47.6 per cent).

Levels of job satisfaction also differ by region, with engineers in the south of England the most satisfied compared to those in Scotland, Wales and Northern Ireland, who were less likely to say they were happy in their role. This may well be related to the opportunities, or

lack of opportunities, currently available in these regions with London and the South East boasting large-scale rail and infrastructure projects while Scotland's previously prominent oil and gas jobs market has been in decline. And it is limited opportunity that is one of the main reasons why some engineers are considering changing roles.

From these findings, it is clear that job satisfaction is not only about salary, but about having valuable career prospects, a manageable workload and feeling valued in your job.

Another theme from the survey that cannot be ignored is diversity in engineering. Out of the 3,698 respondents, 6.5 per cent were female. While this figure was up by 1 per cent from last year's survey, the low number reflects how much work still needs to be done to encourage women into engineering. Not only would this enhance the diversity of the engineering workforce and help decrease the skills gap but it could also have significant economic benefits, according to the Confederation of British Industry, which estimates that women could bring in an extra £2bn to the UK economy if they participated more fully in STEM employment.

The survey also highlighted the importance of retaining women in engineering – 10 per cent less female than male respondents said that they expected to stay in the industry for the next five years. With women earning an average of 10 per cent less than their male colleagues, the gender gap in salaries could well be another barrier in retaining women.

Aside from interesting findings about gender differences, the survey also provided insight to the average age of people working in engineering, with 40 per cent of the respondents stating they were aged 50 or above. This reflects an ageing workforce, who will leave a gap in knowledge and experience when they leave to retire over the next 10 to 15 years. Once more, the importance of securing a talent pipeline is highlighted.

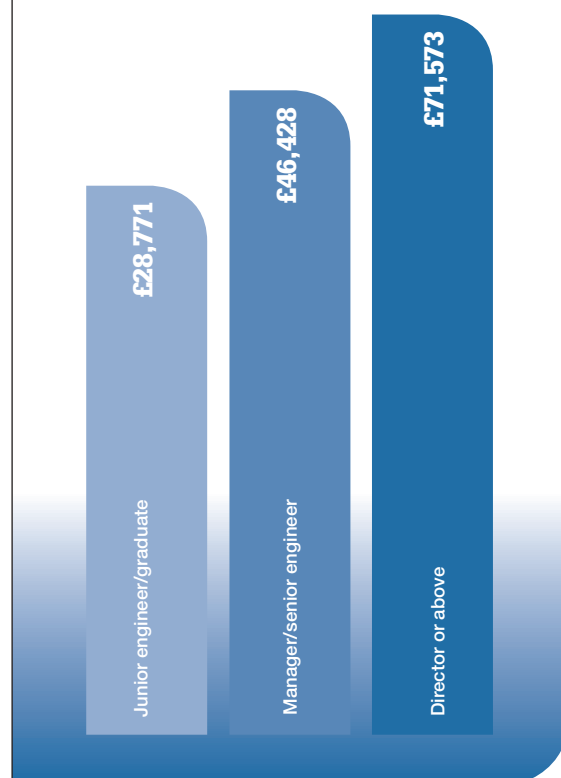
I hope you enjoy reading the results of the Salary Survey – may the findings spur the industry on to inspire diversity, equal opportunities and encourage more action to address skills shortages across engineering.

however, is slightly down on the figure of £55,265 for the same sector last year, perhaps reflecting the continuing difficulties the industry is facing.

Likewise, the energy, renewables and nuclear industries remain in second place with earnings of £50,132, but this again is a decrease on last year's average salaries of £54,408 in energy and renewables and £52,471 in the nuclear sector.

Around a quarter of those surveyed work in the automotive and aerospace industries, and like 2015 most respondents (74.3 per cent) describe themselves as either senior engineers or managers. The largest percentage of engineers, 29.8 per cent, work in the traditional manufacturing heartland of the Midlands and East Anglia. But

### average salary by seniority



# £45k

Average salary for engineers across all sectors

once again this was closely followed in second place by London and the South East, a region more often associated with sectors such as banking, on 21.4 per cent.

The overwhelming majority of engineers responding to our survey were white males, although the percentage of women has increased marginally year-on-year, up from 5.5 per cent in 2015 to 6.5 per cent in 2016.

The average age was virtually unchanged on 43.5, while almost half of those questioned had worked in engineering for between 20 to 40 years. Engineers remain largely content in their chosen career, with 83.8 per cent expecting to stay in the profession for the next five years – a similar figure to 2015.

Over the following pages we have looked in more detail at the findings of the survey, and considered what they tell us about engineering in 2016.

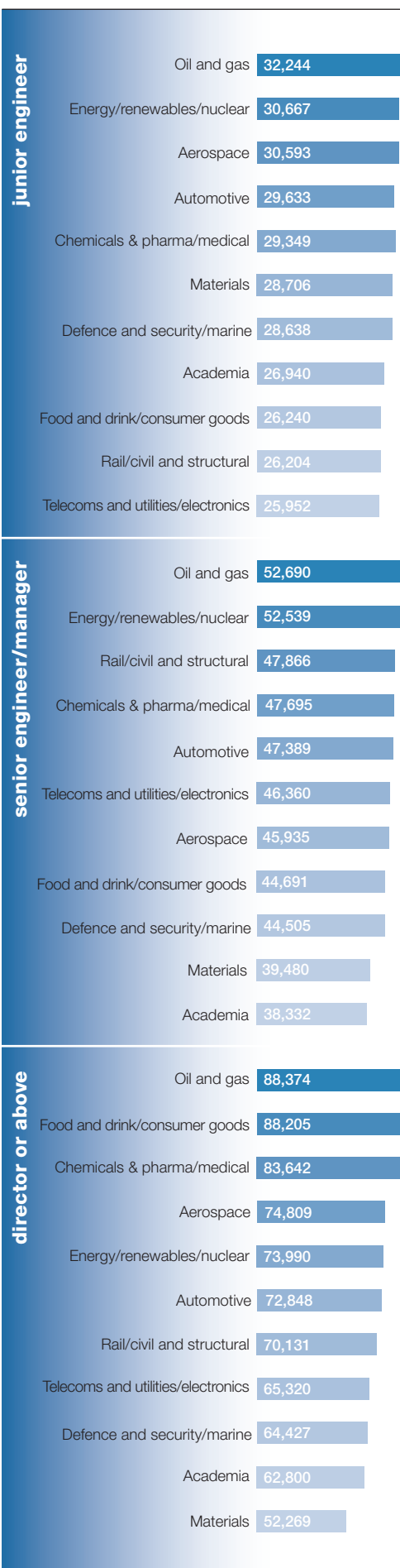
An even more detailed report on the Salary Survey findings, along with an interactive tool that enables you to benchmark your salary, will be published on our website on 27 June. >>

# £46k

Average salary for managers/senior engineers across all sectors

# average salary by industry

The average salary of directors or above working in the oil and gas sector



## 1. seniority

Just as in 2015, the seniority of those responding to our Salary Survey broadly reflects that of the readership of *The Engineer*, with the overwhelming majority describing themselves as senior engineers or above.

Of those surveyed, 42.8 per cent described themselves as senior engineers, while 31.5 per cent said they were managers, and 6.2 per cent directors.

At the other end of the seniority scale, 14 per cent of respondents described themselves as junior engineers, and just 3.6 per cent as graduate trainees or apprentices.

“Worryingly, average salaries for junior engineers across the entire industry appear to have declined significantly this year”

Worryingly, average salaries for junior engineers across the entire industry appear to have declined significantly, from £32,233 in 2015 to £28,771, this year. Salaries for senior engineers and managers have also declined, although to a lesser extent, dropping from £47,238 in 2015 to £46,428.

In contrast, directors have seen their average salary increase, from £68,672 in 2015 up to £71,573 in 2016.

There also remains a considerable pay gap between those working in different sectors of engineering. A director in the materials industry, for example, can expect to earn £52,269 per year on average, which is around £30,000 less than those in the oil and gas industry.

The oil and gas industry continues to offer the best salaries across all levels of seniority. A senior engineer or manager working in the sector earns an average of £52,690, closely followed by those in the energy, renewables and nuclear industry, who earn around £52,539 per year. Senior engineers and managers in academia, however, can expect to earn almost £15,000 less.

Likewise junior engineers in the oil and gas, energy, renewables and nuclear, and aerospace industries can all command salaries of over £30,000 per year, while those in the telecoms, utilities and electronics sectors earn around £25,952.

The average age of engineers across all sectors was 43.5, six months younger than in 2015. However, like last year, more engineers can be found in the 50-54 age band than any other (15.5 per cent). Indeed, almost 40 per cent of engineers responding to the survey were 50 or above.

In contrast, just 14.2 per cent of engineers surveyed were under 30, up slightly from 12 per cent in 2015, but still well under half of the percentage who are in their 50s.

Such a large number of skilled engineers leaving the industry within a decade is likely to have a huge impact, unless more can be done to encourage young people into the profession.



## 1. regions

While many outside the profession still believe that engineering is something that only happens in the Midlands and the north of England, our survey once again shows this not to be the case.

Respondents told us they are based in locations throughout the UK's regions and beyond. And although more engineers could be found in the Midlands and East Anglia than any other region (29.8 per cent), like 2015, this was followed in second place by London and the South East (21.4 per cent).

Overall, engineers working outside the UK were paid the highest salaries among the regions, with an average of £49,979. This was closely followed by those in London and the South East, on £48,000. Both these were substantially higher than salaries in the South West, the region with the lowest rates of pay overall, with an average of £40,827.

### where are the UK's engineers?

**29.8% Midlands and East Anglia**

**21.4% London and South East**

**18.8% North**

**13.8% South West**

**8.7% Scotland, Wales, Northern Ireland**

**7.5% Outside UK**

Once again, the oil and gas sector offers the best rates of pay for engineers working outside the UK, who can command an average of £67,924. Leaving the UK has also proved lucrative for engineers in the telecoms, utilities and electronics industries, who receive an average of £53,514 for working overseas, almost £3,000 more than engineers working in the second-highest-paid region in the same sector, London and the South East.

But unfortunately for engineers based overseas in the automotive and defence, security and marine sectors, salaries are around £10,000 lower than their highest-paid UK-based colleagues.

