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our opinion

Making space

In last month's issue we looked at Project Orion: NASA and ESA's plan to reignite manned space exploration.

It's an exciting and inspiring initiative that *The Engineer* is sure to follow closely over the coming years. But it's also – in conceptual terms – something of a throwback: a return to the tried, tested and extremely expensive Apollo-era approach of sending a crewed capsule hurtling into space on top of a giant rocket.

There seems to be little doubt that Project Orion will help revive our interplanetary ambitions. But the next step is surely to dramatically reduce the cost of access to space.

In this issue's cover feature (p18), we look at an area of technology that promises to do just that: off-planet manufacturing.

As we report, the International Space Station is already home to a 3D printer, while back on Earth a number of companies are working on the development of manufacturing techniques optimised for use in orbit. Among them, UK firm Magna Parva believes it could help dramatically reduce the cost of putting satellites in space by doing much of the manufacturing in orbit.

Further into the future, engineers even envisage the development of techniques that make use of the raw materials to be found on the Moon, Mars and beyond. ESA, for instance, has been looking at whether lunar regolith could be used as a feedstock material to 3D print lunar bases (see cover image).

"Engineers even envisage making use of the raw materials to be found on the Moon, Mars and beyond"

It's a fascinating field. And as with many other apparently eccentric areas of development, it's perhaps surprising how much has already been done.

No less eccentric is German automation giant Festo's continuing obsession with flying robot animals (p22). It's tempting to dismiss the group's work in this field as a clever marketing stunt but, as we recently discovered, the world of automation has a lot to learn from ants, butterflies, and chameleon tongues.

Finally, in this issue's archive feature (p49) we take a look back at *The Engineer*'s 1859 coverage of Isambard Kingdom Brunel's final project, the ill-fated iron sailing steam ship *The Great Eastern*. Interestingly, the magazine doesn't mention the vessel's famous designer once: a reminder that Brunel was not as universally praised during his lifetime as he is today. ©

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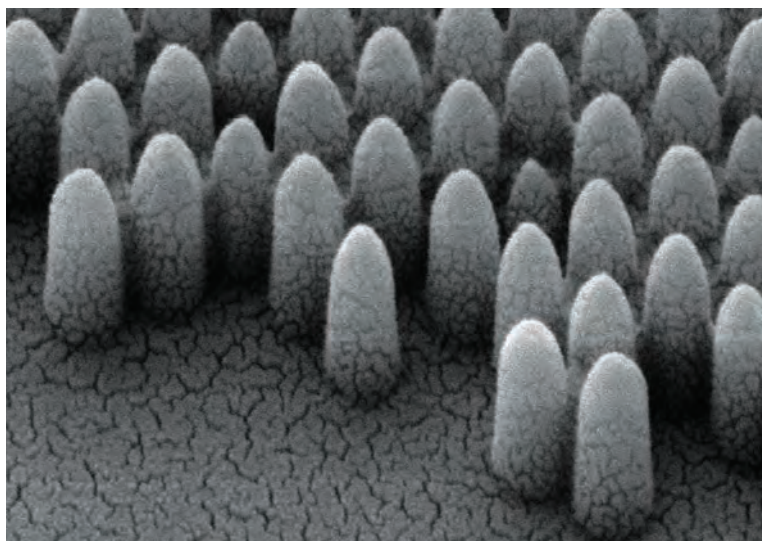
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MATERIALS

Self-clean windows are smart work

New invention also capable of regulating temperature inside buildings HELEN KNIGHT REPORTS



The windows are engraved with a series of pencil-like conical nanostructures

Intelligent windows, capable of cleaning themselves while also regulating the temperature of the building and reducing glare from sunlight, have been developed in Britain.

Buildings consume 40 per cent of the energy that is used in the developed world, with heating and cooling accounting for around 66 per cent of this.

The smart windows, developed at University College London (UCL) with EPSRC-funding, could help reduce the cost of cleaning the large number of windows in modern office buildings, cut energy use and slash heating bills by up to 40 per cent.

The windows are engraved with a series of pencil-like conical nanostructures. These trap air and ensure only a tiny amount of water touches the surface of the glass.

As a result, any rain hitting the windows forms into spherical droplets that simply roll off the glass surface, picking up dust and dirt in their path as they do so.

In contrast, raindrops hitting conventional windows cling to the glass, causing them to slide down it and leave streaks and dirt behind.

The pattern of the nanostructures

also gives the windows the same anti-reflective properties as the eyes of creatures such as moths, which allow them to hide from predators. This reduces glare by cutting the amount of light reflected internally within a room, to less than five per

“If you compare the [surface] area of planar films with our nanostructured material we have enhanced the area over 10 times”

Ioannis Papakonstantinou
UCL

cent. This compares with the 20-30 per cent found with other prototype energy-saving windows.

Finally, the nanostructured windows are coated with a thin film of vanadium dioxide on top. This prevents heat escaping from the building on cold days, and stops infrared radiation from sunlight passing through the glass on hot days.

That is because vanadium dioxide is a thermochromic material, meaning that it can switch from blocking all infrared radiation to allowing it to pass through, depending on the temperature applied.

Unlike the gold or silver coatings used in some smart windows, vanadium dioxide is a cheap and abundant material. What's more, only a very thin layer of between 5-10nm of the material is needed, making it more cost-effective and sustainable than other technologies.

The windows are the first to combine this thin thermochromic coating with a nanostructure engraving, according to the project leader Dr Ioannis Papakonstantinou at UCL.

“Unlike gold coatings used in some smart windows, vanadium oxide is cheap and abundant”

The two technologies complement each other, with the nanostructure helping to enhance the thermochromic properties of the coating, he said.

That is because unlike smooth films of vanadium dioxide, which require a very large area to achieve a thermochromic effect, the nanostructures increase the surface area of the film significantly. “If you compare the [surface] area of planar films with our nanostructured material, you will see that we have enhanced the area by over 10 times,” according to Papakonstantinou.

This means a very thin layer is needed to achieve the same effect as much thicker smooth films, he added.

The researchers are in discussions with UK glass manufacturers in a bid to commercialise the smart windows. This will involve scaling up the manufacturing methods the researchers have developed to produce the nanostructured glass, as well as the coating process used.

If these discussions are successful, the researchers believe the smart windows could be commercially available within three to five years. They have been awarded a five-year European Research Council grant to build the windows and test them under realistic conditions.

The team is also hoping to develop a smart polymer film incorporating the nanostructures, which could be applied to existing windows. ©

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NUCLEAR

NuScale looking for a reaction in UK

Plutonium stockpiles could form basis of new small modular reactors STUART NATHAN REPORTS

The UK's plutonium stockpile could be used to fuel a new design of small modular reactor proposed by US company NuScale.

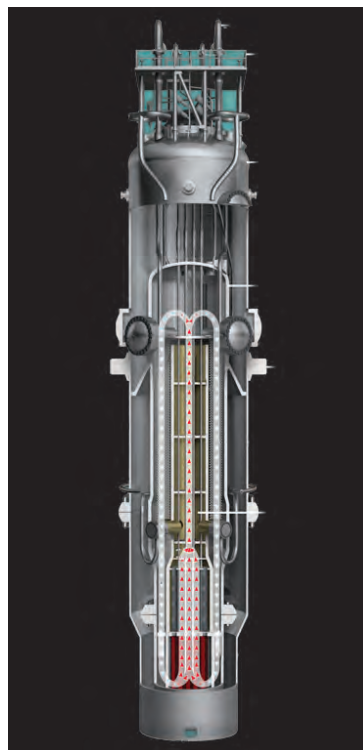
NuScale Power, the Oregon-based nuclear hardware specialist that last autumn unveiled small modular reactor (SMR) technology that it hopes to use in the UK market, has now revealed that its design has been evaluated for partial or full fuelling with mixed uranium and plutonium oxide (MOX) fuels. The company commissioned a study from the UK National Nuclear Laboratory to evaluate whether the reactors could be used to run with the fuel, which can be formulated to use up a stockpile of civil (i.e. non-weaponised) plutonium.

The SMR technology, currently untried but slated to come into service in the US in 2023 consists of 50MW pressurised water reactor units designed to be installed in a cluster of up to 12 units within single power stations, to give an option for flexible-output stations whose output could be varied quickly, for example to balance intermittent renewables. Like all SMRs, they could be built

in relatively small factories from components cast in conventional foundries, thereby reducing the cost and difficulty of building nuclear reactors.

The NNL study looked at both partial and full loading of the reactor core with MOX, and confirmed that neither scenario would affect the reactor's design or operation. It also showed that a 12-unit power station running on full MOX would consume a 100-tonne stockpile of plutonium – similar to the size of the UK's plutonium holding, which is stored at Sellafield – in about 40 years; this would generate 200 million MWhr of electricity, while degrading the isotopic content of the plutonium to make it unusable for nuclear weapons.

"The National Nuclear Laboratory has been pleased to work with NuScale on a commercial basis to help demonstrate the capability of their SMR in relation to MOX fuel," said NNL business leader for fuel and reactors, Dan Mather. "Reuse of the plutonium for low-carbon power generation could be a valuable way forward for dealing with the UK's nuclear legacy." One option currently being considered for the UK's plutonium stockpile is conversion



NuScale Power's SMR technology

to MOX by a process used by Areva on France; Areva already has an important foothold in the UK with its plan to build its EPR reactor design at Hinkley Point in Somerset.

Chancellor of the exchequer George Osborne announced in December's Spending Review that the Treasury had earmarked at least £250m to be spent on SMR technologies by 2020, and indicated that there would be a competition to identify the best-value design from prospective vendors with a view to building power stations in the 2020s. ©

Newsinbrief

Spreading its wings

George Osborne and Airbus chief operating officer Tom Williams have announced a £37m investment in a new Wing Integration Centre. Due to open in 2017, the Filton-based facility will be an advanced testing centre for large structural components that will enable Airbus and its partners to develop cutting-edge ideas.

Sense of loss

Britain's steel industry is suffering further job losses following the announcement that up to 100 jobs will go at Sheffield Forgemasters. Tony Pedder, chairman of Sheffield Forgemasters, said: "Of particular concern has been reduced activity in the traditional oil and gas sector, with oil prices down to a level that is deferring much potential new investment."

For the record

Last year was a record year for Britain's car manufacturers who produced more vehicles than any year since 2005 when 1,595,697 vehicles were made. According to figures from the Society of Motor Manufacturers and Traders (SMMT), production increased 3.9 per cent on 2014, with output at 1,587,677 overtaking pre-recession levels for the first time.

Regional outlook

Four UK regions have been named winners of the Go Ultra Low City Scheme after proposing initiatives to support greener vehicles as part of a government competition. The winning regions – London, Milton Keynes, Bristol and Nottinghamshire/Derby – will deliver a roll-out that includes rapid-charging hubs and street lighting that double as charge points and prioritising ultra-low emissions vehicles.

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MATERIALS

Project works on graphene enhancement

Manchester and Abu Dhabi researchers collaborate

HELEN KNIGHT REPORTS

Manchester and Abu Dhabi universities will collaborate on graphene-containing 3D foam that could enhance the material's properties in sensors and other electrical components.

The use of graphene in batteries, composites, micro-sensors and ion-exchange membranes will all be investigated as part of a new collaborative research programme.

The programme, which will bring together researchers at Manchester University and the Masdar Institute of Science and Technology in Abu Dhabi, will focus on three projects on the use of graphene and two-dimensional materials in a range of applications.

Graphene is a single layer of carbon atoms, which is 10 times stronger than steel while 1,000 times lighter than a sheet of paper per unit area.

In one project, researchers will develop low-cost ink-jet printing for building micro-sensors designed to

operate in challenging environments found in high-temperature energy and military applications.

A separate team will investigate the using graphene-based ion exchange membranes in water desalination.

Finally, researchers will attempt to develop low-density graphene nanocomposite foams for use in batteries and supercapacitors, and to stiffen composite materials.

The advantage of using a 2D material such as graphene in battery electrodes, for example, is that it has a very high surface area, and yet is only one atom thick, according to Prof Brian Derby at Manchester University, who is a member of the research team. ©

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MEDICAL

Project could offer boost for biopsy

Research could aid more accurate screening for breast disease HELEN KNIGHT REPORTS

Faster, cheaper and more accurate biopsy screening for breast cancer and other diseases could be made possible, thanks to a European-wide project.

The MRI and Ultrasound Robotic Assisted Biopsy (MURAB) project, led by Prof Stefano Stramigioli at the University of Twente in the Netherlands, is aiming to develop a system that can reduce the number of patients wrongly discharged with an all-clear.

Existing image-guided biopsies are typically carried out with an ultrasound device. However, the imprecise nature of images produced with ultrasound means that the sample of tissue can sometimes be taken from the wrong place, according to Foad Sojoodi Farimani, a member of the project team at the University of Twente.

This results in a false negative rate of 10-20 per cent. "So you either take a couple of biopsies, and have a false negative rate of 10-20 per cent, or you increase the number of biopsies taken, but this also increases the risk of complications," Farimani said.

In contrast, MRI scans are much more accurate, but can take up to 60 minutes to complete, and are too expensive to be used in widespread screening programmes, Farimani said.

So instead, the MURAB team want

to combine the accuracy of a much shorter MRI scan with cheaper, real-time imaging.

"The patient would go into the MRI, for no more than around 15 minutes," he said. "Then, using cheaper imaging sensors such as ultrasound, we would fuse the detailed, precise image of the MRI with that from the cheaper sensor," added Farimani.

"We would fuse the MRI with that from the cheaper sensor"

Foad Sojoodi Farimani
University of Twente

The researchers plan to develop algorithms to fuse together information from the offline MRI images and real-time ultrasound into a single scan, to allow the suspicious tissue to be precisely located.

A tele-operated biopsy robot, controlled by the surgeon, would then be used to take a tissue sample, said Farimani.

The €4.3m project, whose members include Siemens and Kuka, will also investigate the use of the technology in biopsies for muscle diseases. Ultimately though, it could be used to diagnose any disease where a biopsy is needed. ©



The project will investigate the use of the technology in biopsies for muscle diseases

MATERIALS



The Namib Desert beetle has a surface studded with bumps that attract water

Coming out of their shell

Technique for anti-frost coating takes its inspiration from the Namib Desert beetle

An advanced coating that has been inspired by a beetle's shell could be used to prevent frost forming on aircraft parts and windscreens, a US research team has claimed.

Developed at Virginia Tech, the technology uses photolithography to create chemical micropatterns to control the growth of frost caused by condensation.

According to a paper published in *Scientific Reports*, the technique takes

its inspiration from the Namib Desert beetle, which has a water-repellent surface studded with bumps that attract water. These bumps enable it to collect airborne water, which then flows down water-repellent channels towards the insect's mouth.

Jonathan Boreyko, an assistant professor of Biomedical Engineering and Mechanics in the Virginia Tech College of Engineering, said that by mimicking this ability to control where dew-drops grow it is possible to create frost-proof surfaces.

In 2012, US start-up NBD Nano said it had copied a beetle's ability to develop a self-filling water bottle. **JE**

BATTERIES

Nissan takes the lead for lithium ion

Project works on batteries for electric cars

HELEN KNIGHT REPORTS



Hoping for a battery breakthrough

Nissan is leading a £19.4m UK project to develop next-generation lithium-ion batteries for electric cars.

The project, with funding from the Advanced Propulsion Centre, is aiming to develop new and improved chemistry and manufacturing processes for li-ion batteries.

The UK consortium includes Warwick Manufacturing Group (WMG), Hyperdrive, Newcastle University and

Zero Carbon Futures and research will be based around Nissan's Sunderland battery manufacturing plant.

WMG researchers will investigate potential improvements to li-ion battery chemistry and manufacturing yield, and develop automated production processes, according to David Greenwood, professor of advanced propulsion systems at Warwick.

"For passenger cars, in particular, the trend towards electrification, whether that is hybridisation, plug-in hybrids, or full electric, is marching inexorably onwards," he said. "But one of the challenges we have is in bringing down the cost of the systems."

Researchers at WMG have been working to improve the chemistry of li-ion batteries in a bid to achieve higher energy densities for every cubic metre of material used, he said.

"There is a lot of work going on [at WMG] at the microscopic scale, on the structuring of the electrode materials to give the greatest surface area for reactions to take place, and to allow the lithium ions to circulate freely through the carbon matrix," he said.

The consortium team is also attempting to better understand the electrochemistry behind some of the processes involved in manufacturing batteries, including adding electrolyte to the electrodes, and when the device is given its first charge. ©

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TRANSPORT

Emissions control is on an anti-roll

Light anti-roll bars could cut fuel consumption and control emissions HELEN KNIGHT REPORTS

A UK consortium is developing lightweight anti-roll bars that could cut fuel consumption and emissions from rail and heavy road vehicles while improving reliability.

The project, co-funded by Innovate UK, will develop high performance metal composite hybrid anti-roll bars for trucks and trains.

The research team consists of South Yorkshire-based companies Tinsley Bridge and Performance Engineered Solutions, plus Sheffield

Centre. "We've shown in a previous project that we can achieve weight savings of over 60 per cent," he said. "We now hope to improve on that while also improving [the material's] performance."

As well as reducing a vehicle's fuel consumption and emissions, the development could also help to cut maintenance costs as the composite metal hybrid bar should

never need replacing, unlike its metal counterparts, he said.

The composite component should also be able to withstand larger dynamic loads than metal bars.

Composite anti-roll bars are emerging in luxury cars, such as the Audi R8 e-tron electric vehicle. "However, it's a lot more challenging to manufacture a composite anti-roll bar for heavy commercial vehicles as the loads and forces involved are considerably higher," said Smith.

One of the biggest challenges in the project will be finding the best way to bond the composite bar to the metal end pieces, and the team is planning to investigate a number of possible solutions to this.

Performance Engineered Solutions will lead the design and engineering of the bars. AMRC's Composite Centre will then use Finite Element Analysis to ensure the bars are capable of

resisting the type of loads anti-roll bars undergo.

AMRC researchers will then produce the bar automatically, using a filament winding system. This is a technique in which filaments of glass or carbon are wound onto a rotating mandrel to form a desired shape before being impregnated with resin.

Finally, the AMRC team will use a CT scanner to study the structural integrity of the bar, and verify the build quality. If successful, the technology could also have applications in the aerospace industry. ©



The team hopes to reduce the weight of the bars

"We've shown in a previous project we can achieve weight savings of over 60 per cent. We now hope to improve on that"

Matt Smith
AMRC Composite Centre

University's Advanced Manufacturing Research Centre (AMRC).

By producing the bars from composite with metal end pieces, the project team hopes to considerably reduce weight of the components, according to Matt Smith of the AMRC Composite

SENSORS

Concept joins the queue for development

System could tell users which is quickest queue HELEN KNIGHT REPORTS

Arguably, there is nothing more annoying than joining what you think is the shortest queue, only to find that those on either side of you are moving much more quickly.

Now, an infrared-based queue-monitoring system that has been developed by Cambridge Consultants, could tell a user which line to join to ensure that they reach the front fastest – even if the line is at the other side of the building.

Dubbed ZipLine, the system uses infrared sensors to count the number of people lining up in each queue and detect how fast they are moving, according to Tim Ensor, head of connected devices at Cambridge Consultants.

"It is like a low-resolution infrared camera, in that we can see a blurry image of what we're looking at, although we can't see who the people are," he said.

An algorithm on the sensor then calculates where the people are in this infrared image, how they are forming themselves into lines, and how fast the lines are moving, he said.

A long-range, low-power radio link transmits this data from sensors dotted around the area to a central server, where it is converted into user-friendly information that can be displayed on a screen or website, for example.

The ZipLine system is able to operate over distances of up to several kilometres.

"We could put Bluetooth beacons up at checkouts, for example, and then push a notification to consumers' smartphones, to ask if they are interested in checking out of the store in the quickest way," said Ensor. "Those that click yes to that would then be directed to a webpage, which would give them the information they want", he said.

Having developed the queue-monitoring concept, Cambridge Consultants is now seeking to talk to other interested companies about the possibility of commercialising the technology. ©

3D PRINTING

Hypersonics – one layer at a time

Hypersonic engine is produced through additive manufacturing process

Orbital ATK has successfully tested a 3D-printed hypersonic engine combustor at NASA's Langley Research Center in Virginia.

Produced through an additive manufacturing process known as powder bed fusion (PBF), the combustor was subjected to a variety of high-temperature hypersonic

flight conditions over the course of 20 days, including one of the longest duration propulsion wind-tunnel tests ever recorded for a unit of this kind.

One of the most challenging parts of a hypersonic propulsion system, a scramjet combustor houses and maintains stable combustion within an extremely volatile environment. According to ATK, analysis confirms the unit met or exceeded all of the test requirements.

The company said the use of an additive process to build up the component one layer at a time, enable it to incorporate design features that couldn't be produced using conventional techniques. **JE**

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Help facts rise up from fiction

Children's natural curiosity for STEM subjects, often sparked by popular science fiction films, can be engaged in a highly productive fashion

Throughout my life I have always thoroughly enjoyed watching sci-fi films. They have become a welcome extension of my personal and professional interests in STEM subjects. I can remember, as a young adult, the thirst for scientific answers I was

left with after watching and contemplating some of the ideas in Stanley Kubrick's *2001: A Space Odyssey*, or the excitement I felt as a child when I saw Patrick Moore's *Sky at Night* – my imagination went into overdrive. But, do sci-fi films still inspire our kids in the same way?

Taking into account the list of the most well-known sci-fi films, it's easy to recognise that most of them explore ambitious topics that many people might struggle to comprehend. Some tackle complex subjects such as genetic modification, aliens, time travel and artificial intelligence.

Although these popular films do touch upon a myriad of intelligent ideas, a lot of the time they offer little explanation into the science and engineering of how the devices shown could feasibly work. The audience is expected to accept the intellectual ingredients at face value. With both science and engineering driving the plot, I imagine some people can be left bewildered by the concepts.

It's with my own personal experience in mind that I do firmly believe that films, and particularly sci-fi films, have the power to spark the creativity inside people when it comes to science and engineering but what is just as important is a parent recognising this and doing something about it. We play a huge part in supporting and encouraging young people – inspiration is only half of it. It really is quite possible to be visionary and exciting but still keep the STEM essentially accurate.

Thinking about the power of film to influence youngsters when it comes to STEM, myself and the Institution of Engineering and Technology (IET), as part of most recent Engineer a Better World activity, put it to the test and asked some of the UK's children sci-fi film questions that have left them perplexed. In fact, some of the questions asked reminded me of the types of things I wanted to know the answer to and this fills me with hope there is potentially a whole generation of budding engineers out there.



By listening and responding to children, I'm delighted to be part of nurturing their natural STEM curiosity, in this case sparked by popular films. I feel that topical activities such as this will help to change perceptions of what modern engineering is and what it can offer young people as a career.

Here are the top questions with my answers.

Would it be possible to make a light sabre

– how much would it cost? (Becky Francas, aged 12)

It depends on what you mean. Clearly, every toy store has examples and I believe the original movie used wooden sticks wrapped in reflective tape with a lamp mounted near the camera to make them look bright. This is clearly quite cheap and you could make your own to video with a smartphone and its built-in lamp, but it would not cut bits off people (or aliens), which is perhaps just as well.

Could you make a very powerful laser, say, in a small package that would cut things? Yes indeed – fibre lasers, including ones made at Southampton, are fairly compact and will cut thick steel plate and though they are normally invisible you could certainly make a visible green one.

Sci-fi films still have the potential to inspire children's questions

Image: Lucasfilm

"This fills me with hope there are budding engineers out there"

Will Stewart

Of course the reflected backscatter from any piece of bright armour you happened to touch might blind you.

Are there aliens, like the one shown in *E.T.*? (Ines Rognaldsen, aged 12)

Yes, almost certainly. We just haven't found any yet. People are looking for oxygen, presuming this is a good marker for life (probably single-cell life, as life was on Earth for the majority of the time that living things have been around).

They have not found evidence of it yet because, although

spectroscopy (looking for specific colours that are absorbed by specific gases) should be simple, it is very difficult to see a small planet in the much bigger glare from the nearby star.

Thousands of planets have been seen now, mostly big like Jupiter but some near Earth size, but seeing them well enough to do spectroscopy is still difficult. Good space telescopes being planned should be able to do this and I am guessing that we will see oxygen on a distant planet relatively soon.

Would it be possible to bring dinosaurs back to life as in *Jurassic Park*? (Becky Francas, aged 12)

Probably not; we do not have enough dinosaur DNA. The issue with dinosaurs is nothing specifically to do with them, it is that DNA is a big and complex molecule and, like other living things, it decays fairly quickly after death. All we have is fossils: imprints in soil that have been 'cast' into shapes with other soil and then made into rocks for preservation, not actual bits of dinosaur. The movies did recognise this and suggested blood from mosquitoes in amber, but even this would contain very little, if any, DNA.

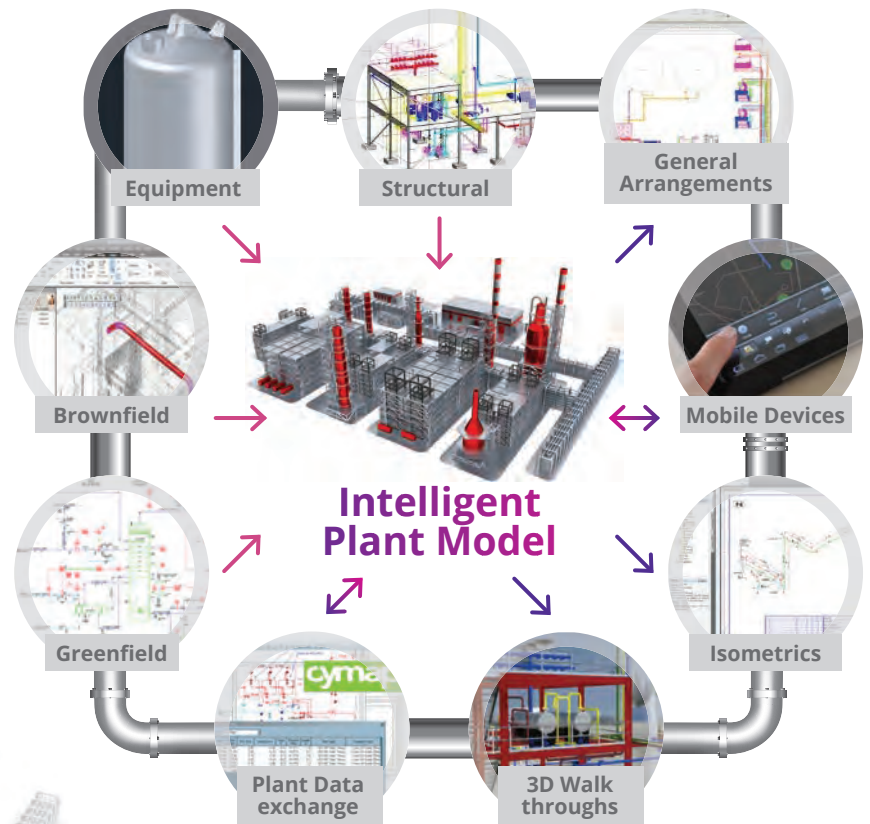
Could a car actually run on uranium like in *Back to the Future*? (Josh Wood, aged 13)

Yes and it would last a long time. Radioactive fuel was, and indeed still is being, used by the Voyager spacecraft. However, the risks of radioactivity would be significant. It is hard to contain radioactivity in a small vehicle because the shields need to be very thick and thus heavy; so ships and submarines but not really cars and aircraft. ☹

Will Stewart is chair of the IET Communications Policy Panel and a former chief scientist at Marconi

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Thehotopic

Hinkley Point C faces delays

EDF's reported postponement of a funding decision for the plant sparked a heated debate



I will wager it never gets constructed. That way we become irrevocably tied to the continent via the inter-connector and mercilessly milked to subsidise their ever-rising costs.

David Waring

Our poor country must have had some of the most short-sighted decision makers over a very long period for us to end up with this mess. Private enterprise can do great things on big projects as is evident with SpaceX, Blue Origin and others in the US space industry. However, you would be hard pushed to dream up this debacle. Given our

illustrious past in the development of nuclear, who is responsible for us being at the mercy of foreign governments and for offering them incentives that future generations will have to suffer? I'm sure it's too late for any change now but will we ever learn?

Luke Ruttle

The way forward is small modular reactors, British designed and built, and located adjacent to existing coal and nuclear sites for connectivity. I would rather have a Rolls-Royce-derived SMR on the doorstep than a waste-to-energy plant (and I used to work on W2E technology).

Ewan Macdonald

Is it possible that the project decision is 'delayed' because of the current (no pun) renegotiations on UK membership of the EU – prior to Brexit referendum?

Jim Ball

This was an awful deal and I'm glad it is being postponed. I am all for private enterprise but on such large scales, both in terms of money and time, only states have the gravity to manage the risk and thereby keep a lid on associated costs. I would not be surprised if EDF's failure to get an EPWR online and to budget elsewhere is behind this. I'm guessing

they're not confident of the risks involved and if this goes wrong it would pose an existential crisis to the company. I'm not sure EDF's investors would be keen on this. Unfortunately due to Labour's procrastination through the 1990s and 2000s we are facing an energy crisis and need something soon. Surely the EPWR is the closest of the next generation of plants to design completion, I fear we're stuck with it and the ridiculous strike price.