Engineers in the north of England are least likely to believe they are fairly remunerated (31.4 per cent), closely followed by those in the South West (31.7 per cent). Happiest with their pay though are engineers working outside the UK, with 34.9 per cent describing themselves as appropriately remunerated. Engineers in the Midlands and East Anglia were most likely to say they would be staying in the industry for the next five years (85.9 per cent). >>

### London/South East England

Oil and gas	£58,500
Energy/renewables/nuclear	£54,276
Rail/civil and structural	£50,738
Automotive	£50,066
Telecoms & utilities/electronic	£49,392
Chemicals & pharma/medical	£48,506
Defence and security/marine	£46,589
Aerospace	£46,012
Food and drink/consumer goods	£44,172
Materials	£40,150
Academia	£39,263

### Midlands/East Anglia – England

Energy/renewables/nuclear	£48,720
Automotive	£48,050
Chemicals & pharma/medical	£47,789
Aerospace	£46,149
Rail/civil and structural	£45,968
Food and drink/consumer goods	£45,378
Oil and gas	£44,452
Defence and security/marine	£44,441
Telecoms & utilities/electronics	£43,206
Academia	£43,052
Materials	£39,767

### North England

Energy/renewables/nuclear	£51,269
Chemicals & pharma/medical	£49,248
Oil and gas	£47,486
Defence and security/marine	£45,217
Aerospace	£43,080
Academia	£42,727
Automotive	£42,247
Telecoms & utilities/electronics	£41,615
Materials	£41,200
Food and drink/consumer goods	£40,893
Rail/civil and structural	£37,230

### South West England

Energy/renewables/nuclear	£47,500
Telecoms & utilities/electronics	£42,719
Defence and Security/marine	£42,126
Aerospace	£41,900
Automotive	£40,806
Food and drink/consumer goods	£40,140
Oil and gas	£39,416
Chemicals & pharma/medical	£37,413
Materials	£37,111
Rail/civil and structural	£34,833
Academia	£32,230

### Scotland, Wales, Northern Ireland

Oil and gas	£56,604
Aerospace	£46,520
Energy/renewables/nuclear	£46,437
Chemicals & pharma/medical	£44,625
Food and drink/consumer goods	£44,333
Automotive	£42,818
Materials	£41,200
Defence and security/marine	£39,600
Academia	£38,666
Telecoms & utilities/electronics	£36,241
Rail/civil and structural	£26,333

### Outside UK

Oil and gas	£67,924
Chemicals & pharma/medical	£55,631
Food and drink/consumer goods	£54,363
Telecoms & utilities/electronics	£53,514
Energy/renewables/nuclear	£51,273
Aerospace	£43,546
Automotive	£38,106
Rail/civil and structural	£37,680
Defence and security/marine	£34,337
Materials	£33,971
Academia	£28,679



# Work on a project that will stand the test of time

There is a wealth of opportunities for engineers looking for a fresh challenge across the infrastructure, automotive, aerospace, maritime and energy sectors. Here are just a few of the projects you could be working on.

## INFRASTRUCTURE

Some of Europe's largest infrastructure projects are currently underway in the UK, offering a range of exciting opportunities for civil and structural engineers.

2017 is set to be a landmark year for the rail industry with significant phase 1 design and construction packages set to gather momentum for HS2. With such a large and complex project, there are a range of job opportunities available including Design Engineers, BIM/CAD Coordinators, Project Managers, Project Planners, Field Engineers, Quantity Surveyors and Commercial Managers.

The first new Crossrail passenger train services are expected to be in operation from 2017 and the project will continue to need more engineers as it reaches the final stages. Opportunities on this project include Site Managers, Quantity Surveyors, Project Managers, Field Engineers, Project Planners, Quality Assurance and HSQE.

If you'd like to find out more about working on the latest rail projects, please contact our rail team.

[rail-engineer@matchtech.com](mailto:rail-engineer@matchtech.com)

## AUTOMOTIVE

The UK automotive industry is bucking the trend across Europe by achieving record growth, creating thousands of jobs and attracting major inward investment. Companies like Tesla are investing heavily to ramp up production. Recent reports estimate the firm is aiming to make as many as 1m a year by 2020. The London Taxi Company is set to launch its first electrically powered black cab in 2017, ahead of Transport for London legislation that all new taxis must be 'zero-emission capable'.

With a booming market there are many opportunities available for Electrical Leads, Design Engineers and Managers looking to drive through innovation in the industry. Whilst these opportunities are predominantly in the UK, there are also some available in other European locations such as Germany and Sweden.

To find out more about working on the latest automotive projects, please contact our automotive team.

[automotive-engineer@matchtech.com](mailto:automotive-engineer@matchtech.com)

## AEROSPACE

The aviation industry is entering an exciting phase. Aircraft are being re-engineered and upgraded and the race is on to produce newer, faster, quieter and more fuel efficient aircraft. Aerospace companies across the world are looking for engineers who can drive innovation in the industry.

With such strong competition, large projects are driving a range of job opportunities across airframe, systems and interiors including Design Engineers and Manufacturing Engineers. Working on these projects, you will get the chance to shape the use of game changing materials, and design and manufacturing methods.

Contact our aerospace team to find out more about jobs within the latest aerospace projects.

[aerospace-engineer@matchtech.com](mailto:aerospace-engineer@matchtech.com)

## MARITIME

There is a strong demand for maritime professionals, not just in the UK but around the world.

There are numerous opportunities available for people looking to work at shipyards overseas. In Canada, the National Shipbuilding Strategy has increased the demand for maritime professionals including Ship Managers and Production Supervisors to help build the country's shipbuilding future over the next two decades.

If you'd like to find out more about opportunities within the latest maritime projects, please contact our maritime team.

[maritime-engineer@matchtech.com](mailto:maritime-engineer@matchtech.com)

## ENERGY

With difficult sea-bed conditions and deep waters, Wiking Offshore Windfarm is a technically challenging project. Located in the Baltic Sea, Wiking has been designated as a Priority Offshore Development Area by the German authorities. The site covers 34 km<sup>2</sup> and will host 70 wind turbines, generating up to 350 megawatts. There is a range of opportunities on offer for experienced site-based staff and engineers to work on this unique project.

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Sector	Average salary (£)	Average age	Percentage content with salary	Percentage happy in current job	Percentage considering change of job	Percentage likely to stay in industry for five years
Oil and gas	51,370	42.9	40.3	55.2	48	81.9
Energy/renewables/nuclear	50,132	42.7	39.6	47.8	49.2	85.7
Chemicals and pharma/medical	47,506	44.1	36.6	49.8	51.3	80.1
Automotive	45,879	42.5	32.4	51.2	51.1	86.5
Telecoms/utilities /electronics	44,898	44.6	30.8	50	47.9	83.1
Aerospace	44,580	42.7	33.4	51.3	47	84.1
Food drink and consumer	44,196	43.5	30.3	43.5	52.9	81.7
Defence and security/marine	43,698	44.4	28.3	50.7	47.2	83
Rail / civil and structural	43,181	42.7	36.1	55.4	50.9	85.5
Materials	39,494	44.1	32.8	53.4	46.1	84.7
Academia	38,029	44.8	28	56.1	49.4	79.3

### 3. sectors

Although average salaries in UK engineering vary from sector to sector, those at both the top and bottom of the pay scale have declined since 2015.

The highest average salary can be found in the oil and gas industry (£51,370), but this is down from £55,265 for the same sector 12 months ago.

Similarly, at the bottom of the scale, the lowest average salary in the 2016 survey was £38,029, found in academia. Last year's lowest average salary in contrast, found in the food and drink industry, was considerably higher, at £42,082.

However, it does not necessarily follow that lower salaries breed discontent, as engineers in academia tend to be the happiest in their jobs (56.1 per cent). Similarly, those in the materials industry, which has the second-lowest average salary (£39,494), were the least likely to say they were considering a change of job.

At the other end of the scale, higher salaries do

not necessarily guarantee a happy workforce either. Despite average salaries that sit just beneath the oil and gas sector at the very top of the table, engineers in the energy, renewables and nuclear industry were among the least likely to be happy in their jobs, on 47.8 per cent. They are also among the least likely to feel valued in their current role. Engineers in the sector were also among the least content in 2015, with more than half considering a change of job, perhaps suggesting there are wider concerns in the industry over the direction of future government energy investment decisions could perhaps be creating insecurity among engineers, for example.

Engineers in the food and drink and consumer goods industries are also a discontented bunch, being the least likely to describe themselves as happy in their jobs (43.5 per cent), while less than a third felt they were appropriately remunerated (30.3 per cent).

Professionals in the rail, civil and construction industries, in contrast, are among the most content, with 55.4 per cent happy in their job. They were also the most likely to say they felt valued (47.6 per cent).

Likewise, engineers in the oil and gas sector appear to be pretty pleased with their lot, being the most likely to say they felt appropriately paid (40.3 per cent), and among the most happy and valued in their work.

Among the sectors, engineers from telecommunications, utilities and electronics are the most likely to want a change of career, with 9.9 per cent unlikely to stay in the industry for the next five years. This is remarkably similar to last year's survey results, when engineers from the sector topped the table with 10 per cent expecting to leave the industry.

At the other end of the scale, engineers from the food and drink and consumer goods sectors were least likely to be planning a change of career, with

# £45.8k

Average salary in the UK's booming automotive sector

# £55.2k

Percentage of oil and gas engineers happy in their jobs

# £52.9k

Percentage of engineers in the food and drink sector considering a change of job

“Lower salaries do not necessarily breed discontent. Higher salaries do not guarantee a happier workforce”



	Percentage that feel valued in current role	Percentage that do not feel valued
	42.3	28.2
	33.5	26.8
	41.1	29.1
	39.3	31.1
	37.1	31.5
	36.3	33.2
	35.2	27.4
	39.4	33.8
	47.6	28.3
	32.1	32.8
	35.4	34.1

only 4.8 per cent saying they were unlikely to stay in the industry for another five years.

Rates of paid holiday are unsurprisingly highest in academia once again, with 35.7 per cent of engineers receiving over 30 days leave, compared to just 2.2 per cent in the materials industry.

Over 90 per cent of engineers in the defence, security and marine sector have received a bonus in the last 12 months, compared to 77.3 per cent in the aerospace industry, the lowest figure in our survey.

In terms of routes into engineering, the energy, renewables and nuclear sector once again has the highest percentage of engineers with a degree (53.1 per cent) outside academia, while the lowest proportion of graduates can be found in the food drink and consumer goods industry.

Half of all engineers in the aerospace industry entered the profession through an apprenticeship, compared to just over a quarter working in the materials sector.

## 4. gender and diversity

Despite the best efforts of industry and the professional bodies to encourage more women into engineering, the gender imbalance continues to be a major concern for industry.

Although the percentage of women in engineering has risen very slightly since 2015, up from 5.5 per cent to 6.5 per cent in 2016, it remains extremely low, particularly when compared with other professions. For example, around half of all practising solicitors in 2015 were women, according to figures from the Law Society.

In the individual sectors, the industry with the highest percentage of female engineers is rail, civil and structural engineering (10.3 per cent). This does mark a decline on last year's share, when 15 per cent of respondents from this sector were female, but this could be explained by the relatively low overall sample size (there were 185 respondents from this sector).

Closely behind is the materials industry, where 9.8 per cent of engineers are women, and the energy, nuclear and renewables industries (9.6 per cent).

In contrast, just 3.4 per cent of the professional workforce in the aerospace industry are female, and 3.9 per cent of the chemicals and pharmaceuticals sector.

The average salary for women in engineering continues to be £10,000 less than their male counterparts, at £36,201. But once again, this is due in large part to the differences in seniority between male and female

engineers. Just 13.3 per cent of men described themselves as junior engineers, for example, compared to 24.4 per cent of women.

At the other end of the seniority scale, however, there has been some improvement, with 31.7 per cent of men describing themselves as managers, compared to 29 per cent of women.

Job satisfaction levels remain fairly evenly spread between the sexes, with 47.4 per cent of women and 50.6 per cent of men happy in their jobs, and a similar percentage declaring that they feel valued by their employers. Even when it comes to salaries, the gap in satisfaction levels does not reflect the size of the difference in pay, with 29.1 per cent of women and 33.2 per cent of men saying they felt appropriately remunerated.

The gender gap remains a priority for many in the profession, with a quarter of respondents agreeing it is an important issue, a similar percentage to last year's survey.

The diversity gap, meanwhile, has, if anything, widened very slightly since the

2015 survey, with 92.1 per cent of engineers describing themselves as white, compared to 89.9 per cent in the previous year. Just 6 per cent described themselves as BAME (Black, Asian and minority ethnic).

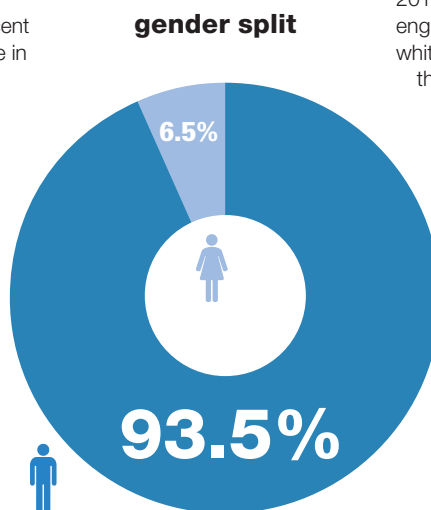
However, the percentage of ethnic minorities varies considerably across the different sectors. In the materials industry, for example, 7.7 per cent of engineers described themselves as BAME, of whom 6.9 per cent were Asian. Similarly, 7.3 per cent of engineers in the oil and gas sector said they were from an ethnic minority.

In contrast, just 1.6 per cent of engineers in the chemicals and pharmaceuticals industry described themselves as BAME, down from the already low percentage of 2.8 per cent last year. Indeed, there were no black engineers in the sector at all.

Black, Asian and minority ethnic engineers also continue to fare less well than white engineers in terms of their average salaries. White engineers responding to the survey said they earn £46,892 on average, compared to the £40,979 earned by BAME engineers.

Like the salary gap between women and men, at least part of this may be explained by the difference in seniority of those responding to the survey. While the number of BAME respondents describing themselves as senior engineers is roughly the same as the number of white senior engineers. ■

“Although the percentage of women in engineering has risen very slightly it remains extremely low compared to other professions”



### average salary by gender



£35,188



£46,020

# Making better medicine

**UK life sciences and pharmaceutical firms are embracing automation in order to maintain their position.** Evelyn Adams reports

**T**

he UK has one of the strongest and most competitive life sciences industries in the world. The sector has annual turnover of more than £50bn, employs over 180,000 in 4,400 companies and attracts a huge amount of direct foreign investment.

But expiring patents, rising costs and a competitive marketplace mean that UK life sciences and pharmaceutical manufacturers need to change their practices if they are to maintain their world-leading position. This means increasing the use of automation on the factory floor – and a number of novel applications

have already proven the importance of investment in such technologies.

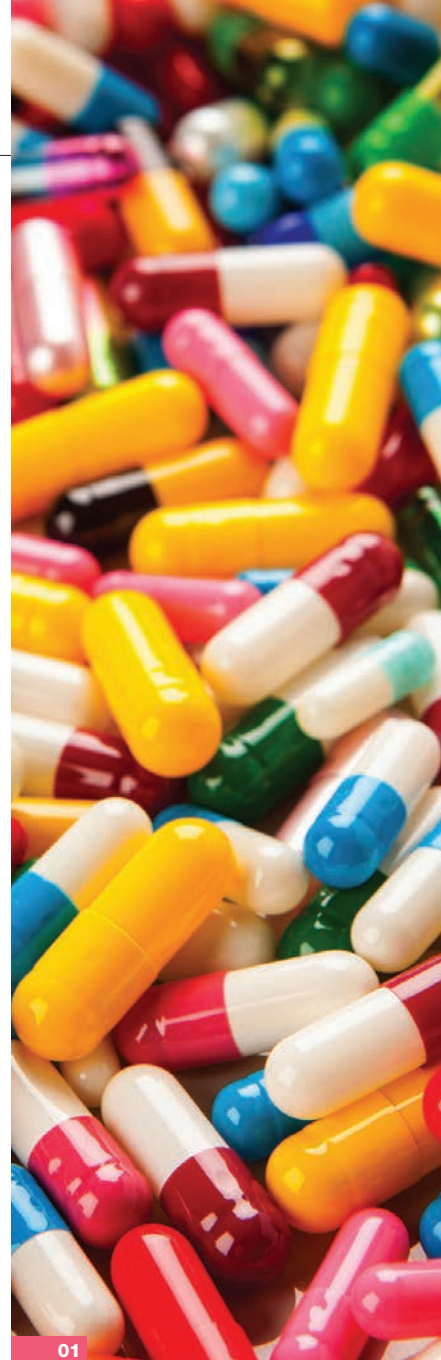
One of the major shifts is to abandon batch processing and embrace a more continuous approach to manufacturing. This allows for an uninterrupted flow in the process from putting together the starting materials to creating the final product. By getting rid of individual batches, manufacturers can create more products for less costs while producing higher-quality drugs. The technology also takes up less space. Siemens claims its oral solid dose continuous manufacturing unit occupies a space that is just a tenth of what is needed for traditional batch process equipment.

Moving from batch to continuous processing means a major overhaul in infrastructure and a high initial investment. But the rewards are significant. The

approach has been adopted by the Centre for Process Innovation (CPI), a UK-based technology and innovation entity, which has been working with Novasep, a supplier of services and technologies for the life sciences industry, to equip the National Biologics Manufacturing Centre with BioSC Lab, a new type of continuous manufacturing process for protein purification.

BioSC Lab is designed to purify a few grams of proteins per day. According to Novasep, this allows users to develop cost-effective, high-yield production processes while maintaining the same quality of the protein each

**01** UK life sciences turn over £50bn annually

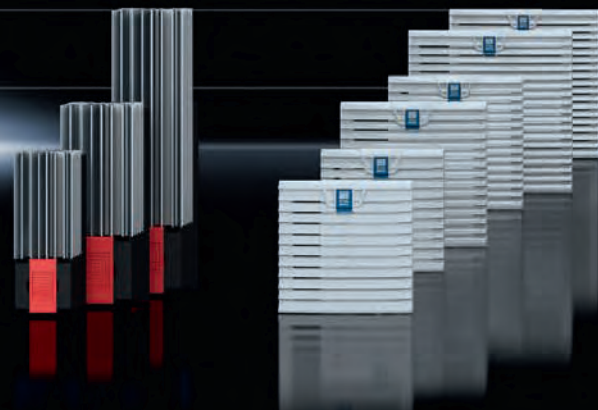


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time. It is flexible and supports any process operating mode, including batch parallel batch and continuous. It also uses simulation software, known as BioSC Predict, which frees the process developer to set the most efficient parameters to purify biomolecules.

"Novasep and CPI both use innovation as a strategy to solve problems in biopharmaceutical manufacturing," said Alain Lamproye, president of the Biopharma Business Unit at Novasep. "We believe our BioSC Lab will contribute to helping the UK biopharma sector step into the future of manufacturing, where the demand is for simplification and flexibility."

The life sciences industry has a huge amount to gain from investment in automation such as this, according to a recent report by Barclays. The survey revealed that drug makers are among the biggest investors in manufacturing robots with 63 per cent of those questioned reporting they have spent money automating production processes.

One example from the Barclays survey is Eakin Group, a manufacturer of medical products, which will have invested around £7-8m in automation at one of its subsidiary companies, Pelican Healthcare. This has helped it generate an annual turnover of £28m. Eakin Group's automated process line for the Cohesive Seal was last year replaced with new machines that can now integrate packaging, making production completely automated. As such, volumes of Pelican Healthcare's ostomy pouches have risen from 2.5 million a year close to eight million last year.

**"This project will help put the UK in a position to make innovative medicines more available"**

Alison Clough, BPI

The UK can also learn some lessons from abroad. For instance, Rockwell Automation was recently asked to provide a solution for contamination during packaging of sterile injectables, which were causing a US company major losses every year. Creating liquid drugs is a huge challenge for



manufacturers due to the complex process required to protect drug purity during production. For this particular manufacturer, the contamination was occurring during the transfer of medication from bulk vessels into individual plastic vials using a blow, fill and seal machine.

To solve its issue, the drug manufacturer used Automated Systems Inc (ASI) to upgrade its control and visualisation system. ASI helps automatically contain contamination on the line, issue alarms when any processes varied outside of pre-set ranges, and track and record key process data to verify the sterility of each completed batch. The solution used a new Allen-Bradley ControlLogix programmable automation controller, as well as FactoryTalk software from Rockwell Automation.