Nath

EDF is in serious financial straits due to problems with other projects, and French government policy changes in relation to nuclear. Such a fundamental infrastructure project must surely be saved, especially as coal is being prematurely closed down and we are becoming dependent upon wind and gas. Except that the gas-powered stations cannot be built as they cannot sell electricity profitably against highly subsidised renewables. Load shedding and diesel generators are the current big hope to prevent the lights going out: what a shambles.

Jack Broughton

Are we surprised by this? No, of course not. I was just leaving school as the whole AGR thing at Dungeness began to unravel and I wondered then whether our nuclear industry would survive. Over the years I've watched us squander yet another lead in an essential technology. The debacle over the waste reprocessing plant at Windscale/Sellafield only increased concerns. The UK government works on a maximum of five-year cycles; its main interest is in getting re-elected. But like most infrastructure projects it needs long-term planning and commitment. As the moment where we get caught between the rock of the lights going out and the hard place of our carbon-reduction commitments, it's beginning to feel like musical chairs, no one wants to be the party in power when this moment arrives. Small modular reactors seem to offer the only surefire solution given the ever-shrinking timescale for solving our self-imposed energy crisis.

Peter Thomas

Inyour opinion

Air of concern

Our article on the role technology can play in addressing air pollution generated a lively response

● Diesel vehicles are mostly used for transport – of people and goods. Switch transport to other means or reduce the need for transport and you have reduction of diesel vehicles in the city. It would also help to switch off diesel engines while waiting in railway stations. Cross-country trains usually run all the time.

Ralf Mueller

● There is uncertainty about the health implications of ground-level NOx and fine particulates: some

parties believe that the dangers are well proven; others doubt the science behind it. It is very difficult to prove or disprove most public-health-related science, which lays the subject open to charlatans. As a recent example, you can accept the 14 units per week of alcohol limit or be sensible.

Jack Broughton

● If the number of vehicles overall in London was reduced then essential vehicles could travel around much more freely and minimise engine running time and emissions.

Malcolm Scott

Green focus

A piece on using 'green' technology in troubled times led to this response

● Using lower resources and energy will lead to more savings, especially when the prices rise again. I used to employ new people when other companies were

firing them. Then I had enough time to train them in our way of doing things, and when the business shot up again, I had a full team busy serving customers and didn't need to waste time and money for interviews and training.

James Stirling

Flying the flag

In last issue's archive piece we took a look at an icon of British engineering: the Lancaster bomber

● A fantastic feat of engineering and a great credit to the man who created two great iconic aircraft: the Lancaster and the Vulcan, which have both served their country well. The Lancaster was nimble and a great aircraft to fly but the crews who died for their country shouldn't be forgotten. RIP.

Clive Broadhead

● Is it essential that we engineers are always directed



The **secret** engineer

Has our anonymous blogger become a 'trophy engineer'?



For most of my career I have felt undervalued in one way or another, the root cause for this not being terribly important.

A genuine lack of appreciation for my abilities by my various superiors; a culture that doesn't allow these abilities to shine; mismanagement of my undoubted qualities; or just good old-fashioned self-delusion. Any, or possibly all of these at some points over my varied career, may well apply.

In fact, it could be so simple as mistakenly having an expectation for some outward acknowledgement of my work, rather than automatically assuming everything's going well apart from when I'm being blamed for something. However, no matter why, the point is that there has always been this small nagging irritation.

Please trust me when I say that, rather than getting bitter about it, I have used it as a personal spur to try to improve myself. Instead of getting more and more disillusioned, and thereby straying from my usual response of viewing it all with wry humour, I metaphorically roll up my sleeves and try to earn some kind of approval instead (something undertaken with equal knowing humour).

Things have been rather different since joining Sleepy Hollow. My arrival wasn't exactly met with liveried pageboys blowing a fanfare on bugles while hand maidens spread rose petals at my feet – but I do get the distinct impression they feel lucky to have secured my services. As I sit writing this I still feel a sense of mild surprise, quite possibly with overtones of smugness. However it's not the unmitigated positive experience I always thought it could be. I have no problem with the accompanying expectation of my performing at the top of my game, I use this once more to maintain motivation. Incidentally, an adaptation of approach that sees my working as hard as ever I did but deriving a greater satisfaction from it. I don't mind that I now wield an authority that brings more responsibility; for differing reasons I had this earlier in my career and am glad to once more hold this status within a company. It's just that when I'm wheeled out to customers primed with a strategy to explain why I should deign to work for my current employer (a fine company in itself and with a good reputation), it feels – well – tawdry. It all seems perfectly sincere but it's a very strange sensation. Is this what the pneumatic blondes seen on the arms of withered octogenarian millionaires feel like? Have I become the 'trophy engineer'?

towards so-called prestige products? Yes, there is some PR value in prestige, but surely, the ascent of mankind is advanced just as much by the development of a particular mundane item that is used by millions of people (a household item; an improved manufacturing technique; a less-expensive method of containing groceries; the computer programme that enhances bus timetables; and so on) than weapons.

Michael Blamey

● Would any similar icon be achievable in the UK of today?

Philip Hayter

Space exploration

Last issue's cover story looked at NASA's Orion project

● I have a nasty feeling this rocket is so expensive to fly that it will do so only a couple of times, maybe

three, and then be abandoned for cheaper systems such as Falcon9 heavy.

Julian Blundell

● There is quite a difference in sub-orbital and LEO flights but even so, with how far the 'X-Prize' folk have come, a one-shot system seems very much like a backward step. Good to see the programme proceeding though.

Stephen Mosley

● This collaboration shows it can be done in a big way. If we can reach Mars, as a species we have a future.

Luke Ruttle

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Despite the positive and significant contribution that engineering makes to our economy, its future is still fragile because of a skills gap

“A strong engineering industry has a powerful ripple effect – for every new job in engineering, two are created outside the sector”

Paul Jackson

The recently published Engineering UK 2016 *The state of engineering* report highlights the fact that the sector is driving the economy, driving employment and driving productivity. Engineering is a considerable 68 per cent more productive than retail and wholesale,

with apprentices making a significant contribution.

More than 27 per cent of total UK GDP is now generated by engineering, amounting to £445.6bn and turnover for engineering has grown by 3.4 per cent to £1.21tn. It's not just turnover that has grown. Employment in engineering has grown to more than 5.5 million and the industry now supports 14.5 million jobs overall. A strong engineering industry has a powerful ripple effect – for every new job in engineering, two are created outside of the sector and every £1 GVA generated in engineering generates £1.45 elsewhere.

Yet, despite the positive and significant contribution that engineering makes both to the economy and our lives, we are right to be concerned for the long-term future of the industry. Why? Because there is still a considerable gap between the supply of and demand for people with engineering skills. And we can't sit back and hope that the education system will spit out the requisite number of new recruits because it simply doesn't

currently have the capacity (or indeed the required rate of growth) to do so. While there have been huge advances in engineering in the past 30 years, very little has changed in terms of the make-up of the sector. We need to do things differently. We need to join in concerted and coordinated action to work with education to inspire young people to make the subject and career choices that will close that skills gap.

Skills strategies such as that announced by the Department for Transport are right to call for the community to focus on the programmes and interventions that are showing real results rather than looking to launch new initiatives. That strategy also includes specific targets and action for boosting apprenticeships, attracting more women into the industry and a year-long celebration of engineering in 2018.

Our strong, consistent and positive message about working in engineering needs to reach young people whatever their background, wherever they live and whatever their gender. Unless it does, talent will be missed, opportunities will be wasted and the UK will be left behind.

As a community we need to build on the strong foundations laid by the

The report shows that the sector is driving the economy

Engineering UK 2016

The state of engineering



Tomorrow's Engineers programme to boost the volume, reach and quality of engineering employer engagements with young people. We need joined-up education policies that deliver easy-to-follow academic and vocational pathways for those in education today and commitment across government, education and business to work hard and to work together to inspire those young people to become the industry's talent of the future. ©

Paul Jackson
Chief executive, EngineeringUK



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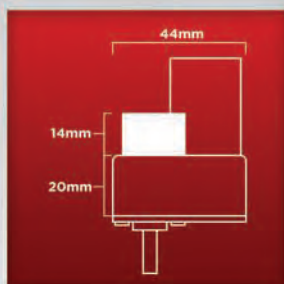
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Made in space: new production frontiers

The challenges of manufacturing beyond our own planet will need to be met to support a long-term presence in space.

Andrew Wade reports

With the recent success of the Rosetta and New Horizons missions, along with Tim Peake's adventure on the ISS, space exploration seems to have regained a foothold in the public consciousness. Last month, *The Engineer* reported on NASA's Orion programme, the Multi-Purpose Crew Vehicle that should herald a new era of manned space flight, with Mars the ultimate goal. Mars now seems tantalisingly within reach, and both ESA and NASA predict that humanity's first steps on another planet will happen some time in the 2030s.

But while the technology to get there is reasonably well established, surviving on the red planet for any length of time will be a major challenge. Creating a long-term presence on the Moon or Mars will mean making use of indigenous resources, using native soil and rock to build structures and habitations. To do this, the challenges of manufacturing beyond our own planet will need to be met.

In-orbit manufacturing is the first step of that journey. As well as being a vital testing ground, manufacturing off-Earth also has a number of practical and economic advantages.

Although UK involvement in this nascent sector is limited, Magna Parva, based in Leicester, UK, has been developing its COPMA prototype since 2007. The system, which uses a form of miniaturised pultrusion, is designed to build large carbon-composite 3D structures in space. COPMA stands for Consolidated Off Planet Manufacturing and Assembly System for Large Space Structure.

"Really it's a spin into the space industry of a common terrestrial technology," Andy Bowyer, director and co-founder of Magna Parva, told *The Engineer*. "The technology itself is relatively elegant, in the sense that it's not hugely complicated in terms of a manufacturing technology. There's not a lot of elements or components in it, but it needs a fair amount to get it to work in a space environment, because that's where the challenge is."

That challenge includes variations in gravity, the vacuum of space, high levels of radiation, and temperature extremes. In the face of such obstacles, one may ask: why go to the trouble to manufacture in space? As usual, the answer can be found in the bottom line. Launching pre-fabricated structures is inevitably less efficient and more costly than launching the raw materials required to build them. By sending spools or containers of component materials and manufacturing in orbit, the cost of launches could fall dramatically.

"It's a lot easier to fly raw materials to space than it is to fly a component that's been folded up into 100

01/02 ESA has explored the potential of using lunar soil to 3D print a base on the moon

different levels," said Bowyer. "So you can design the end component to only work with the end use requirements. Whereas if you're designing a structure for end use in space now, you've got to design it to be used on Earth."

A related benefit is that space-built structures no longer have to be designed to withstand launch. Anything sent into space has to endure the extreme forces associated with escape velocity. If it is built in orbit, that requirement disappears and further efficiency gains can be made.

"You've got to design it for the test environment, which is gravity and all those sorts of things," Bowyer explained. "So it is, by its very nature, a more massive structure than is actually required by the end use. By designing your end structure to be specific for that, you reduce the mass significantly. Also, a roll of carbon fibre, a jar of resin, is a lot more compact than a component that has got lots of air around it and in between it."

Terrestrial pultrusion devices tend to be room-sized machines, built for heavy industrial use. The challenge for Magna Parva is to miniaturise the technology to make it practical for operation in space. The only in-orbit environment to currently test this type of equipment is the



02



International Space Station, so engineers tend to have it in mind when designing orbital manufacturing systems.

"We've got our prototype down to about the size of a shoebox," Bowyer said. Future versions will be even smaller, he claims, as the prototype is gradually refined. COPMA's current capabilities are limited to manufacturing, but Magna Parva is also looking at incorporating assembly into the system's evolution. The plan is to embed elements such as copper wiring and fibre optics into the structures, and there are early-stage concepts for assembling multiple structures together. How soon we might see the system in action is a matter of funding, according to Bowyer.

"It's always down to money ultimately," he said. "If you can get the funding, the development itself is quite rapid, it's probably only a couple of years. The challenge with space technology is not necessarily designing and building it. There are clever engineers around, we employ clever engineers and you can design and make stuff with the right budget. The challenge is how you get the flight opportunity. Who's going to put it on whose spacecraft? Ideally, we'd like to go to the ISS, go as an experiment. It's where most people get their first opportunities for new technology."

"There's a set process. We're British, so we go through the European Space Agency. You get on to a programme, you lobby to get a slot. We're doing all the appropriate lobbying at this point so that in a couple of year's time we could be in a position to do it. But it's highly competitive. There's lots of people with good ideas, and it's a very competitive marketplace, but that would be the ideal place for us to trial."

Magna Parva's ambitions certainly have precedent. Since 2014, the ISS has been equipped with a 3D printer designed and built by US company Made In Space (MIS). In December of that year, the crew of the space station printed a tool using a design file transmitted from Earth for the first time. The small ratchet wrench that was printed was subsequently returned to Earth for testing, but the exciting potential of printing on demand in space was confirmed.

"The main lesson was that it worked," Brad Kohlenberg, business development engineer at Made In Space, told *The Engineer*. "We weren't sure if extended microgravity and printing multiple times would work. We'd done it in little bursts through parabolic flights, but we had never had that extended microgravity kind of experience."

It worked so well, in fact, that a considerably more advanced device will soon be joining it. The

commercial-grade 3D printer, known as the Additive Manufacturing Facility (AMF), was due to be delivered to the space station last year. However, a string of ISS resupply failures means Made In Space is now looking at a March 2016 launch date. Initially, the AMF will only print polymers, but there are plans to adapt it in future to print with metals and other materials.

"It's designed to be modular so we can actually swap out the plastic extruder for potentially a metal extruder," Kohlenberg explained. "It has the ability to upgrade to do that, but right now it's only going to be polymer."

Assuming the AMF is delivered safely to the ISS, the added capability it will bring opens up interesting new scientific and commercial opportunities. In August 2015, MIS announced that it was teaming up with fellow US company NanoRacks to develop an orbital construction-and-deployment service for CubeSats. Called Stash & Deploy, the service will use a variety of components stored on the ISS to build custom CubeSats for >>

"The challenge with space technology is not necessarily designing and building it. The challenge is how you get the flight opportunity"

Andy Bowyer, Magna Parva

>> customers. The plan is for many of these components to be built on board the space station using the AMF.