Using software to digitally design the manufacturing processes for the UK pharmaceutical and life sciences industry is also a major component of streamlining processes and increasing automation. The ADDOPT (Advanced Digital Design of Pharmaceutical Therapeutics) project was launched in January to do just that.


The project aims to use computer modelling to reveal new links between raw materials, formulation, manufacturing processes and drug product quality. It spans all operations,

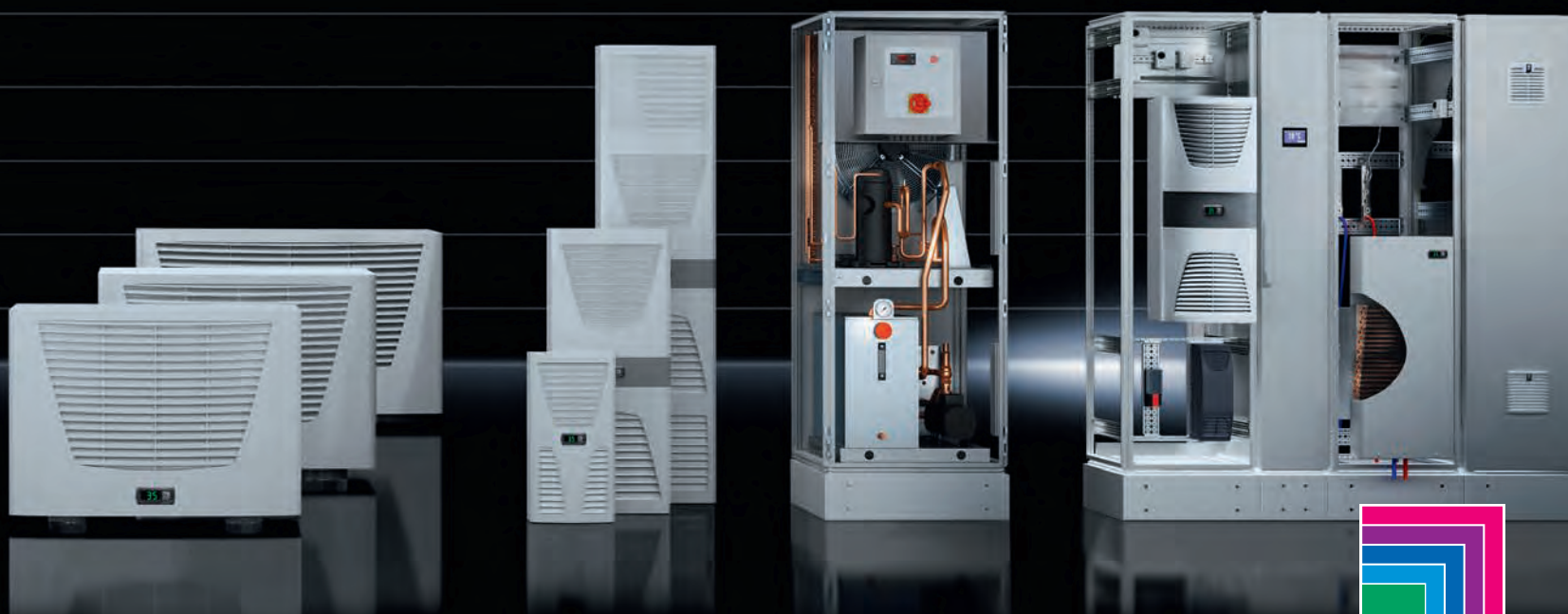
processes and procedures during the development and manufacture of medicines, and their *in vivo* application.

ADDOPT is a four-year collaboration between government, industry and academia. Led by Process Systems Enterprise and supported by the Medicines Manufacturing Industry Partnership (MMIP), it involves pharmaceutical companies, as well as leading UK universities, research centres, and knowledge-driven technology SMEs.

Alison Clough, acting chief executive of the Association of the British Pharmaceutical Industry, said: "This project will help to put the UK in a position to make innovative medicines available to UK patients more quickly by future-proofing our advanced pharmaceutical manufacturing sector. By reducing the risks associated with the manufacture of medicines we can provide the UK with an advantage in a globally significant sector."

George Freeman, life sciences minister, said: "The global business model is continually changing and presents challenges as personalised medicines, outsourcing and offshoring result in fewer large single-business manufacturing and R&D sites.

"Working together, government and the sector can ensure the continued growth of the UK life sciences industry that plays a vital role in contributing to prosperity and improved healthcare." 



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# Drives double up for efficient water pumping

**Variable-speed drives cut energy use of submersible pumps at water station.** Supplier: ABB



A surface water pumping station expects to cut the energy use of two submersible pumps by between 10 and 15 per cent following the installation of ABB variable-speed drives (VSDs). The VSDs also avoid the cost of installing a new transformer and improve the site's pumping system.

Susworth Pumping Station, located in Lincolnshire, is managed by the Shire Group of internal drainage boards. The station, which discharges into the River Trent, uses the submersible pumps to transfer surface water run-off from the low-lying catchment, protecting people, property, agriculture and the aquatic environment. The pumps are rated at 65kW and 75kW, with a combined full-load current of 202A. Both pumps run at 950rpm.

The pumping station's electrical supply is via a remote pole transformer rated at 100kVA. Because of the transformer's rating, only one pump could run at a time, even during periods of prolonged rainfall.

The solution was to use VSDs to run pump one at 41Hz, drawing 38kW with pump two running at 37.5Hz, drawing 28kW. This means that both pumps run at 80 per cent capacity, with 29A spare, over the full-load current for both pumps.

Running at this capacity means that the transformer is not overloaded and together the two pumps achieve a higher pumping volume than a single pump working at full rate.

Inverter Drive Systems (IDS), an ABB authorised value provider, installed two 75kW ABB general-purpose drives and conducted a four-week trial to determine the motor's best speed for optimum pumping.

During the trial, the normal pumping rate during non-storm conditions was optimised to achieve the lowest energy use for each cubic meter of water pumped. This has been set to match natural flow in the dyke, avoiding surges and unnecessary starts.

Following the trial, the VSDs were fitted in a permanent installation.

Because both pumps can be run at the same time, the pumping system is more reliable and can run in fully unmanned mode. Sharing the load between the pumps means that there is no need to invest in a costly transformer, achieving further savings.

With lower speeds and soft starts, the VSDs place less stress on the motors, helping reduce wear.

Better control of the outflow also alleviates ditch erosion by avoiding water pressures that would damage the bank. ☺

# Automation technology shows smart moves

**New methods for approaching the packing of pharmaceuticals.** Supplier: Beckhoff

A novel approach to packaging machinery is informing new technology for packing bottles of pharmaceuticals into cartons produced by machinery builder Uhlmann, with automation and drive technology from Beckhoff. Rather than using an intermittent motion drive with a set pitch to move the bottles and filled cartons through the machine, the Cartoner C215 machine uses an XTS (Extended Transport System) with separate 'movers', each with a product tray that travels along a guide rail.

Control of these aluminium movers is via magnetic fields, generated by independently switchable magnetic coils within the transport system, whose fields interact with those of permanent magnets attached to the movers themselves. Each mover can be moved and controlled irrespective of how other movers are moving, which is not possible with belt drives. "The use of XTS rules out the necessity to choose between intermittent or continuous motion transportation. Every product has its own motion profile instead. Acceleration and deceleration phases, such as fast transport of the empty movers, reduced speed during manual feeding, or a short stop when inserting pack

enclosures, are possible," said Thomas Aumann, design engineer development and XTS project manager at Uhlmann. "This brings about new levels of freedom in packaging machines, and processes can be decoupled."

The system has closed surfaces, making it easy to clean and especially useful for liquid pharmaceuticals. It also eliminates far fewer boxes, because the product can wait at the loading point for a perfect carton and doesn't have to reject imperfect cartons to ensure the line can continue moving.

Uhlmann began work on the system in 2011, primarily designing the system's guide rails, movers and product trays. The cartoner machine is an initial step for the XTS system, with other packaging operations targeted in the future. "The outcome of the cooperation between Beckhoff and Uhlmann clearly shows that we are in the forefront when it comes to the development of mechatronic solutions for pharmaceutical packaging machines," said Jürgen Walser, global product manager for the Uhlmann project. ☺







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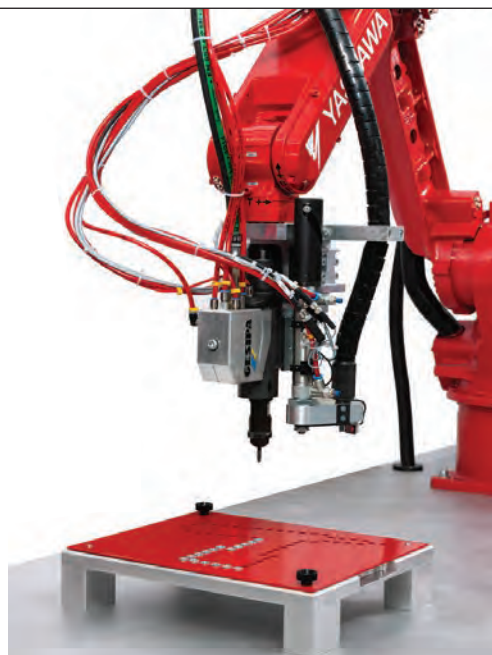
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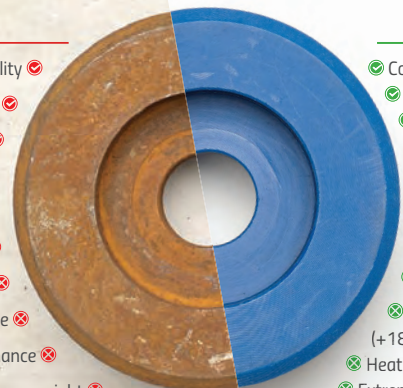
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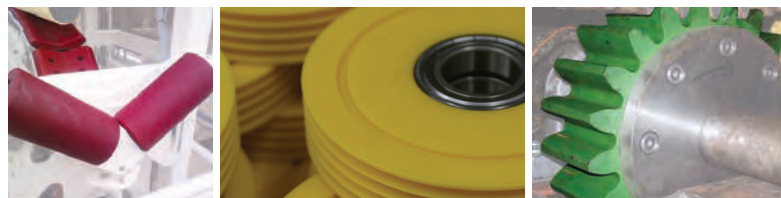
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## Helping the robots get around on the shopfloor

**Safety laser scanner helps industrial work assistant.** Supplier: Sick

Safety laser scanning technology from Sick is being used by Kuka to help its KMR intelligent industrial work assistant (iiwa) navigate the factory floor.