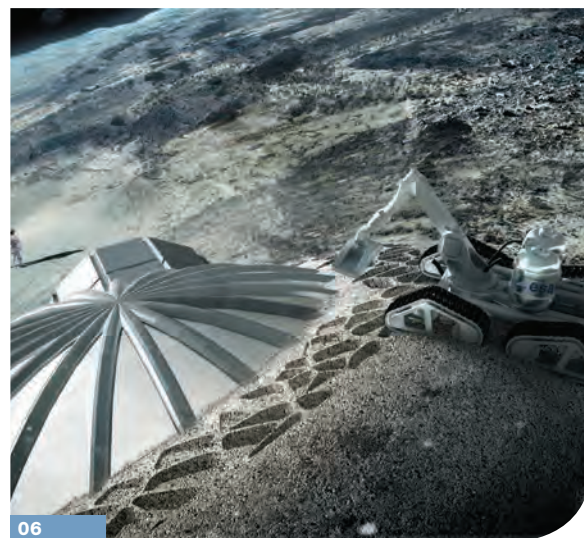
"You will have an inventory of commonly used space components on board," said Kohlenberg. "Things such as radios, processors, gyroscopes – things that every CubeSat has."

Developers on Earth will be able to look through this inventory, and rather than launching complete CubeSats, will only have to launch certain components. These will then be supplemented with stock from the orbiting inventory and integrated into 3D-printed structures, saving considerably on launch costs.

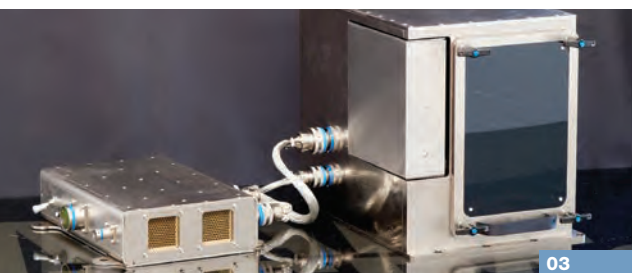
"Eventually you will integrate all those parts and pieces," Kohlenberg added, "ideally in a really easy, almost



05



06



03

snap-together Lego kind of fashion, and are left with this hybrid '3D printed/electronic components' spacecraft."

Made In Space's plans don't end there. In November 2015, the company secured funding from NASA to progress with Archinaut, a project that Made In Space said will deliver the first additive manufacturing, aggregation and assembly of large and complex systems in space without the aid of astronaut extravehicular activity.

It will be a free-flying spacecraft that is capable of 3D printing and assembling large structures in orbit, including antennae, booms, and even other spacecraft.

"Archinaut is definitely something that we're really proud of," said Kohlenberg. "It's the realisation of the vision we've had since the beginning. We started [the company] thinking one day everything in space will be made in space, and we'll be building these giant spaceships in space. But how do we get there?"

"So if 3D printing was one big step, this is kind of the next big step on that path to this overall grand vision. Now instead of inside the ISS with astronauts printing 3D-printed parts, you're outside the station, completely autonomous, this robot is using robotic arms to 3D print struts and beams and using its arms to

03 World's first space-based 3D printer

04 Magna Parva is adapting pultrusion for space manufacturing

05 Lunar regolith sample

06 Artist's impression of an ESA lunar base



connect those beams together and building up scaffolding."

Once this scaffolding is in place, electronic components could then be integrated and large capable structures could begin to take shape. While it may sound like borderline science fiction, amazingly, the initial stages are just a couple of years away, according to Kohlenberg.

"The timeline is about two years," he said. "We're getting the money from NASA later this year, and we hope to have the first demonstration of the overall programme in 2017."

Looking even further ahead, concepts are already in place for space-based manufacturing on both the lunar and Martian surfaces. In 2013, ESA revealed concepts it developed with architects Foster + Partners to 3D print a lunar habitation using regolith from the Moon's surface. By using indigenous materials to create structures on other worlds, long-duration missions could one day become a reality. Unsurprisingly,

"We've actually had some success using lunar simulated soil, as well as Martian regolith, and using that as 3D-printing feedstock"

Brad Kohlenberg
Made In Space

it's an area where Made In Space is also active, using simulated Martian and lunar soil developed by NASA to carry out research.

"We've actually had some success using lunar regolith – lunar simulated soil – as well as Martian regolith, and using that as 3D-printing feedstock," said Kohlenberg. "They call it ISRU: In Situ Resource Utilisation. When we land on these planets, actually using the planets and the atmosphere of these planets themselves to be the resources that we use to create whatever we need in our surroundings."

"We've done a lot of tests. We're located at NASA Ames [a major NASA research centre in Mountain View, California] so we've actually been able to use some of NASA's resources, and one of those resources is access to all this lunar regolith simulate."

While technology has brought ISRU into the realms of possibility, there are still a few obstacles to clear before we start breaking ground on the first Moon bases. There are two main methods for printing with lunar regolith. One involves mixing it with some form of organic binder to create a cement-like substance that is then printed. The other is to melt the regolith using high-energy X-rays, essentially sintering the rock and printing it while still in a molten state. While the first method involves transporting large volumes of binding agent to the Moon – or perhaps even growing it there – the second involves huge quantities of energy. Each presents unique challenges.

"The technology is here and now," Kohlenberg said. "We can do this. It's just figuring out the cost-benefit analysis of doing it – does it actually make sense? I think it does make sense, but if we are going to do it, we're probably going to have to make some automated systems, because either way you look at it it's going to be a slow process. So what we want to do is throw these robots on the planet and just have them going 24/7, building out these infrastructures so that by the time we put boots on the ground we have roads and landing pads and structures and habitats waiting for them."©

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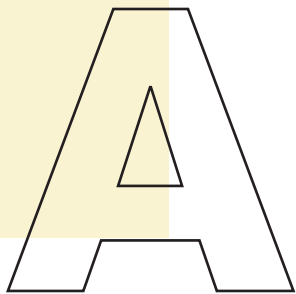
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Mimicry becomes second nature

German industrial giant Festo is turning to the natural world to solve its industrial challenges.

Jon Excell reports



A spontaneous aerobic display by giant robotic butterflies isn't, sadly, a regular feature of the traditional factory tour.

But, late last year, this was exactly how German automation giant Festo chose to mark the opening of a flagship manufacturing facility in Scharnhausen,

on the outskirts of Stuttgart. The giant 66,000-square-metre factory, now home to the firm's valves and electronics production operations, is about as modern and hi-tech as manufacturing plants get. This, claims the company, is Industry 4.0 in action. A meticulous use of data; a relentless focus on energy efficiency; 'co-bots' on the factory floor and even touchy-feely breakout spaces more redolent of Silicon Valley, conspire to create the kind of ultra-modern facility that will surely become commonplace in the years ahead.

But it was notable that among the presentations at a conference convened to celebrate the plant's opening, one topic Festo chose to focus on was its – some would say eccentric – obsession with bionics.

The company's interest in the field, sometimes also known as biomimetics, is well known. In recent years it has unveiled a succession of astonishing and frequently beautiful robotic creations – seagulls, jellyfish, dragonflies, and even a robot kangaroo – that have grabbed the headlines and helped cement the perception that this is a company at the top of the innovation game.

But according to Festo's Dr Heinrich Frontzek, who heads up the firm's bionics work, while the research is undoubtedly an exceptionally effective marketing tool, that's not its only value to the company.

Bionics has been an area of interest for the firm since the early 1990s. And although it accounts for a relatively tiny proportion of the company's R&D budget it has perhaps become more of a focus in recent years.

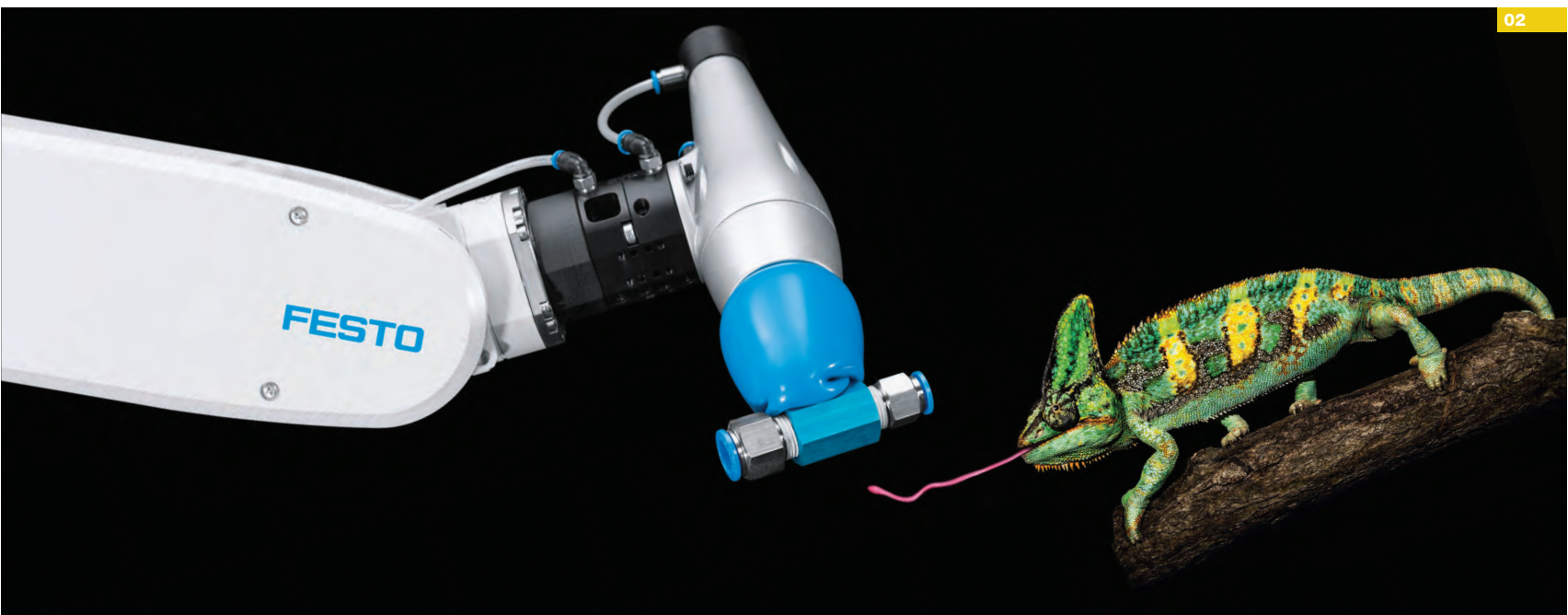
In 2006, the company established the Bionic Learning Network, a cross-disciplinary group of scientists and engineers tasked with developing a handful of concepts each year. And although none of the technologies

emerging from the laboratory have yet made it directly onto the factory floor, there are signs that the research is becoming increasingly focused on solutions that could have industrial benefit sooner rather than later.

Increasingly, explained Frontzek, bionics is playing a very real role in helping to develop and inform the company's understanding of some of the technologies that will become central to the future of manufacturing: areas like soft-robotics, wireless connectivity, energy efficiency and autonomy.

The natural world, he said, holds the key to many of the challenges faced by industry. Elegantly efficient approaches to movement, positioning, monitoring, process control and communication can all be found in nature and it would be wasteful, he said, not to make use of evolution's vast repository technical solutions.

In one of the firm's most striking recent projects, the group turned its attention to the ant: a creature that has long interested developers of intelligent systems.



In an effort to understand whether the famed collaborative behaviour of ants could be used to develop new approaches to intelligent systems the group developed bionic versions of the insects.

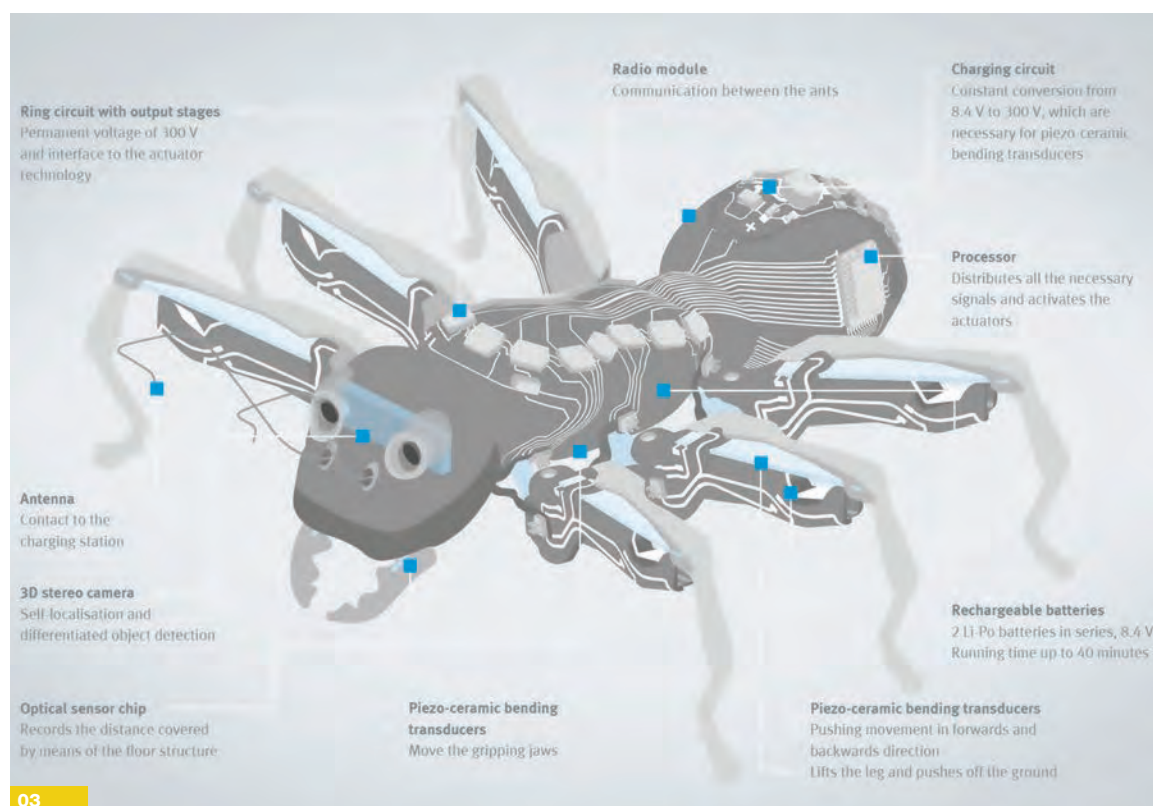
These so-called BionicANTs mimic precisely the anatomy of their natural equivalents. Tiny, highly efficient piezo-electric transducers are used to actuate the mouth pincers and the legs while a 3D stereo camera in the head and an opto-electronic sensor in the abdomen helps the ant understand its position.

The ants communicate with each other via a radio module located in the torso, and complex control algorithms ensure that rather than operating individually, each ant forms part of a multi-agent system that is able to carry out an intelligent division of labour.

During demonstrations, rather like their natural cousins, the bionic ants were able to work together to push and pull objects across a defined area.

Frontzek said that the lessons learned from the project are helping inform the company's thoughts about future factories, which will be able to adapt flexibly to different production scenarios and thus take on tasks from a higher control level. "The BionicANTs communicate with each other and coordinate both their actions and movements," he added. "Each ant makes its decisions autonomously, but in doing so is always subordinate to the common objective and thereby plays its part towards solving the task at hand."

The group's eMotionButterflies, which it also demonstrated at the Scharnhausen opening, represent



another effort to find a natural solution to collective behaviour. These robot insects are able to coordinate flight paths so that they don't collide with each other thanks to an indoor guidance and monitoring system, which uses a network of cameras around the room to constantly record the butterflies' position. These cameras transmit the position data to a central master computer, which coordinates the butterflies from outside.

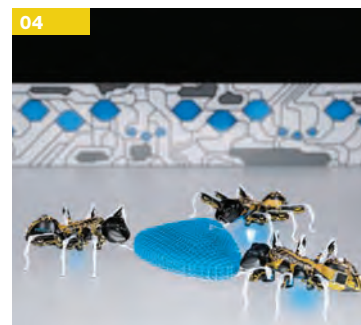
Frontzek said that the project has taught the team valuable lessons about real time-optimised communication between individual systems. "The eMotionButterflies will not fly through the factory of the future; rather, they will suggest

new approaches to the functioning of a networked overall system or show us what future industrial logistics applications could look like."

While in many cases these projects are fairly abstract, other more tangible technologies that could have direct industrial applications have also emerged through the route.

One particularly notable example is an industrial gripping mechanism, jointly developed with researchers at the Oslo and Akershus University College of Applied Science, which is modelled directly on the behaviour of a chameleon's tongue.

When catching prey a chameleon shoots its tongue at high-speed towards its unsuspecting target. During this process, just before the tip of the tongue reaches its target the middle of the tongue retracts while the edges continue to move forwards. This enables the tongue to adapt to the shape and size of the prey and firmly enclose it. The Festo team mimicked this ability using a water-filled silicone



01 Festo's eMotion Butterflies take flight

02 The chameleon's tongue has inspired a new kind of gripper

03/04 BionicANTs point the way to future industrial control systems

05 A 'co-bot' at work on the Scharnhausen factory floor

Indepth Biomimetics

In turning to nature for ideas, Festo joins a long line of engineering innovators keen to tap into the innovative solutions delivered by millions of years of evolution.

In perhaps one of the most well-known examples of the discipline Swiss engineer George De Mestral invented Velcro after studying burdock burrs that had become tangled up in his dog's fur.

More recently engineers have developed new adhesives inspired by the Gecko's feet, while defence industry developers of next-generation UAVs are taking their lead from insect flight.

As our knowledge and understanding of the natural world increases, we can expect to see ever more examples of biomimetics in the years to come from the development of self-healing structures and materials to morphing aircraft wings that help aircraft become more manoeuvrable and more efficient.

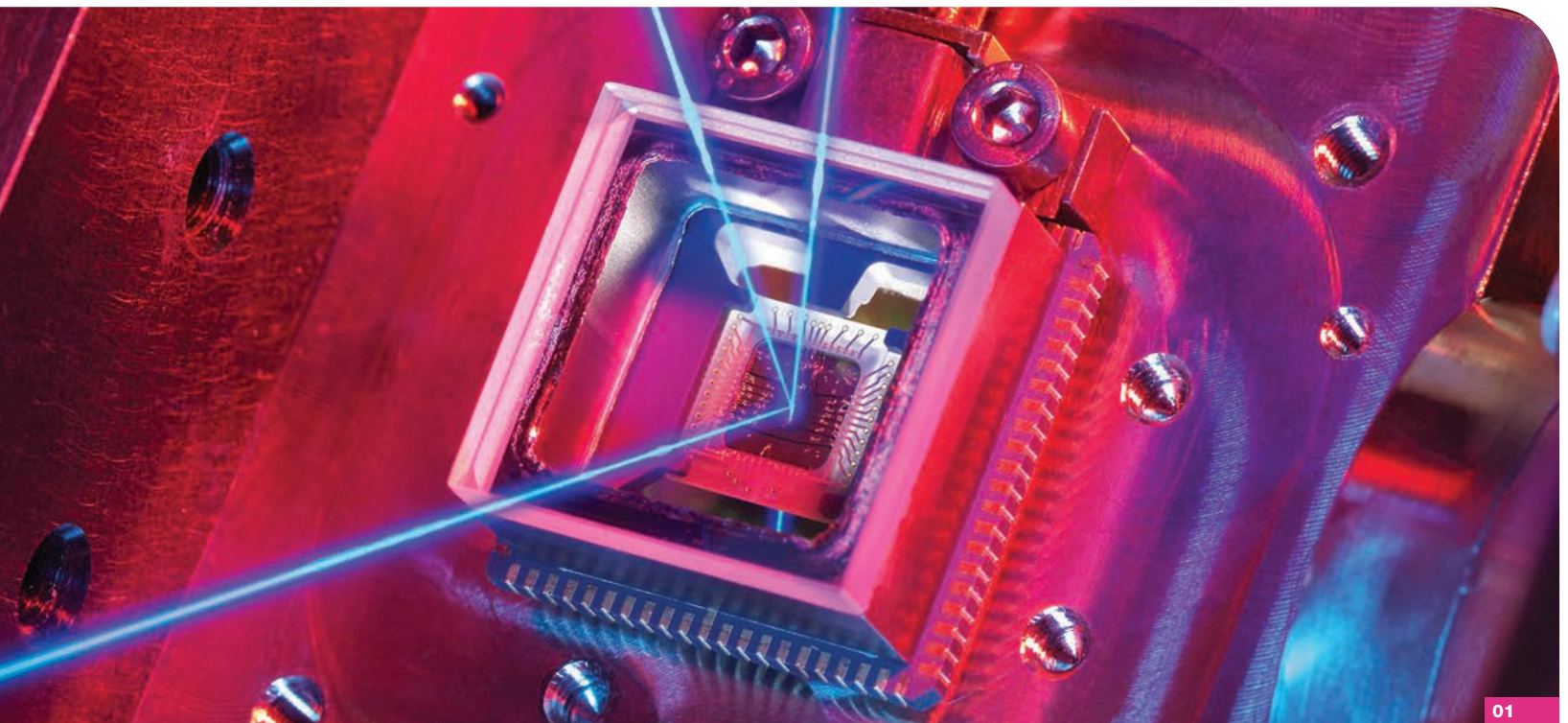
cap, which wraps itself around the items being gripped in a flexible and form-fitting manner. The resulting device, the FlexShapeGripper, is thought to hold promise for any application where multiple objects with a range of different shapes are handled at the same time.

It's tempting to dismiss Festo's bionics work as a sideshow. But while it is the case that flying insect robots are a world away from its core business, there's little doubt that the lessons it is learning from its eccentric specialism are becoming increasingly relevant to modern manufacturing. ©



Aiming to be less disruptive

Quantum technology strategy chief hopes to utilise ideas on incremental rather than disruptive technology. Stuart Nathan reports



01

How

ow to fund science and engineering research is a perennially tricky question: although most people in the sector probably have ideas on how much taxpayers' money is allocated to research and how it's shared out, the overwhelming feeling is probably one of relief that they don't have to make the actual decision. With *The Engineer's* remit to spotlight disruptive technology, readers might expect us to advocate spending where there's the potential to be truly life changing. But one prominent UK figure who's spent decades in the thick of the politics of research funding thinks this is precisely the wrong approach.

Prof David Delpy is a physicist by training, but said that he's "really more of an instrumentation engineer". Unsure on leaving school whether he wanted to be a scientist or an engineer, he studied applied physics on a sandwich course at Brunel "because I thought it would allow me to go in either direction once I graduated; and I still think sandwich courses are the best thing out there if you like actually doing stuff rather than just sitting in lectures, even though there are far fewer of them now". After a brief period in industry working for a conglomerate of around 16 small engineering companies, Delpy realised he missed both London and physics, and returned to UCL on a studentship to develop miniaturised catheters to measure blood pressure in premature babies. "I got hooked on medical instrumentation and stayed for 35 years."

During that period, Delpy climbed the career ladder to head of department and vice-provost for research. "At that point it would have been very awkward for the new head of department if I had returned," he said, "but I got headhunted for the CEO position at EPSRC." Years of university

politics had given him a good understanding of policy, while a period as representative of the Russell Group universities to the Research Councils provided a taste of working with government. "But the steepest learning curve when I joined EPSRC was learning about dealing with government from the other side, as it were. Theoretically, the Research Councils are the most arm's length of quangoes, but they are still much closer than universities, and it depends on the length of the minister's arm."

While at EPSRC, Delpy was concerned with changing the culture of research. "EPSRC is a grant-awarding body; it doesn't operate research centres or have any scientist working for it, unlike other research councils," he explained. "When I joined, the majority of grants were for three years and covered a principal investigator, a research assistant and a PhD student; as if everything worth researching could be tackled like that. I wanted much more ambitious research proposals."

The culture Delpy promoted involved the establishment of Doctoral Training Centres (DTCs). "These are an award of 10 PhD studentships for five years, to be funded in an area of

work rather than one specific subject – synthetic biology, say. There's a cohort of the students coming together in the first and fourth year. This was to get across the concept of research as a collaborative venture with a lot of things done in teams. We originally pushed out 44 DTCs and by the time I left we had 113, and the other councils use them as well. It promoted ambitious projects, getting people to work in a more interdisciplinary manner, and an idea of the breadth of input needed to tackle a subject area." It also helps make the best use of skills gained on a PhD, he added. Previously, projects had been very good at 'cloning' a principal investigator in academia, but 70 per cent of DTC graduates are working in industry within three years.

Delpy then moved to the Ministry of Defence, and chairs the UK National Quantum Technologies Programme Strategic Advisory Board, as well as sitting on the Royal Academy of Engineering's MacRobert Awards panel and advising the academy and the government. It's here that he hopes to leverage his ideas on incremental rather than disruptive technologies. "Look at any area of science and you'll see relatively rare disruptive innovation," he said. "Most of the big leaps come about through increments. The transistor is the perfect example: from the late 1940s, all the developments into integrated circuits have been incremental, but the impact on society has been enormous. Electronics has been disruptive, but that's come about through the incremental development of that basic concept."

"Most of the big leaps come about through increments. The transistor is the perfect example: from the late 1940s, all the developments into ICs have been incremental but the impact on society has been enormous"

02



03



CareerCV

Prof David Delpy Chair, Defence Scientific Advisory Council Chair, Quantum Technologies Strategic Advisory Board

Education

- 1966–70** Brunel University,
UK, BSc applied
physics
- 1990** London University,
UK, DSc, medical
physics

Career

- 1970–71** Technical
Management
Services
Department,
Darchem,
Darlington, UK
- 1971–76** Non-clinical
lecturer, University
College Hospital
(UCH) Medical
School
- 1976–82** Senior physicist,
UCH
- 1982–86** Principal physicist,
Medical Physics
Department, UCH
- 1982–86** Honorary lecturer,
University College
London (UCL)
- 1986–91** Senior lecturer,
medical physics
and bioengineering,
UCL/director,
Centre for Medical
Technology
- 1991–99** Hamamatsu
professor of
medical photonics
- 1992–99** Head of department
medical physics
and bioengineering,
UCL
- 1999–07** Vice-provost
research, UCL
- 2007–14** CEO, Engineering
& Physical Sciences
Research Council
(EPSRC)

It's probably fair to say that the smartphone is the epitome of a disruptive technology. The ability to carry a mobile phone that not only can connect to the internet but display on a large, legible screen that is also an integral part of a tactile, intuitive operating system and incorporates a camera changes many aspects of our day-to-day routines in a profound way. In many parts of the developing world, their impact has been even greater, as they are the main way that most people in India and much of Africa and Asia access the internet and telephony.

But Delpy points out that the smartphone was never developed specifically as a disruptive technology in a single project. Rather, it's the result of a gradual accretion by the first to market, Apple, of a whole portfolio of enabling technologies: mobile telephony itself; touchscreens; multi-touch sensing; reduced instruction-set computing; compact antennae; and a huge body of software know-how. "All of those were the result of incremental innovation, developed step by step over years, and most of them weren't developed with any foreknowledge that they were to be used in a smartphone," he said, "because there wasn't any such thing, and nobody has a crystal ball."

Although Delpy conceded that picking a 'killer app' is as difficult as devising the technology in the first place, he said that there are ways to incubate disruptive technologies by focusing on the increments. In quantum technologies, for example, he is spearheading the implementation of a £75 million grant awarded by the chancellor of the exchequer in 2013.

Although quantum science is a century old, it's only been in the last few decades that products using it have become available, and Delpy believes there is still great scope. One potential use is in using quantum phenomena as a key for secure communications. While nobody knows what an instrument to do this would be, there are some things that it is clear that it will need. "We have a hub in York to develop these modules. We know we'll need sources of light that have known properties at a known rate; and we need detectors that can detect polarisation and precise timing. We can start to build an industry around that, even before we have the device itself."

In another example, a group in Birmingham is looking at modules for quantum gravity devices. "These are based on the effect of gravity on single atoms or ions in a specific quantum state that is very sensitive to changes in local gravity," Delpy said. "You could use that to look for holes, sinkholes, underground pipework, the changing water table, you could hunt for oil and gas, but you need the core modules. Those are going to be present no matter what the application turns out to be." Working alongside is the National Physical Laboratory, which is developing standards for these modules. "Hopefully some really big companies will come out of this work, but the component integrators won't come in until they can see an application and a market. They'll be able to buy into these modular technologies that they know they will work to as particular standard."

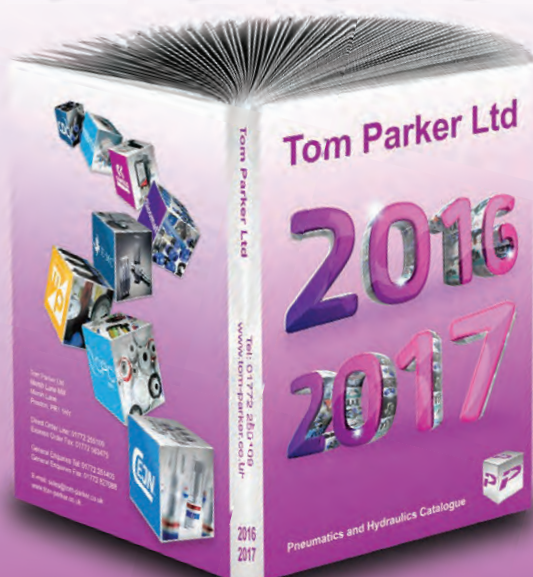
The difference between this approach and the smartphone analogy is that Delpy thinks it needs to be general. "Steve Jobs had an idea of what he wanted, but it had to be an Apple product," he said. "We're trying to create an ecology to supply a growing industry in a general manner. It's focused around the development and growth of new companies in the field." ■

01 A module
of a quantum
gravity detector

02 The
smartphone
might be
disruptive in
its impact
on society...

03 ... but it
is the result
of incremental
development
of components

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Imagining the new beetlemania

Novelist Jon Wallace considers the science fiction implications of engineering stories that have caught his eye. This month: the boundless possibilities of 'Bug-Fi'

Insects can get something of a bad rap in science fiction. From the 'monstrous vermin' body shock of *Metamorphosis* and *The Fly* to the giant armies of *Them!* and *Starship Troopers*, bugs are often deployed by authors to play on our primal fears – of twitching larvae, pupating transformation and alien growth; of a swarming, ravenous, elemental threat.