The KMR iiwa picks up boxes containing a range of materials and delivers them to the production line as and when they are needed.

It shares the routes it travels, as well as shelving areas, with trolley trains and human workers, so a reliable navigation system is essential for factory safety.

Using Sick's S300 safety laser scanners, the KMR robot creates a real-time map of its environment, determining its position within the coordinates.

Fixed objects along the route are interpreted as stationary reference points, while moving objects are

'ignored', with the KMR able to autonomously avoid objects that are in its way.

"The navigation software continually evaluates the distance measurements taken by the safety laser scanner," said Kuka's Klaus Mattuschat. "It then uses this information to create a kind of 'map' of the environment and determine the KMR iiwa's position within these coordinates.

"Objects that are always found at the same point, such as pillars in the hall or fixed parts of plants, are interpreted as established reference points. However, moving objects or objects that undergo dynamic changes are ignored, so to speak. In most cases, the KMR iiwa either moves along defined paths from one specific point to another, or it navigates freely. It's able to avoid objects that are in its way by itself."

The S300's 270° scanning angle ensures all-round surveillance, and the system's 16 freely configurable protective fields allow the platform to adapt to a range of travelling situations and environmental conditions.

According to Sick, robotic systems such as KMR will be a key component of smart factories and Industry 4.0, as networked production becomes the norm. ☐

## Showcasing for Industry 4.0

**Networking in the Cloud and robotics on show.** Supplier: Kuka

Kuka is set to showcase its Industry 4.0 capabilities at Automatica, the trade fair for automation and mechatronics that takes place this June in Munich.

Kuka will present its capabilities in three key areas of Industry 4.0, namely networking in the Cloud, advanced robotics in an era where humans and robots collaborate, and new robots for new markets and industries.

Kuka believes that it makes the complex topics of the Cloud and Big Data tangible and will use Automatica to demonstrate the added value customers stand to gain when conventional high-tech solutions are combined with the latest IT services.

Cloud computing and networking in a modern factory simplify asset management and minimise downtimes and service costs, and Kuka said it will demonstrate this to visitors on the basis of specific scenarios.

The Augsburg-based company will also show new concepts in human-robot collaboration (HRC). Kuka's concept is claimed to be opening industrial robots up for direct cooperation with human operators and thus combining the precision and speed of a KR Agilus machine with the wide range of possibilities of HRC. Beyond this, trade-fair visitors will be able to program an LBR iiwa robot graphically for themselves, even if they lack programming skills.

Automation is growing in importance in every industry and market, and Kuka is reacting to this development and presenting a small robot at Automatica that is specifically tailored to the needs of the electronics industry, one of the largest and



fastest-growing markets for automation. The newest member of the Kuka small robot range, the KR 3 Agilus, is not only fast and extremely precise, but also particularly compact. Furthermore, its maximum payload of 3kg makes it suited for small cell concepts in confined spaces. ☐





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# Moving forward at a good CLIP

**Continuous liquid interface production (CLIP) looks set to make its mark on the ever-evolving world of additive manufacturing.** George Coupe reports

**01** Carbon's CLIP technology draws shapes from a liquid resin bath

**02** The M1 – the first CLIP-based AM machine

To watch a demonstration of the latest 'breakthrough' additive manufacturing technology is to invite a reasonable doubt: could this be an elaborate April Fools? Before your very eyes a geodesic sphere is drawn magically from a pool of resin, like the sword from the stone, in one smooth motion. It is indeed 1 April, the commercial launch date of the M1, an additive manufacturing machine made by Carbon, a start-up company based in Redwood City, California. As the last few drops of resin fall away from the sphere, we are told it has the mechanical properties and the surface finish of an injection-moulded part, but is far too complicated to be injection moulded. So how is it done? What's the catch? There is no part handling, no re-dipping, no repetition or layering of any kind. It looks like a miracle.

According to Kirk Phelps, vice-president of product management at Carbon, this is continuous liquid interface production (CLIP) in action.

Early adopters of this new technology include Ford, BMW and Johnson & Johnson. It is the product of a brand-new approach to additive manufacturing, which combines innovation in hardware, software and chemistry. The launch of the M1 includes seven engineering-grade proprietary materials, which Carbon said enables the production of parts

with the mechanical properties of a final part.

"While traditional approaches to additive manufacturing make trade-offs between surface finish and mechanical properties, the M1 produces high-resolution parts with engineering-grade-mechanical properties and surface finish," said Phelps.

Additive layer manufacturing has typically been used for years as a prototyping technique. Recently manufacturers have successfully incorporated aspects of additive layer manufacturing (ALM) into conventional production methods, combining additive and subtractive techniques to improve efficiency and enable new types of part design.

ALM on its own, however, is generally considered to be far from maturity and not a reliable means of making end-use parts, mainly because there are few established standards by which parts can be validated.

But this gap between prototyping and manufacturing was the inspiration for Carbon's founder and CEO, Joseph DeSimone, who decided to look for a new approach to 3D printing.

As a professor of chemistry at the University of North Carolina, DeSimone was working with a post-doctorate student on a project to reduce the costs of 3D printing.

"While they were looking at 3D printing patents for part of their research project, DeSimone realised that no one was really trying to innovate 3D printing in a new way. Eventually, with the help of his son, Phil, DeSimone built a prototype for the CLIP technology in their garage, and realised how much impact their product, which combined hardware, software, and chemistry, could have on the world of manufacturing," said Phelps.

CLIP differs from other forms of ALM by making parts in a single continuous process, rather than by >>



01



02



>> building in layers, an approach which improves the mechanical properties of the final piece and the quality of its surface finish.

A continuous sequence of UV images, generated by a digital light processing unit, are projected through an oxygen-permeable, UV-transparent window, below a liquid resin bath. The oxygen that makes it through the window is enough to prevent the resin from curing directly onto the window itself, maintaining a continuous layer of liquid beneath the growing part. Above this 'dead zone', the curing part is drawn out of the resin bath creating suction that draws in more reactive liquid resin to the UV light.

"By carefully balancing the interaction of UV light, which triggers photo-polymerisation, and oxygen, which inhibits the reaction, CLIP continuously grows objects from a pool. This continual process is fundamentally different from traditional bottom-up printers where UV exposure, resin renewal, and part movement must be conducted in separate steps that results in the layered nature of the parts," said Phelps.

The process enables the creation of complicated geometrical shapes in a relatively short period of time, sometimes quoted as between 25 and 100 times faster than other ALM methods. In one of the first demonstrations, given as part of a TED talk by DeSimone, CLIP produced the geodesic sphere of injection-mould quality in a matter of a few minutes.

Carbon said that CLIP has also opened up the range of materials available for 3D printing.

"Traditional manufacturing processes have a lot of limitations when it comes to design and material availability. We want to open up the opportunity for these creators to think beyond those limitations. Our process employs a huge range of polymeric materials to facilitate the production of final-quality parts," said Phelps.

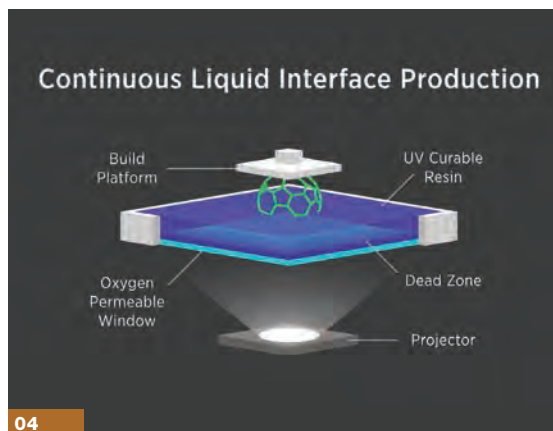
He added: "We can leverage the whole polymer family to address specific application requirements. Our work with elastomers, for example, covers a broad range of needs – from high elasticity for athletic shoes to damping properties for vibration control in automotive applications."

The range of new materials includes rigid and flexible polyurethanes, elastomeric polyurethanes, cyanate esters and prototyping acrylate.

"Our polyurethane materials are extremely versatile and can be tuned to achieve desired mechanical properties. At Carbon, we've developed novel classes of thermoset polyurethanes, which are designed to meet common engineering requirements.

"This makes a range of features and applications possible for industries as varied as automotive, medical and consumer electronics," said Phelps.

"Flexible polyurethane is a semi-rigid material with good impact, abrasion and fatigue resistance. This material was designed for applications that require the durability to



withstand repetitive stresses such as hinging mechanisms and environmental resistance."

Phelps said the elastomeric polyurethane could only be used with CLIP and was the only additive manufacturing material with true elastomeric behaviour. "It is useful for demanding applications where high elasticity, impact and tear resistance are needed. We are continuously striving to push the boundaries of chemistry and physics to improve the mechanical properties of our advanced materials and the functionality of customers' creations."

Customers include BMW and Ford, which used an early release of the M1 machine to make elastomer grommets for the Focus Electric and to evaluate designs for a damping bumper part on the Ford Transit Connect.

Designers also used the process to solve a problem that concerned the oil filler cap on the V8 engine. The team was able to rapidly design, prototype and manufacture an oil connector using rigid polyurethane and elastomer materials to access the oil fill tube

**03** The technology uses a range of polymers

**04** Schematic showing how process works

**05** The process enables the rapid creation of complex shapes

without needing major redesigns to several components of the vehicle.

Ford said it used CLIP to make parts in a fraction of the time it would have taken using conventional methods and with material properties much closer to the final properties desired for the part.

Medical supplies giant Johnson & Johnson is also collaborating with Carbon to produce surgical devices. While medical 3D printing is still in its infancy, the partnership is seen as a major step for the adoption of the technology.

Phelps said the company believes it is now on the path towards making '3D manufacturing' a reality.

"The 3D-printing industry has been relegated to fit prototyping for years. We have developed technology that can address fit and functional prototyping, as well as low-volume manufacturing. Our groundbreaking materials and the gentle nature of the CLIP process allow for the production of final parts.

"For the first time, product designers and engineers can produce parts that have the resolution, surface finish and mechanical properties required for both functional prototyping and production-quality parts."