Insects have different but equally unfortunate connotations for sci-fi's audience, particularly cinemagoers. Over the years too many bug movies have made it impossible for viewers to suspend disbelief, leaning on cheap effects that provoke laughs instead of gasps, such as the killer cockroaches of *Damnation Alley*.

The writer has often been at fault too. It can be hard for characters debating some arthropod threat not to sound ridiculous. For example, Michael Caine shouts his way through 1978 killer-bee thriller *The Swarm*, presumably to drown out the sheer absurdity of exchanges such as the following.

Michael Caine – Are you endowing these bees with human motives, General?

General – I always credit my enemy, no matter what he may be.

On this evidence, you might conclude there's little hope for Bug-Fi. Fortunately, *The Engineer* is here to offer inspiration, sparking ideas of an alternative insect future, one that ends centuries of mutual hostility between human and hexapoda, bringing us closer in the most intimate fashion.

The Engineer reported in January on a new kind of defrosting technology for employment in windscreens, wind turbines and aviation components. Virginia Tech researchers have been inspired by the Namib Desert beetle's remarkable outer wings, which, lined with hydrophilic bumps and waxy hydrophobic troughs, harvest moisture from the air and channel it to the hardy bug's mouthparts, helping it endure the harsh conditions of the desert. By mimicking this ability to control where dew-drops grow, engineers believe it is possible to create new frost-proof surfaces, saving huge amounts of energy currently consumed by defrosting.

This kind of story opens up all kinds of intriguing avenues for a science fiction writer. How else, might 'insectech' find application in future societies?

One intriguing avenue is space exploration; beetles are thought to have been around since the Lower Permian, so they must surely have plenty to teach us about adapting to hostile environments.

Spacesuits that use beetle tech to harvest water would surely come in handy when settling arid worlds. A story might follow some fragile human colony marooned on a planet abundant in alien fauna.

These are people who have had to learn to be prey again, turning to entomology to engineer defences against numerous outside alien foes. Our story sees the colonists adapted with unique beetle defences: a Bombardier beetle man who sprays attackers with hot pulses of corrosive from engineered pygidial glands; a Minotaur beetle woman who digs tunnel hideaways with powerful adapted forelimbs; a Blister beetle child, whose reflexive bleeding offends the senses of its alien predators.

Perhaps, placed under the same evolutionary pressure as our bug brethren, humanity might become pests and parasites? We could tell the tale of a group of starving colonists on a desperate water-scavenging mission, penetrating some enormous alien hive, hiding among the hostile residents by mimicking their chemical secretions, as ant nest beetles do. The story takes a twist as our heroes find no water, only stored alien pupae – on which, having no choice, they begin to feast.

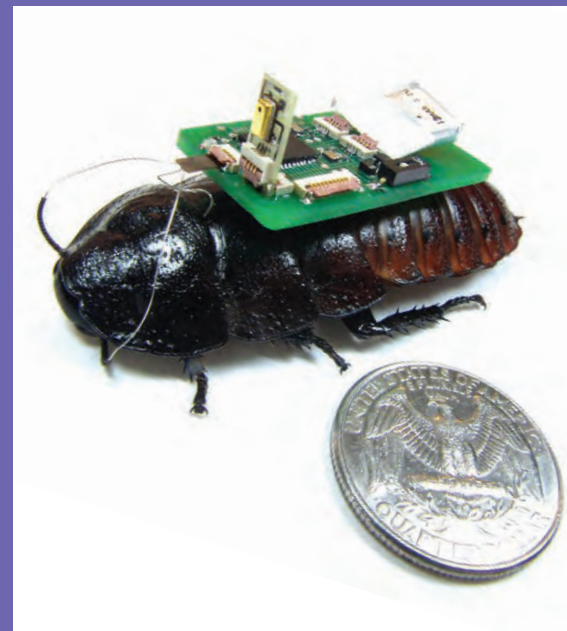
Perhaps our colonists would themselves become the larvae, like the young of California root borers and mountain pine beetles: people who live their lives in a shadow world, mining the bark and roots of vast alien trees for sustenance – an infestation that devastates the ecology and leaves a lifeless, husk world.

We could expand our tale to follow the colony's 100-year history, from terrified colonists to willing Gregor Samsas, genetically adapted in myriad ways. An entire new culture emerges, where the fashion is for bright and dazzling chitin clothes, mimicking the glossy iridescent patterns of jewel beetles.

Perhaps there's no need for our story to leave Earth at all. Research is underway on methods of remote controlling beetles, and this could prove to be a means to explore humanity's poor treatment of the insects.

Researchers are already looking at how to remotely operate beetles

Image: NCSU



In northern Thailand, for example, rhinoceros beetles are made to fight for sport, and it's not hard to imagine remote-controlled examples being employed for a more interactive experience. Still, remote beetles could have equal application in tales that incorporate a search-and-rescue theme. Perhaps a story could follow an activist and her remote-controlled beetles mounting a jailbreak of the brutalised rhino fighters?

This would be only right; beetles deserve our respect. Coleoptera make up around 25 per cent of all known lifeforms on our planet. As a student, Darwin's favourite hobby was collecting them; Ancient Egyptians thought them sacred. John Lennon even named his band after them. Their beautiful parallel world deserves sci-fi's admiration and attention. Just a little research can turn anyone into a beetle maniac. ☺

Jon Wallace is a science fiction author living and working in England. His first novel, *Barricade*, was published in 2014. Check out his website jonwallace.co

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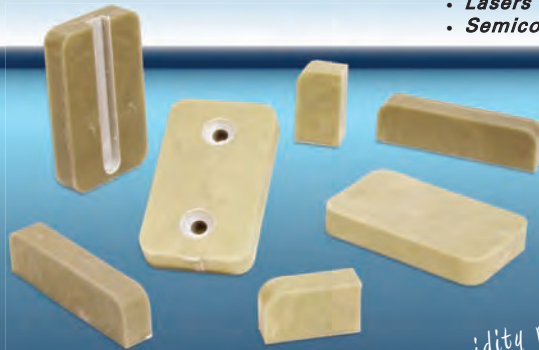
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Engine steps on the gas

Bearings are assisting an engine design that could tackle greenhouse gases.

Helen Knight reports



A new aircraft engine design that could cut greenhouse gas emissions from air travel is a step closer to reality, thanks to the development of advanced bearings.

The new engine design, known as Open Rotor, is being developed as part of the EU's huge Clean Sky research programme, in

a project called Sustainable and Green Engine (SAGE) demonstrator SAGE2.

Open-rotor aircraft engines generate most of their thrust from two counter-rotating propellers, rather than the ducted fan that drives conventional turbofan engines.

This means the engine diameter can be larger, improving its efficiency, without creating the need for an excessively big and heavy engine nacelle.

The concept was first investigated in the 1980s, following the oil crisis where the price of fuel sky-rocketed. But as the oil price dropped again, interest in the idea waned. Now the concept is being revived, in a bid to reduce fuel consumption and carbon dioxide emissions from air travel.

With two propellers spinning in open air, the engine design can, in theory, significantly increase air flow and thrust, thereby reducing both fuel consumption and emissions.

But in order to make the design a reality, advanced bearings are needed to manage the loads produced, and to control the angle of the propeller blades. To this end, a technology development call was issued under the Clean Sky programme, which was answered by bearings manufacturer NTN-SNR, based in Annecy, France.

As a result, the SNRPBBEARING project was established in 2013, to investigate different bearing designs, and to develop whichever concept offered the greatest potential to withstand the large loads and high temperatures the devices would be subject to.

The SAGE2 demonstrator consists of two propeller modules, one fitted with 12 blades, and the other with 10 blades, according to Guillaume Lefort,

aeronautical product design engineer at NTN-SNR.

"It's a new design of engine, with two big propellers at the rear of the engine, and the bypass ratio between the low pressure airflow and high pressure airflow is higher (than a conventional turboprop engine)," he said.

In aircraft engines, the bypass ratio refers to the ratio between the mass of air passing around the engine core, and the mass of air passing through it. Engines with higher bypass ratios typically consume less fuel.

Each of the propeller blades within the two modules are attached to polygonal rings, and set at different angles by devices known as pitch control mechanisms.

The role of the bearings is to ensure that any aerodynamic or centrifugal

loads on the blades are transferred to the polygonal rings, while also allowing the blades to change pitch as needed.

"All the blades on each propeller have to face the same direction, so in order to move the blades it is necessary to have bearings on each blade root," said Lefort.

"These blade roots are similar to those on conventional turboprop engines, but the rotation speed is higher, so you also have some physical loads that are higher, and the temperatures are also higher," he added.

"Current designs, and in particular bearing lubricant and sealing, are not compliant with these new specifications," said Lefort.

Indeed, the blades on open-rotor engines can be subject to temperatures ranging from -55°C to 180°C .

To design the components, NTN-SNR performed finite element calculations to determine the impact of the stiffness of the polygonal rings and blade root on the bearings themselves. The company then had to develop a complex tribological system inside the bearings, in order to minimise friction.

Extensive work was also carried out to design complex sealing devices, in order to avoid lubricant leaking outside of the bearing, and to prevent pollution from the environment getting into the bearing.

The bearings then underwent a successful preliminary design review, after which the project team made some improvements to the components based on comments from manufacturers.

By the end of last year, the project had developed and manufactured 26 bearings up to technology readiness level five. This means the prototypes had been thoroughly tested.

"Once the bearings had been manufactured, we tested one of them under representative conditions, to validate the product before delivery to the customer," said Lefort.

The manufactured bearings have now been delivered to the engine maker, who will assemble them onto the SAGE2 demonstrator.

The completed SAGE2 engine demonstrator is due to undergo a set of ground tests at Istres in southern France, by the end of this year. ☺

The SAGE2 open-rotor engine



Robots can start moving into new flats

Flat motors can aid the work of bomb-disposal robots and medical exoskeletons. Supplier: Maxon Motor

A bomb-disposal robot is normally twin caterpillar tracks with a robotic arm, with up to seven joints that move in multiple axes to reach its target, often in confined spaces.

Military and security customers need them fitted with small and compact actuators to drive these multiple, small movements that do not require high motor speeds.

A good solution is a flat brushless motor that comes in a kit. In a flat motor there is a flat plate and the rotor spins on the outside, with the shaft protruding to which your PCB or control is attached, rather than a normal motor where the shaft itself spins. Normally with motors, the bigger the diameter the higher the torque. For these flatter motors, it's about more torque and less speed.

Maxon Motor has introduced an DC brushless motor in kit form, for these space-restricted and low-speed

applications. They have standard 20mm to 90mm sizes, but the kit form allows a company to customise it to the – perhaps low volume, but not on-off – application.

The two parts are the core part containing the winding, which the electronic board and controller is attached to, plus a lid that contains the magnets. "It's up to the customer then to fit them together. The advantage is they get an even more compact package than they would do with the shaft hanging out and it means that customers can better integrate our motor into their application," said Maxon Motor managing director William Mason.

Another good application is for medical exoskeletons. "If a person loses the use of their legs, for example, they can have a powered knee joint to help support them in recuperation,"

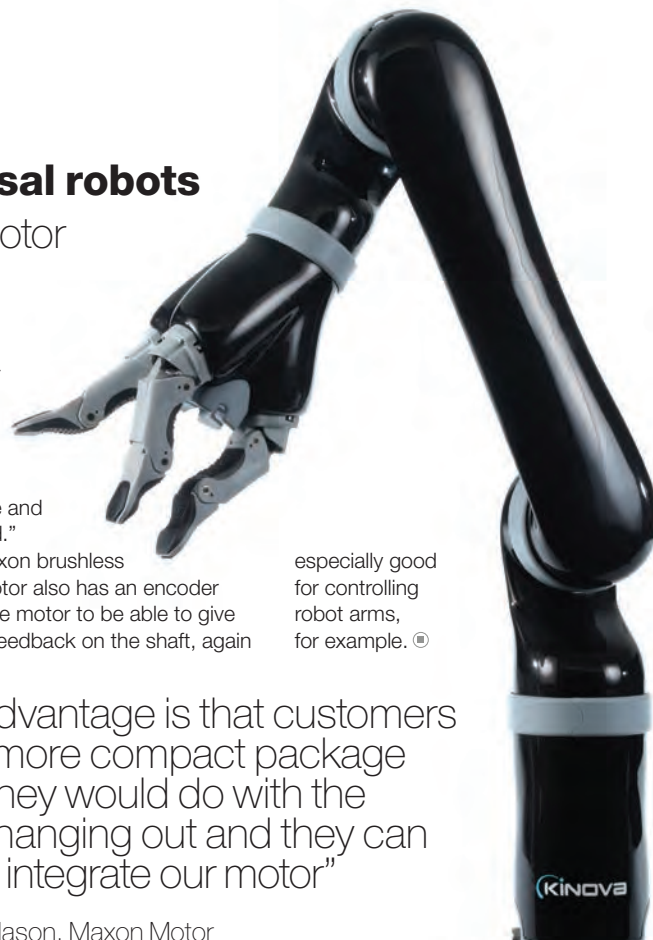
says Mason. "The motor in the joint must be quite thin, relatively high torque and slow speed."

The Maxon brushless kit form motor also has an encoder built into the motor to be able to give positional feedback on the shaft, again

especially good for controlling robot arms, for example. ©

"The advantage is that customers get a more compact package than they would do with the shaft hanging out and they can better integrate our motor"

William Mason, Maxon Motor



Driving towards the goal of breathing space

Drives save valuable space on the workfloor and have a variety of applications. Supplier: Bosch Rexroth

Machine footprint is a growing issue in manufacturing because factory space is often rented by area and often the only alternative to moving to a new premises is to fit more machines into the existing site.

Sometimes, even seemingly small reductions in drive size can help reduce the size of drive cabinets. This, in turn, ensures that machine users of all types get more production capacity from their current space.

The saving of space on the workfloor is one of the key features associated with the IndraDrive ML units, manufactured by Bosch Rexroth, according to head of product management, Mike Lomax. "The ML units extend the IndraDrive family to include the higher output range, capable of generating up to 500kW,"

said Lomax. "Up to eight units can be connected in parallel to reach outputs as high as 4MW."

He added: "These space-saving, modular inverters can therefore be regarded as something of an all-rounder, with applications ranging from metal forming through to test-rig equipment, marine and packaging."

"The ML can be used as mains or motor inverters to minimise the number of variants, simplify handling, and reduce your storage costs while saving energy."

IndraDrive ML is also equipped with a Smart Energy Mode that actively regulates the mains inverter to ensure a reliable supply of DC bus voltage that is independent from the mains voltage, while continuously using the DC link capacitors for energy storage.

The benefit is significant energy reduction, particularly when generator and motor power modes are frequently switched, as is the case with intermittent acceleration and braking cycles. Peak loads on the line side are also avoided, and average energy consumption is reduced. ©

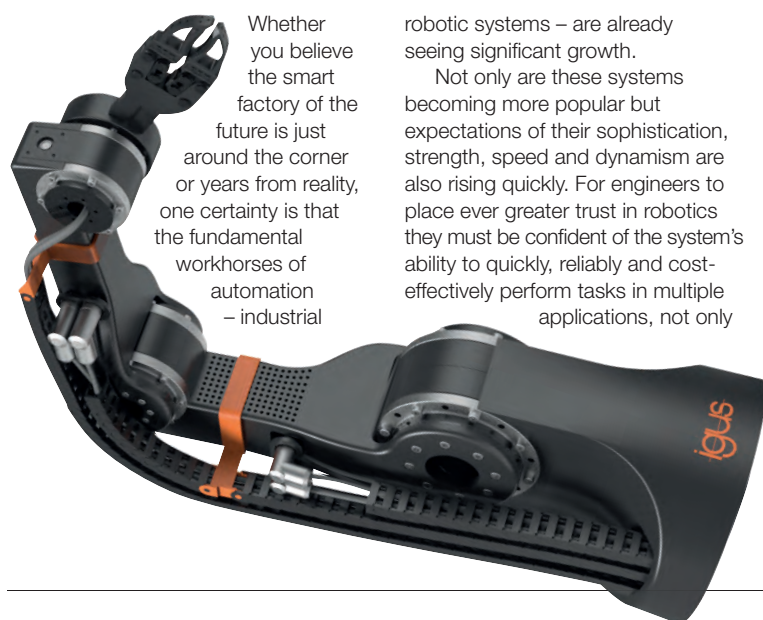
"These space-saving, modular inverters are all-rounders and have applications ranging from metal forming through to test-rig equipment"

Mike Lomax, Bosch Rexroth

Articulate response to the needs of the robotic arm

Robolink D is a modular kit that enables customised construction of an articulated arm. Supplier: Igus

"The system is driven by a worm gear driver and a NEMA 17 or 23 stepper motor"



Whether you believe the smart factory of the future is just around the corner or years from reality, one certainty is that the fundamental workhorses of automation – industrial

robotic systems – are already seeing significant growth.

Not only are these systems becoming more popular but expectations of their sophistication, strength, speed and dynamism are also rising quickly. For engineers to place ever greater trust in robotics they must be confident of the system's ability to quickly, reliably and cost-effectively perform tasks in multiple applications, not only

in labs but in critical working environments.

To help make reliable robotic technology accessible and affordable to a broader cross-section of industrial companies, Igus launched Robolink D, a modular kit that enables customised construction of an articulated arm. Costing as little as €1,500 for a basic kit, the Robolink D concept provides robot manufacturers, mechanical engineers and automation integration specialists with a lightweight and highly customisable range of options comprising articulated joints, motors and connecting components.

The system offers lightweight but strong plastic construction, offering a payload up to 4kg. The articulated arm is driven by directly

positioning the motor on the axle, and is made possible with the Igus line of self-lubricating PRT slewing ring bearings, which are installed in a plastic housing.

The system is driven by a worm gear driver and a NEMA 17 or 23 stepper motor, which, alongside other engines, are managed by commercially available standard control modules. The latest Robolink D kit represents a big advance upon previous articulated arms where the stepper motors had to be housed in a separate drive unit.

Now, greater toughness and durability open up new opportunities for lean automation, and the flexibility of Robolink D allows manufacturers to respond to the evolving needs and adaptations of their workload. ☐

Precision performance on the micro scale

Compact and high torque motors for medical prosthetics. Supplier: Faulhaber

"The improvement in power and torque is based on a redesign of all of the motor's elements"

Stewart Goulding, EMS

Medical prosthetics and other micro-scale engineering applications need small but relatively high torque motors to achieve the necessary force in a small space. Operators of such precision equipment need good power performance but also low vibration and noise levels, and lightweighting. Faulhaber has launched a new generation of metal brush commutated motors, the 1024...SR series with a diameter of 10mm.

In combination with a gearhead, its output torque can be up to 300mNm thanks largely to a superior torque/speed ratio. The model's flat speed/torque curve produces, Faulhaber said, the strongest motor in its class and means that it can deliver consistent torque without compromising the output speed.

Engineering design has been key. "The huge improvement in power and torque achieved by the 1024...SR series is based on a complete redesign of nearly all of the motor's elements, including a new high copper density coil, a new commutation system and a new magnet," said Stewart Goulding, managing director of Electro Mechanical Systems. The combination results in a significantly wider speed range under load, delivering a continuous torque of 1.5mNm at 7,500rpm, exhibiting output power above 3W, and is available in windings of 6V, 9V and 12V DC.

The 1024...SR motor's high performance and low vibration levels makes it suitable for medical devices, prosthetics and optical equipment, and its small dimensions and low weight makes it really suitable for all portable devices. When electromagnetic interference is a risk the motor can be equipped with either a magnetic or optical encoder and is available with different gearheads,

including the 12/4 planetary gearhead.

This unique gearhead delivers the highest power output levels available with motors of this class with a continuous torque of 300mNm from a combined length, including encoder of just 51mm. ☐





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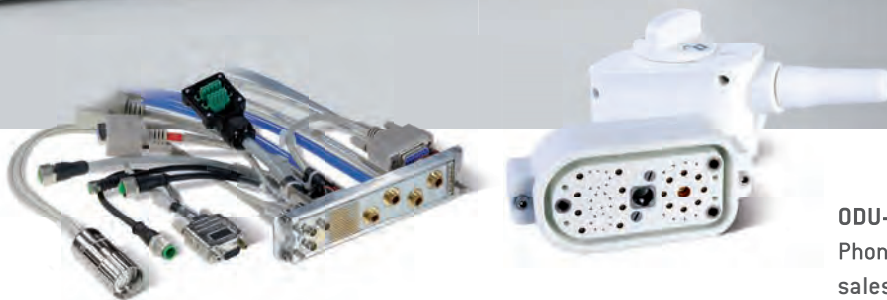
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Waste shows big potential

Process could turn food waste into a variety of specialist materials that could be utilised in medicine and aerospace



A process that could turn food waste into specialist materials with potential applications in medicine, aerospace and motorsport has been developed by a graduate student from Reading University, with the assistance of automation specialists at Maxon Motors. Funded by the EU

and a consortium of industrial partners, the project is part of the Electrospun programme and is the brainchild of Saeed Mohan at the university's Centre for Atomic Microscopy.

Mohan's research involves electrospinning: a process that uses electric fields to draw charged threads of a polymer solution into threads. The project sees Mohan create a viscous solution of a polymer that is placed into an extrusion drum with fine apertures. This spins at a high rate and the solution is forced through the holes, forming fibres; it's very similar to the way a fairground candy-floss machine works. Mohan needed a system that would allow him to test different spin-rates and viscosities, which led

01 Electrospinning uses electric fields to draw a polymer solution into threads

him to contact Maxon. The company, which has a special programme for educational projects, worked with Mohan to specify a brushless EC-max 30 motor with an ESCON servocontroller, capable of up to 150,00rpm, to fit to his prototype extrusion drum. "I liked the idea that Maxon had a motor and controller package that made it fairly easy to get started," he said.

Mohan came up with a hollow shaft to be fitted to the motor and gravity-fed with a constant stream of the polymer solution, which would then be let into the extrusion cylinder via a valve that would only open when the system was up to the speed required for fibre extrusion: this minimised waste of the polymer solution and was automated via the ESCON's speed monitoring output.

The food waste aspect of the project comes about from selecting the feedstock. For example, apple juice production involves discarding fibrous pulp, which could be used to generate a natural polymer solution; these would also have the advantage of being environmentally friendly. Such fibres could be used to form scaffolds for bone or tissue regrowth, fine filters for respirators, or as a component for lightweight composites for aircraft. ©



Indepth

'Co-bots' will be able to work alongside human counterparts on inspection lines



Industrial Vision Systems is supplying machine vision for a new generation of robots that are designed to work alongside humans, rather than segregated away from them for safety reasons. These so-called collaborative robots or 'co-bots' will work on inspection lines for complex parts and components.

The systems were supplied to a Danish company, Universal Robots, for use in its lightweight UR3, UR5 and UR10 models. According to IVS director Earl Yardley, "Collaborative robots are designed so that the robot and human can work side by side without barriers. By offering ready-to-run inspection solutions utilising robots and vision in tandem, we are opening a new era for real-time machine vision inspection."

Robotic heavy work is all in the proximity of humans

Heavy-lifting collaborative robots can work hand in hand with human operatives. Supplier: FANUC

The robot revolution in manufacturing has had a variety of challenges, whether due to cost, lack of education or potentially fear of the unknown.

Companies and universities are currently working hard on adapting heavy robots to work safely in the proximity of humans – something highly desirable in applications such as high-rate aircraft wing manufacture, for example.

In April 2015 Fanuc launched what it claimed to be world's first heavy-lifting collaborative robot, the FANUC CR-35iA: an ergonomic robot that can work hand in hand with human operatives.

The CR-35iA can perform both simple and complex tasks, lifting payloads of up to 35kg, and is suitable for several manufacturing industries.

The robot can also work in a variety of applications that include machine tending, and where heavy lifting is a feature such as handling heavy payloads, higher payload mechanical assembly, palletising or packing, and tote or carton handling.

Worker safety has been improved, as intelligent sensors on the robot automatically stop it if it comes

into contact with a human, ensuring this 'collaborative robot' can work alongside humans more efficiently, removing the need for fences.

Fencing was a previous requirement for all industrial robots on the shopfloor.

In the automotive industry, for example, where workers are required to lift spare tires into vehicles on the assembly line, the robot can work alongside employees to help reduce repetitive stress injuries and those caused by heavy lifting.

This will mean ultimately that some workers' physical jobs will be supplanted by the robot and they can be deployed to more desirable employment. At the same time, better collaboration between the robot and human worker will lead to an increase in manufacturing productivity.

"Collaborative robots offer exciting new opportunities for the manufacturing industry and are an indispensable part of production," said Tom Bouchier, managing director of FANUC UK.

"They enhance machines with vision, force sensors, and artificial Intelligence, greatly improving

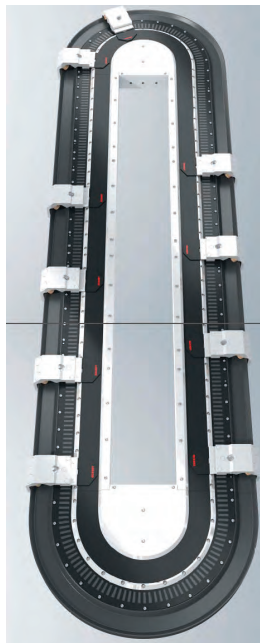


the rate of industrial production. This not only makes processes more cost and energy efficient, it improves sustainability by reducing waste."

He added: "At the same time, complex adaptive systems and multi-processing will take over from real-time systems, thus further increasing productivity and profitability for manufacturers." ■

"Collaborative robots offer exciting new opportunities for the manufacturing industry"

Tom Bouchier, FANUC



Applying labels with a high degree of accuracy

Linear Servo Systems underpin fully automated labelling. Supplier: Beckhoff New Automation Technology

Automation integrator SP Technology in Dunsee was asked to apply labels to cylinders within 0.1mm accuracy and up to 100 parts per minute.

SP Technology was asked to develop a fully automated labelling machine for a UK healthcare customer, which had to apply labels with a high degree of accuracy and then package them into storage trays at a rate of up to 100 parts per minute.

The main challenge was to overcome the inaccuracies and create a system that would allow labels to be repeatedly applied and wrapped around 370° on a cylindrical device. Typical accuracies achieved by standard solutions is within 0.5mm and 5° from reference features on the label, however, in this application the accuracies required were within 0.1mm and with no visible overlap.

Core to the machine's accuracy were three Beckhoff XTS Continuous Linear Servo Systems totalling almost 30m in combined length. In addition the machine used a selection of 48V Beckhoff servo motors and a Beckhoff industrial PC, controlling the automation and motion solution over a TwinCAT Ethernet-based control network. Several

third-party devices were also deployed, including vision and code readers, pneumatics for the pick and place operations and a six-axis robot.

Trays populated with parts were manually loaded into the machine and separated to present a single tray for the unloading of devices. A servo-operated pick-and-place system then loaded an array of devices on to purpose-built nests, which were bolted to the individual XTS Movers. The nests had to be designed with spring-loaded retention fingers in order to keep the product stable during the rapid accelerations and decelerations with speeds of up to 2m/s from station to station. As the nest carried an odd number of parts, and the tray had an even number in each row, intricate programming of the TwinCAT software was required in order to sequence the movers into the correct positions.

Before a nest reached a labelling station, the labels were peeled off and presented to a vacuum pad where they would be inspected by a vision system. This would feed back the angular and linear displacement from datum edges and write these parameters to the Beckhoff IndustrialPC controlling the system. ©

"The main challenge was to overcome the inaccuracies and allow labels to be repeatedly applied"

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Why two arms are sometimes better than one in electronics

YuMi industrial robot works in a collaborative fashion without barriers, cages or zones. Supplier: ABB Robotics

“ABB has begun to sell the YuMi system to a number of end users since the end of last year”

Colin Dullaghan, ABB Robotics

Shortage of skilled labour to meet rising demand in the electronics industry, especially, has led manufacturers to look for alternative production methods. Research from Boston Consulting Group predicts that by 2025, the adoption of advanced robots will boost productivity by up to 30 per cent in many industries.

ABB Robotics said YuMi, recently launched in the UK and Ireland, is the world's first truly collaborative dual-arm industrial robot. Short for ‘you and me’, YuMi has no barriers, cages or zones, has the ability to feel and see, and can work safely alongside humans in small parts assembly applications.

The accuracy of the robot makes it suitable for handling small components in the electronics industry, as well as several other operations including camera-based inspection, parts-feeding, packaging and testing.