The M1 is also able to collect process control data, which makes it possible for Carbon to provide remote diagnostics, assist with print optimisation, and improve print quality over time, said Phelps.

"An internet-connected architecture ensures latest features, performance enhancements and resins are always available to users, while the browser-based interface enables printer operation inside a network without the hassle of software installs or compatibility problems." ©

"Product designers and engineers can make parts that have the resolution required for production"

Kirk Phelps

**05**





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# Design and build in tune with structure of Bebop drone

**Parrot's aim was to optimise the drone's structural performance with short lead times. Supplier: CRP**



In late 2015 Parrot launched Bebop 2, the company's second-generation Bebop drone, with design and build assistance from CRP Technology.

The first Bebop 2 structure was built with injected parts made with a polyamide-based glass-reinforced composite material, but the final iteration was made possible with the help of CRP's Windform GT material, a polyamide-based glass microfibre reinforced composite material for SLS (Selective Laser Sintering).

Parrot's aim was to optimise the drone's structural performance with short lead times, and to avoid costs associated with injection tooling. It also wanted to consider a range of iterations more quickly while improving time to manufacture.

In order to meet these criteria, the company, which is based in France,

entered into collaboration with CRP Technology to investigate solutions presented by SLS technology and additive manufacture (AM) with Windform GT.

The drone's many features include an integrated front-facing camera. Digitally stabilised on 3-axis, images are said to be bright, stable and free of distortion.

Parrot carried out an original development approach that included FE (finite element) modelling that was aimed at improving the quality of video capture during flight through the optimisation of the drone's design.

Parts manufactured with Windform GT material contained natural frequencies that are similar to injected parts made with the polyamide-based glass-reinforced composite material. Combined with FE analysis, Parrot was therefore able to reduce development time and evaluate the toughness of the product's structure.

Bebop 2 parts made in Windform GT include the main structure and single arms; the body is robust and flexible, and the arms are reinforced.

From CRP Technology's point of view, requirements included fast iteration processes, and finding the best ratio between structural strength and weight. ©

# Some testing times for 3D printing

**Industrial-grade 3D printing under the microscope. Supplier: Proto Labs**

Additive specialist Proto Labs has been chosen by HP to test its new Multi Jet Fusion technology for industrial-grade 3D printing.

HP's first foray into additive manufacturing saw the US tech giant unveil two high-end printers (Jet Fusion 3D 3200 and Jet Fusion 3D 4200) in May, which it claims are significantly faster and cheaper than rival systems. Proto Labs is one of several companies HP is collaborating with as part of its Early Customer Engagement Programme, designed to provide feedback to accelerate the technology. Other partners include Shapeways, Materialise, Jabil and Siemens.

"The new HP Multi Jet Fusion 3D Printing Solution looks like a truly exciting leap ahead in industrial-grade 3D printing," said Rob Connelly, vice-president of additive manufacturing for Proto Labs.

"We at Proto Labs look forward to collaborating with HP to help develop this new platform that could result in higher productivity and quality at a lower cost."

For now, HP's new products are restricted to monochrome thermoplastic. While this might limit their appeal, the speed of the machines and their low cost per unit could see them adopted for rapid prototyping. Longer term, HP has said that it wants to move 3D printing beyond prototyping and into production.

Despite announcing in 2014 that it would compete in the additive market, HP has waited until now to make its first play. The intervening period has seen competitors such as Stratasys and 3D Systems come to dominate the sector. But HP is hoping that early collaboration with Proto Labs and its other partners will help it make an impact.

"We are pleased to have Proto Labs as a customer, providing its input and manufacturing expertise to help us continue to advance the HP Multi Jet Fusion 3D Printing Solution for our customers," said Stephen Nigro, president of HP's 3D printing business. ©





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



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# Seating plans taking shape through print

**Objet500 3D printer reduces time for aircraft seats.** Supplier: Zodiac Seats

Faced with the challenges of reducing the time taken to produce prototype components, airline seat specialist Zodiac Seats decided to install a Stratasys Objet500 Connex1 3D printer.

Since installing the system the firm has reported a reduction of up to six weeks (up to 92 per cent) when producing prototype parts. This has significantly alleviated pressure on development schedules by not having to wait for external suppliers.

The system has proven particularly useful during the design process for first-class, business and premiere economy seating products, which tend to be modified more regularly than standard seat designs.

"For us, adapting a seat design for changes in trim and finish takes about nine months," explains David Hayward, industrialisation manager at Zodiac Seats UK. "For a bespoke design, the process takes 20-24 months. It sounds like a long time, but it's a detailed process, and even though we do much of our own manufacturing, we are dependent on a large number of suppliers to meet our deadlines."

The deadline – the 'unlock date' – is important. All components must be delivered on time. New or refurbished

planes must be loaded and fitted in a particular order and installation crews can't be idle.

Hayward and his team began researching 3D printers and were quickly drawn to the technologies from Stratasys through UK Gold reseller, Stanford Marsh Group.

The group was attracted to the Objet500 thanks to its ability to print in multiple materials.

"Since it can print hard and soft materials in varying levels of rigidity, we can not only produce prototypes of parts that will be made of metal or composite materials, but also of soft parts such as seals and gaskets. To be able to produce these prototypes in materials that simulate the performance of the final manufactured part has changed how we design for manufacture," said Hayward. ©



# Desktop printing offers endless applications

**Technology is for more than just prototypes.** Supplier: Creat3D



It is well known that desktop 3D printers have a low investment cost and low running costs, but it is also widely assumed that desktop is just for printing plastic prototypes and that if you want to take 3D printing seriously, you have to invest tens or even hundreds of thousands of pounds.

The truth is you need to understand the capabilities and limitations of the different 3D printing technologies available. Desktop 3D printing in particular is not just for prototypes (although it's a big percentage of overall usage), but the applications are endless, and the resource benefits are clear to see.

Make Ltd is a large firm based in London for whom innovation is at the heart of its design practices. Model

shop manager Paul Miles said: "Desktop 3D printing has increased the capacity of what we can do. We are more efficient and can do more, with less people. Previously, no one would be available to generate a model so we would have had to use a bureau. Typically, a print would be £120 from a bureau, but using our own printers it is £3 or £4."

The trick is to know which printer is going to be best suited for your job, and that's what Creat3D specialises in. In relation to desktop 3D printers, Creat3D said its mission is to work with its clients to understand exactly what is to be produced and how it will be used.

Creat3D's clients use its desktop machines for tooling, jigs and fixtures, casings, enclosures, sacrificial parts, end-use parts, sales tools, moulds, components that keep a production line moving, casings to house delicate technologies, and more. These applications need different qualities whether that be in material properties, strength or finishes.

Some desktop 3D printers can generate a higher strength-to-weight ratio than aluminium. The recent release of the Mark Two Composite 3D printer is the best example of this. It does this through a composite approach, using nylon as a base material but with the option to incorporate Kevlar, fibre glass or carbon fibre into the part, for enhanced functionalities.

Carbon fibre is the key to very high-strength prints, whereas Kevlar, for example, is suitable in impact or abrasion-resistance applications.

A chain link printed on the MarkForged 3D printer with reinforced carbon fibre by the Olin College of Engineering supported approximately 10 tonnes before failing, all from a print costing less than £20. ©



# Integrating additive manufacturing with standard CNC machining

**Hybrid Manufacturing Technologies has developed a unique CNC-based hybrid tool control solution that enables virtually any CNC machine or robotic platform to deploy both metal-cutting and metal-adding heads in the spindle and conveniently change between them.**



Hybrids system uses Beckhoff controls to integrate additive manufacturing with standard CNC machining

**F**ounded as a commercial entity in 2012 by Dr. Jason Jones and Peter Coates, Hybrid Manufacturing Technologies actually began life in 2007 when the active use of a high-speed milling machine was initiated at De Montfort University's Additive Manufacturing (AM) and 3D printing research laboratory. The cross-pollination of additive and subtractive technologies led to a four year, UK-based research project named RECLAIM (REmanufacture of high-value products using a Combined LAsEr cladding, Inspection and Machining system) with support from the Technology Strategy Board and a number of industrial collaborators.

## **ADDITIVE MANUFACTURING**

Key to the technology is its ability to provide both metal adding and metal removal tools on the same spindle; operations normally undertaken by discrete machines and requiring lengthy additional changeovers and programming steps. This also means that the majority of metal parts made by additive manufacturing can have post-processing operations, such as polishing, milling and surface blasting, performed without

having to locate to another manufacturing cell, resulting in fabrication and surface finishing being achieved in a single setup. The hybrid approach also allows different compositions of materials to be used in the same component, while in-process inspection can assure quality levels otherwise impractical or impossible to evaluate.

The company initially had issues – relating to both the Ethernet communications and the HMI – with its original control solution, which lead to the first contact with Beckhoff Automation in 2014. The result of this collaboration was a control solution that not only addressed the communication and HMI issues, but also facilitated easier connection at customer sites and offered greater capability to expand the solution as the technology and the customers' needs evolve.

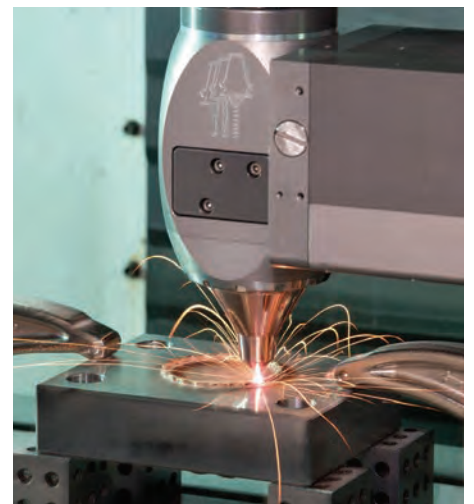
The technology is compatible with most CNC machine configurations and robotic platforms and can be supplied in collaboration with an OEM as an option on a new machine or added as a retrofit to new or used machines already in the field. A machine tool builder adopting Hybrid's system can use it to add additive manufacturing to the capabilities of a

standard machine. Hamuel, for example, first introduced an additive-capable model to a line of their machine tools in 2013 and several other machine tool builders have followed suit.

The current Hybrid system supports a range of AMBIT™ processing heads with different geometries, laser profiles, powder delivery configurations and de-focused energy beams to support tasks including 3D deposition, cladding, marking, cutting, drilling, pre-heating, annealing/stress relieving, surface re-melting and cleaning among others. The default setup accommodates up to 15 processing heads, but it can be expanded indefinitely, subject to space in the tool changer and controller capacity.

Beckhoff's motion control solution comprised a number of elements from its industry-leading portfolio. These included the EK1100 EtherCAT Coupler and other EtherCAT terminals and a Beckhoff CP2218 panel PC running Microsoft Windows 7 and TwinCAT 3 software for programming and control. Hybrid Manufacturing Technologies were particularly impressed by the Beckhoff HMI solution and the ability to deploy EtherCAT in the machine head.

Peter Coates, Co-founder of Hybrid Manufacturing Technologies elaborates on the technology and its capabilities: "We can make bespoke heads for customers, depending on their precise application needs, and these heads can be attached to virtually any machine tool. Looking beyond the machine, Beckhoff's use of EtherCAT means that connection to other cells is straightforward, and being based on a Window platform makes interfacing with Enterprise Systems far simpler from a protocol perspective and can leverage existing communication backbones. We will be looking to deploy Beckhoff systems in our standard product offerings as we expand worldwide, in step with the granting of foundational patents and intellectual property rights around the globe."



The unique head is controlled using Beckhoff's motion control solution

## **EASY TO USE**

Commenting on the move to a new control solution, Peter Coates, explains: "It was a bit of a culture shock, as we were used to working with software and hardware from another supplier, but we were able to do all the programming using the TwinCAT 3 software with minimal training. We found it incredibly easy to use and will exploit further training opportunities to improve our knowledge of the system's capabilities. The beauty of the structured text programming is that we don't have to change the platform, this also allows us to expand it seamlessly by simply adding new PLC code and all of the controls run the same code, which is unbelievably useful. The connectivity will also allow us to license the software in a way that allows users to deploy it on a pay-per-use basis."

By offering an open architecture running on off-the-shelf software solutions, Beckhoff products can be used as separate components or integrated into a complete and seamless control system. This open approach also facilitates integration into customer sites, especially in relation to the deployment of Ethernet-based control and ERP solutions.

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# Shoring up the cyber world

**A number of courses are offering an insight into protecting sensitive data from the predations of cyber attack.** Evelyn Adams reports

M

anufacturing is now undergoing a transformation as part of 'the fourth industrial revolution'. This will see greater integration of digital process and physical products to drive down costs and increase efficiency. For manufacturers, that

means moving certain processes to the Cloud and using the 'Internet of things' to gather huge amounts of data on the products. But that data may not be safe.

Cyber attacks on engineering and manufacturing firms

are on the rise – and the fourth industrial revolution could be about to make things much worse. Now, Britain's manufacturers are being urged to improve their planning to counter the increasing number of cyber security threats. EEF, the manufacturers' organisation, made the call on the back of a new survey showing just how little some manufacturers have been doing to mitigate cyber threats.

EEF's findings, published last month, reveal that just under half of manufacturers have failed to increase their investment in cyber security in the past two years. That number is even greater for small manufacturers at 56 per cent. The organisation also found that two in 10 firms are not actively making employees aware of cyber risks, while less than six in 10 say cyber security is given serious attention by their board.

"Companies will inevitably find themselves more vulnerable to cyber breaches"

Lee Hopley, EEF

**01** Cyber attacks on engineering firms are on the rise

"As technology and data start to play increasingly critical roles in manufacturing, companies will inevitably find themselves more vulnerable to cyber breaches," said Lee Hopley, chief economist at EEF. "Our survey highlights that investment in new technology isn't being matched by investment in managing risks, especially among smaller firms."

Government figures back up this claim. They show that last year, 90 per cent of large businesses and 74 per cent of small businesses reported a cyber security breach – an increase on 2014. It is believed the average cost of these hacks is between £1.46m to £3.14m for a large firm and £75,000 to £311,000 for a small business.

"Technology is set to transform our industry as part of the fourth industrial revolution, opening up immense opportunities and possibilities but risks run alongside the rewards," said Hopley. "It is important that manufacturers are able to identify, understand and put the correct strategies in place to keep their businesses safe and cyber secure."

In response to the threats and, to back its call, EEF has developed a free online tool that will enable manufacturers to benchmark their cyber security skills. But the EEF said what is really needed is for employees to get training in how to best tackle cyber issues and mitigate the risk for their companies. There are an increasing number of continuing profession development (CPD) and training initiatives available that can help employees of engineering businesses learn more about cyber security.

For instance, on 15 June, the IET is holding a one-day seminar titled 'Cyber security in modern power systems'. The course will help address the risks that hackers pose to networks and supply that power critical infrastructure.

"Cyber security for power networks and energy systems is gaining momentum and a higher level of importance with increased threat of attacks to our critical infrastructure. The risk of cyber attacks to vital infrastructure is no longer a new threat and this event will offer an overview on operational and technical strategies for large and complex networks," according to the IET.

Meanwhile, for engineers earlier in their careers, the government-based Cyber Security Challenge this year revealed it is offering the UK's first Extended Project Qualification (EPQ) in cyber security. This is a level-three qualification – the equivalent of an AS level. The qualification is open to >>







03

“Too many firms are losing money, data and consumer confidence with the vast number of cyber attacks. It’s crucial businesses are secure”

Ed Vaizey

>> anyone and can be studied in an independent capacity by registering through Cyber Security Challenge UK.

The EPQ is based on the newly agreed National Occupation Standards (NOS) for cyber security, which is designed to be relevant for industry. It was set up by Cyber Security Challenge UK in collaboration with a number of independent cyber education specialists, including (ISC)2 – the world’s largest body of info security professionals.

“The subject is becoming increasingly important and for it to be officially recognised at this level paves the way for individuals to consider a career in the sector much earlier on,” said Stephanie Daman, CEO of Cyber Security Challenge UK. The qualification can also be used to supplement existing skills in engineering, and, according to CSC UK, would be a good investment in future employment opportunities.

Universities also offer a more traditional route into training by offering short courses in cyber security for engineers. For instance, Glasgow Caledonian University is offering a 10-week course aimed at providing engineers an introduction to core security concepts. The syllabus covers topics from cyber security terminology to devices and strategies used in maintaining secure networks.

For those who prefer distance learning, Queen’s University Belfast is offering ‘Cyber security CPD for industry professionals’. “As the risk of cyber security grows, a major issue for business is the capacity to train existing staff in managing this risk in a cost-effective and flexible way,”

according to the university, whose course is being led by Prof Maria Lee. “Through the design and delivery of an online module, the project plans to test the potential for training staff in-house using a flexible course design model.”

As well as professional organisations and universities, the government is providing help by offering through the ‘10 Steps to Cyber Security’ scheme, which provides advice to large businesses and the ‘Cyber Essentials scheme’ is available to all UK firms. The government is also creating a new National Cyber Security Centre offering industry what it claims to be a ‘one-stop shop’ for cyber security support.

“The UK is a world-leading digital economy and this government has made cyber security a top priority,” said minister for the digital economy Ed Vaizey. “Too many firms are losing money, data and consumer confidence with the vast number of cyber attacks. It’s absolutely crucial businesses are secure and can protect data.”

**02** Data is increasingly important to manufacturing firms

**03** Security awareness is a vital skill for today’s engineers



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# CELEBRATING WOMEN IN ENGINEERING

In celebration of Women in Engineering Day, three female engineers at global engineering, strategic and environmental consultancy Ricardo, share what inspired them to choose a career in engineering and what they most enjoy about working in the industry.

**Angela Johnson is Strategy & Growth Lead for Advanced Technology Development at Shoreham Technical Centre, Sussex.**



## What inspired you to choose a career in engineering?

My dad – I loved the fact that he could explain to me how things worked from cameras to cars, planes and fridges. He could also restore and fix pretty much anything mechanical. From an early age, I wanted to be able to do the same, so I would help him in the garage, passing him spanners and screwdrivers and helping him rebuild engines and vehicles. The smell of 2-stroke and oil always takes me back to my childhood days!

## What do you enjoy most about working in engineering?

I love the variety of my job and the constant need to problem solve. It's exciting to know that projects I'm working on are helping to shape the future of the automotive industry and influencing the products that people will buy and use. I'm also lucky to work in a global company, which hires some of the world's leading experts in the automotive field, as it gives me the chance to learn from them on a day-to-day basis.

One of my career highlights is the first time I saw a product come off the production line that featured a component I had designed.



**Jo Elgood is Vehicle Attributes Engineering Manager and works in Leamington Spa, Warwickshire.**

## What inspired you to choose a career in engineering?

Similar to Angela, my dad has undoubtedly been my biggest inspiration and influence. As an automotive engineer, he is very passionate about innovation and clever design. When I was growing up, he would tinker about with his car, pointing out key features and explaining their function to me. At the time I wasn't always interested, but at school I was strong at maths and science so my dad really encouraged me to go into engineering. In his eyes it is the best career in the world for someone with a technical-minded brain. He would say "the world will always need engineers Jo, everything has to be engineered."

I think my interest in engineering clicked at school when I realised that I could use maths to solve real-life design problems.

## What do you enjoy most about working in engineering?

I love coming up with clever ideas to advance key attributes of vehicles, whether it is enhancing vehicle performance, reducing fuel consumption or improving safety. I work in a great team where we really encourage each other to come up with solutions to solve complex problems together.

As a manager, I also get to use my problem-solving skills to ensure we have the right team and skills in place to deliver on projects in the most efficient and cost-effective way. I thrive on juggling the priorities of multiple projects simultaneously.

In my career so far, I am lucky to have had the opportunity to travel, receive training and progress from being a CAE engineer to an engineering manager. Ricardo has been extremely supportive in helping me find the balance between work and being a mum.



**Penny Atkins is the Chief Engineer for Advanced Technology Development at Shoreham Technical Centre, Sussex.**

## What inspired you to choose a career in engineering?

My family background was an important influence. My dad was an engineer, so I have memories of mini engines on the kitchen table and numerous visits to steam trains as a child. I remember some early experiments in composite materials aimed at improving mud pie stability, and spending many happy childhood hours building things from Lego. I enjoyed science at school and my parents always encouraged and supported me in STEM subjects. I loved physics at A Level, but realised that I was particularly interested in the practical application of the subject and decided to read Mechanical Engineering at university.

## What do you enjoy most about working in engineering?

I enjoy the opportunity to contribute to some of the big questions - e.g. how will future transport look? How can technology changes in transport support national activity to reduce CO2 emissions?

I've worked on a range of great projects over the years. I loved seeing the Jaguar car I'd been working on in production getting good reviews from the motoring press and I was proud to support the development of legislation for CO2 emissions.

My favourite part of working in engineering is the team work. I really enjoy working in collaboration with colleagues at Ricardo and partner organisations. My role is also pretty varied which gives me the opportunity to develop across a range of areas – managerial, commercial, communications, as well as technical.

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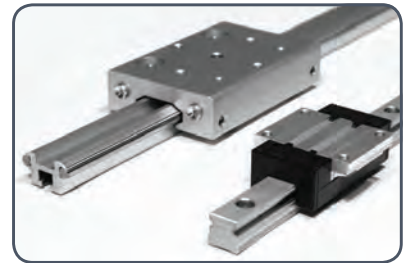
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# Metal moves

**A humble 19th century crank bending apparatus was in fact an important premonition of the future**



ne of the joys of ferreting through *The Engineer* archives is in stumbling upon an article that, while it appears prosaic from its heading and even the accompanying illustration, turns out on closer inspection

to contain fascinating nuggets of history. So it was that, while looking through a piece about the early development of the phonograph it became apparent that the adjacent article, under the unpromising title of 'Bent Cranks', dealt not only with important advances in metallurgy and tooling, but also with a trend in the engineering industry of 1878 that we're still seeing the effects of today.

In engineering terms, the main thrust of the piece concerned the discovery that, if a material is bent slowly and gradually, it can assume a desired form without adversely affecting the material's strength or other properties. It noted that iron cranks had previously been made by forging: "A crank was made, chiefly, by hammering, and each successive blow was attended by a change of form, effected in so short a period that it may be considered as without assignable duration, the iron being much distressed by the process."

An alternative approach had come from research carried out by an engineer the article refers to as 'M Tresca' (Henri Édouard Tresca, a French mechanical engineer who pioneered the study of plasticity in materials in the 1860s and 1870s, and was also one of the designers of the prototype standard metre bar). Tresca had found that the particles of a solid flow when it is distorted, and providing that the distortion is gradual enough, rearrange to preserve the material's strength; in a forging made by repeated impact, they do not have time to flow and planes of weakness in the metal may be formed.

The article then discussed hydraulic crank bending machinery designed by an engineer from Lincoln named Edward Clarke. The device would now seem

quite commonplace but it was obviously a surprise to our predecessors. Simply, the device took a bar of iron heated to yellow heat, or of red-hot steel, placed into a die, where one hydraulic ram would press downward on the middle of the bar. Two other rams press on the end of the bar, pushing it into the desired shape. The process took six to eight minutes, during which the hydraulics were in constant motion. "The movement is so slow and steady that it is difficult to observe it, although minute to minute it can be seen that bending has taken place."

Forging a crank from a 3.5in iron bar would take a smith and two strikers two-and-a-half to three hours, it said, and so "though it may seem paradoxical", Clarke's machine could make cranks in a fraction of the time of conventional forging, and the quality of the product would also be better.

So, we can see here the beginnings of automation rather than hand-making, but the article drew attention to another change in the industry. This, it said, is the rise of the speciality engineering company rather than the "general engineering" firms that had previously dominated the sector, especially in the agricultural engineering industry. "The tendency is...

to extend the division of labour to entire factories, by limiting the number of sorts of articles being produced." This, it continued, reduced the number of draughtsmen needed, as well as the amount of tools, and improved the quality of the products. However, it added, when Clarke founded his factory, "very few believed that a manufactory devoted to the production of a single article could be successful", and only a very few customers who couldn't afford their own forging facilities would go to them.

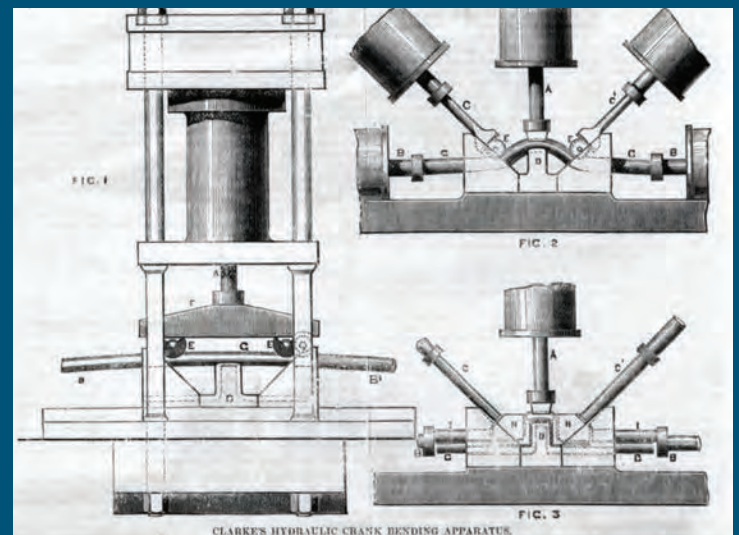
This turned out to be mistaken, however, and "a large proportion of the whole of the firms in Great Britain requiring bent cranks... now find that they can buy crank more cheaply and better made than they could produce them at their own works". Indeed, at the time of writing, Clarke's Crank Company was about to embark upon an expansion.

Edward Clarke would probably find UK industry's current preoccupation with high-value manufacturing of specialised machines and components quite familiar. It certainly seems to have worked out: Clarke's Cranks ceased trading in 2002, and from its ashes was formed Lincoln Crankshaft and Machines in 2003. **SN** ©

"The tendency is... to extend the division of labour to entire factories by limiting the number of articles being produced"

*The Engineer*

Clarke's hydraulic crank bending apparatus as featured in *The Engineer*



## Word of the issue

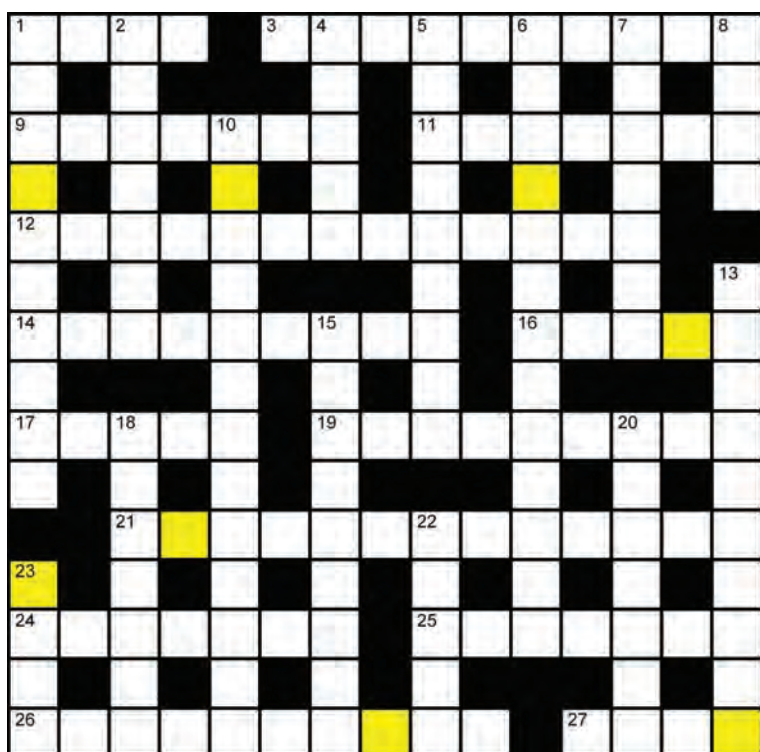
### Anthony Poulton-Smith explores the origins of the word 'brake'

Any machine providing motive power also requires a method of stopping it. Controlled stopping is by means of a brake, be it applied to a wheel or similar moving part. This use as a verb is unknown prior to 1868, although the word had certainly been in use as a noun since the middle of the 15th century. When looking at the noun we discover this is from the Middle Dutch braeke, used specifically for 'a flax break' and also breken, meaning simply 'to break'. Although the different spellings of 'brake' and 'break' in modern English convey different meanings, etymologically speaking these are the same. Initially used to describe any crushing motion or implement, it is also seen in Old French brac or 'arm' where it refers to a lever or handle. This not only represented a crushing tool but how such would have been wielded. It is this early sense that 'brake' also found itself referring to 'a bridle' or 'curb'.

# Big picture



A lot has changed since Otto Lilienthal first took to the skies in Normalsegelapparat, the world's first series-built flying machine that has been replicated by the German Aerospace Center. Normalsegelapparat weighed 20kg and had a wingspan of 6.7m compared to the A380 it is pictured with, which has a wingspan of nearly 80m and weighs 569 tons.



## Prize crossword

**When completed** rearrange the highlighted squares to spell out the central body of an aeroplane. The first correct answer received will win a £20 Amazon voucher. Email your answer to [jon.excell@centaur.co.uk](mailto:jon.excell@centaur.co.uk)

### Across

- 1 Bite and grind up with teeth (4)
- 3 Workplace for the conduct of research (7,3)
- 9 Someone who has had a limb removed (7)
- 11 Paper-like sheet of metal (7)
- 12 Not characteristic of a good employee (13)
- 14 Container for holding gasses (3,6)
- 16 Cause to lose one's composure (5)
- 17 Supercharger driven by an exhaust gas turbine (5)
- 19 Process of combining with water (9)
- 21 Fitness to traverse the oceans (13)
- 24 Impeded the movement of (7)
- 25 A light raft made of balsa (3,4)
- 26 Workplace where lumber is stocked for sale (10)
- 27 Longitudinal beam on the hull of a vessel (4)

### Down

- 1 Agents that form semisolid lumps in a liquid (10)
- 2 Delegate authority to (7)
- 4 Best people or things in a group (5)
- 5 Involved in difficulties (9)
- 6 An arrangement of parts or elements (13)
- 7 Makes less dense (7)
- 8 Screw that goes into a nut to form a fastener (4)
- 10 Had a small rotating radius (6,2,1,4)
- 13 An interruption of normal activity (10)
- 15 Period of work for a student (6,3)
- 18 Platform raised above the surrounding level (7)
- 20 Specify individually (7)
- 22 One who accepts an offer (5)
- 23 A blemish made by dirt (4)

May's highlighted solution was nucleus. Winner: **Robert Burns**



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