The robot is designed for safe operation, allowing it to operate in close collaboration with humans. It has a lightweight, rigid magnesium skeleton covered with a floating plastic casing wrapped in soft padding designed to absorb impacts.

If the robot system senses an unexpected impact, it can stop within milliseconds. YuMi also has no pinch points so that nothing sensitive can be harmed as the axes open and close.

Lead through programming – where an operator programmes via demonstrating positions – makes YuMi simple to set up and operate by moving its arms to the positions that are needed.

Combined with adaptable grippers, ABB said that the YuMi robot system can be programmed to perform new tasks quickly and efficiently.

“YuMi opens up great opportunities for UK and Irish businesses,” according to Colin Dullaghan, product manager for YuMi at

ABB Robotics UK. “The initial market response has been extremely positive. ABB has begun to sell this system to a number of end users since the end of last year and there's a definite growing interest in the product across industrial sectors outside of electronics.”



An intelligent helper for repetitive industrial tasks

Opening up new applications in product service and the medical sector. Supplier: Kuka Robotics

Small robot systems designed to operate alongside the human operator should be versatile, having the capability to lift and hold a useful weight as well as completing fine, precise work in applications such as medical devices.

The LBR iiwa – intelligent industrial work assistant – from Kuka Robotics is both an intelligent helper for repetitive, industrial tasks and opens up new applications in product service and the medical sector.

The lightweight robot is designed for side-by-side collaboration with the human operator. The system has programmable sensitivity, and is precise and flexible, making it possible to automate delicate automation tasks. The LBR iiwa is suitable for operation in normal machine environments and meets the requirements of protection rating IP54. It also meets EN ISO 13849.

The design is based on the human arm and can be operated in position and compliance control. It has seven axes with integrated torque sensors using safe technology. These sensors respond to the slightest of external forces and enables safe collision protection, which according to

Kuka, is a unique feature. These features make the LBR iiwa a good system for delicate joining processes and allows the use of simple tools. The combination of low weight, multiple axes and streamlined design make it suited to confined space installations and is quite easy to integrate into existing production systems.

The system is available with payload capacities of seven and 14kg. KUKA said this is the first and only lightweight robot with a payload capacity of more than 10kg.

With its sensitivity engineering, the LBR iiwa is able to increase the direct cooperation between the human operator and the robot, acting as the ‘third hand’ of the operator and can work directly with humans, without the need for a safety fence. It can relieve the human operator of arduous, non-ergonomic tasks, such as inserting plugs in a vehicle body.

The robot can also be used in the confined interior of a vehicle, for example, moving backwards and forwards in the vehicle body and carrying out screw-fastening tasks, and it can be supported on a mobile platform.



“The LBR iiwa is able to increase the direct cooperation between the human operator and the robot”

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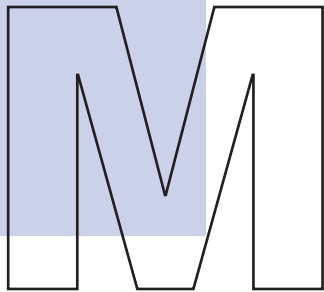
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Looking out for plant and assets

Maintec is seeking to offer its visitors an insight into the very latest industry trends in the plant and asset management sector



Maintec 2016, the UK's leading maintenance, plant and asset management event, returns to Birmingham's NEC on 22-24 March with a new seminar programme, an expanded show floor and an array of top industry suppliers.

Exhibitors at Maintec 2016 include all the major names and show regulars, such as Fluke, Atlas Copco Compressors, Indysoft Europe, UE Systems Europe and Technical Training Solutions, many of whom

will be using the show to launch new products to the market or unveil their very latest upgrades.

Keytracker will showcase its range of products from the original Peg in-Peg out board to the Electronic Key Management Systems, Key Control Software and iLockerz Intelligent locker Systems.

Hansford Sensors will be displaying its selection of market-leading vibration monitoring solutions. This includes the HS-100 series – an AC industrial accelerometer that enables quick and easy measuring of vibrations in rotating machine components. It will also present the HS-620 Vibration Monitoring Kit, which enables maintenance technicians to measure bearing condition and levels of velocity, acceleration and displacement.

UE Systems will present its new Ultraprobe 401 Digital Grease Caddy Pro, which has the ability to measure, data log and trend the amount of lubricant used in order to optimise equipment maintenance.

Dustcontrol UK will exhibit a range of cyclone-based industrial vacuum equipment, including Hepa-filtered equipment, ATEX, centralised systems,

“Many will be using the show to launch new products to the market or unveil upgrades”

mobile vacuums and accessories. This includes its range of ‘plug-and-play’ centralised vacuums that will be demonstrated on the stand.

Technical Training Solutions will showcase its range of practical industrial engineering skills training courses, including Electrical and Mechanical Maintenance Skills, PLC Faultfinding, Instrumentation, 17th Edition Wiring Regulations, Pneumatics and Hydraulics.

Exel Computer Systems will present its Eagle Field Service system, the mobile management solution that provides real-time information and resources to field-based engineers directly their mobile device.

PAR Group will be showcasing its range of rubber plastic and insulation products served to a wide range of industries, including chemical, brewing, mining and quarrying, aerospace, power generation, packaging, recycling and distribution.

New for 2016, the seminar programme will feature two exciting keynote speakers every day, alongside a whole host of exhibitor presentations. This will provide maintenance and engineering professionals with educational opportunities to hear about the latest industry trends.

The keynote sessions will include presentations from Phil Reeves, vice-president of Stratasys Consulting, who will discuss the ‘Potential for 3D printing in the maintenance function’. Also headlining will be Paul Hingley, CMR business manager at Siemens Customer Services, who will look at ‘Where maintenance collides with Industry 4.0 and the internet of things’. Plus, Alan Gane Maintenance Manager at Jaguar Land Rover will explore ‘Developing Maintenance Skills’, with more speakers to be confirmed.

Many Maintec visitors have a wider facilities management and health and safety remit, so, with this in mind, the show will once again be running alongside two highly complementary shows. The first co-location is with the Health and Safety Event, run by Western Business Exhibitions, a leader in the health and safety sector.

The second co-located show is Facilities Management 2016, the UK's only event to focus on the large-scale and multi-site facilities industry, which will also feature the Cleaning Zone. This zone focuses on buyers and suppliers within the cleaning industry and will include the top technologies from the facilities industry.

Those in attendance will have full access to the Networking Bar throughout the event, where they will have the opportunity to meet with industry peers and network with like-minded individuals. ☺



02



01

01/02 Meeting with industry peers and like-minded individuals is an important part of the show



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Drives & Controls is set to include many first-time exhibitors, with some of the biggest names in industrial robot technology also in attendance

The biennial Drives & Controls Exhibition & Conference, – co-located alongside Plant and Asset Management, European Offshore Energy, Fluid Power & Systems and Air-Tech Exhibitions – is once again set to return to Birmingham's NEC (Halls 3/3A) from 12-14 April 2016, alongside MACH 2016.

This year's event will again bring together key suppliers of state-of-the-art equipment representing the multi-tasking culture of today's design engineer, covering critical areas such as energy efficiency, machine safety, drives, motion control, robotics

and automation, plus much more, all under one roof.

It is anticipated that the 2016 show will cover at least 50 per cent more floor space than in 2014 with a prediction of at least 50 more exhibitors in Drives & Controls alone.

New bookings include many first-time exhibitors, including Applied Automation, which will be taking part in the robotics demonstration area, as well as having its own stand. Others include: Cornelius Electronics, a Welsh producer of cable assemblies and manufacturing systems; electrical equipment specialist Mersen; energy and automation supplier Lovato Electric; measurement and controls vendor Techni Measure; small motors specialist Portescap; chain manufacturer Ramsey Chain, which was established in the US more than 90 years ago and has a UK base in Wales; ABB's low-voltage division ABB Controls; enclosures supplier Fibox; and the Haley Group.

Recent sign-ups from abroad include Turkish control gear and electrical equipment manufacturer EMAS; French belt specialist Hutchinson (which will be appearing on the pavilion organised by the European Power Transmission Distributors Association);

01/02 It is anticipated that the 2016 show will cover at least 50 per cent more floor space than in 2014



Italian motor-maker Carpanelli Motori Elettrici; and Apex Dynamics, a planetary gearbox manufacturer with headquarters in the US.

Companies returning to Drives & Controls include: Delta Line; Automation Experts; RS Components; Principle Engineering; WEG Electric Motors; Kormag; Danfoss Drives; Semikron; Phoenix Contact; Beijer Electronics; and Vacon (which will be appearing on the Gambica pavilion).

This year's event will, for the first time, also include a dedicated area where some of the latest industrial robot technology from big names, including ABB, Applied Engineering, B&R, Harmonic Drive AG, Mitsubishi, Universal Robot, RA Rodriguez and Staubli, will be demonstrated.

There will also be several examples of 'collaborative' robots – or 'cobots' – designed to operate safely alongside human workers, without needing a protective cage.

Away from the show floor, the free 2016 seminar and conference programme will have a strong emphasis on technology, entrepreneurship, skills, regulations, the environment, and safety.

Featuring representatives from across industry, including government agencies, the EU, research bodies, trade associations and manufacturers,

the conference programme will focus on practical solutions to real-life industry requirements. For example, GAMBICA's Steve Brambley will be presenting a seminar on future trends – circular economy, Industry 4.0 and EcoDesign, and a panel discussion on trends and influencing factors in the industrial automation sector.

Other highlights include: optimising energy consumption in motor-driven systems, by Steve Schofield of the BPMA, and a seminar on driving the future of robotics by Graham Mackrell, Harmonic Drive. A full seminar programme will be published shortly.

This year's event will also feature a series of panel discussion – jointly organised by The Industry Entrepreneurship Network (IEN) – covering the topics of 'Blended Education', 'Entrepreneurship in Industry' and 'The Economics of Manufacturing' with panels formed from the network's membership of established entrepreneurs, industrial companies and leading UK trade, science, education and engineering organisations. ■



“Suppliers represent the multi-tasking culture of today's design engineer”

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Considering a fossil future?

Despite the current slump there are still opportunities in the oil and gas sector.

Evelyn Adams reports

The current oil and gas slump is the deepest in post-war history. Excess supply has pushed onshore reserves to record levels, causing prices to crash to around £19.60 from a high of £80 a barrel in the summer of 2014. And things could be about to get worse. Analysts are predicting that oil prices could fall to between £17.60

and £7 a barrel, before they make any kind of recovery.

Declining oil prices may be good for the consumer, but they have hit the industry hard, particularly in areas such as the North Sea where activity is at a low ebb. A report out in September by industry group Oil & Gas UK predicted North Sea spending will be cut from a record £14.8bn in 2014 to £7bn or less within three years. It estimates that 65,000

jobs have been axed in the North Sea oil sector since 2014 as a result, leaving a workforce of around 375,000.

So is it a terrible time to consider a career in the oil and gas industry? "I think the important fact to remember is that all markets suffer with similar periodic declines following periods of unsustainable growth, and like other sectors, the oil and gas industry will recover," said Grant Hutchinson, divisional manager of oil and gas at Capp Group, which is part of Matchtech. "Individuals shouldn't be put off the oil and gas industry, as there will always be opportunities for skilled professionals in such a resource-hungry market."

Alix Thom, Oil and Gas UK's employment and skills issues manager, believes that while the sustained drop is making life hard for the UK oil and gas industry, this won't last. "The industry, regulator and governments are all working hard to ensure that when the price does recover. The sector is in the best condition possible for activity and employment to be restored," he said. With up to 20 billion

barrels of oil and gas remaining in the UK Continental Shelf, and the government forecasting that our oil and gas needs will not diminish until 2030, Thom said this is very much an industry with a future.

Both Thom and Hutchinson are confident that these vast reserves could once again be lucrative. Thanks to investment while the oil price was high, the North Sea has infrastructure in place. Like Oil and Gas UK, BP estimates that around 15 to 20 billion barrels of oil may be waiting to be discovered in the region. With better technology, companies are aiming to increase the percentage of oil they can get from reservoirs. And because their production costs have come down following a drop in demand, a number of firms are investing in major projects in anticipation of a recovery.

"The current oil price has provided a cost-effective opportunity for operators to develop and revamp current processing plants," said Hutchinson. "With reduced manpower costs and the lower cost of feedstock reducing the amount of revenue lost through standard shutdowns, a number of operators are taking the opportunity to invest. This investment naturally provides a demand for a variety of skilled oil and gas workers... With an aging workforce, particularly within processing plants, there is certainly room for new talent to enter the market."

01 Previous investment has left plenty of oil and gas infrastructure

Image: Matchtech

02 Graduates could be offered a variety of roles in the industry

Image: Shell



01



02

"The most sought-after skills are always related to the most technical positions"

Andrew Duffy, Petroplan

Oil and Gas UK estimates that output from the UK Continental Shelf last year rose between seven per cent and eight per cent compared with the previous year. Government data for production from the North Sea for the first 10 months of last year revealed that liquid output rose 10.6 per cent and gas was 6.1 per cent higher. These figures are partly down to new facilities coming on stream such as Taqa's Cladhan field off Shetland.

BP, Maersk Oil and JX Nippon are also working together to develop the Culzean gas field at a cost of US\$3bn. This is expected to support up to 6,000 UK jobs and create more than 400. The Culzean gas field is the largest new field discovered in the UK North Sea for a decade. It was discovered in 2008 and is expected to produce enough gas to meet five per cent of total UK demand at peak production in 2020 to 2021. "It will provide significant economic benefits to both the region and the rest of the UK for many years to come," the government has claimed.

Some argue that trend won't last. Shell has already cut down on some of its investment in the region. But Elmer Schaap, the company's graduate recruitment manager, said there remain roles for talented engineers, particularly in mechanical and marine engineering. "In Europe, attractive opportunities for graduates exist across our organisation, in particular in the Netherlands and the UK, in our Upstream

and Downstream operations and our global Projects and Technology division," he said. "We need core engineering skills... We also look for evidence of leadership potential, particularly in graduates."

Andrew Duffy, a recruitment consultant at Petroplan, said that the market has a track record of rebounding. He advises engineers to get the relevant qualifications and build relationships with industry specialists. "The most sought-after skills are always related to the most technical positions," he said. "Being a good engineer is about creativity, thinking outside the box and good project management skills."

Yasmin Ali, a former IET Young Woman Engineer of the Year finalist, agreed. "There are definitely still opportunities out there," she said. "In the UK North Sea, decommissioning of ageing assets will become a large area of focus. This is something we, as an industry, don't have a lot of experience in. We will have to tackle the issue very soon as more and more oil and gas fields reach the end of their lives. These large-scale projects will require engineers to solve the technical challenges presented in a cost effective, safe, and environmentally sustainable way." ©

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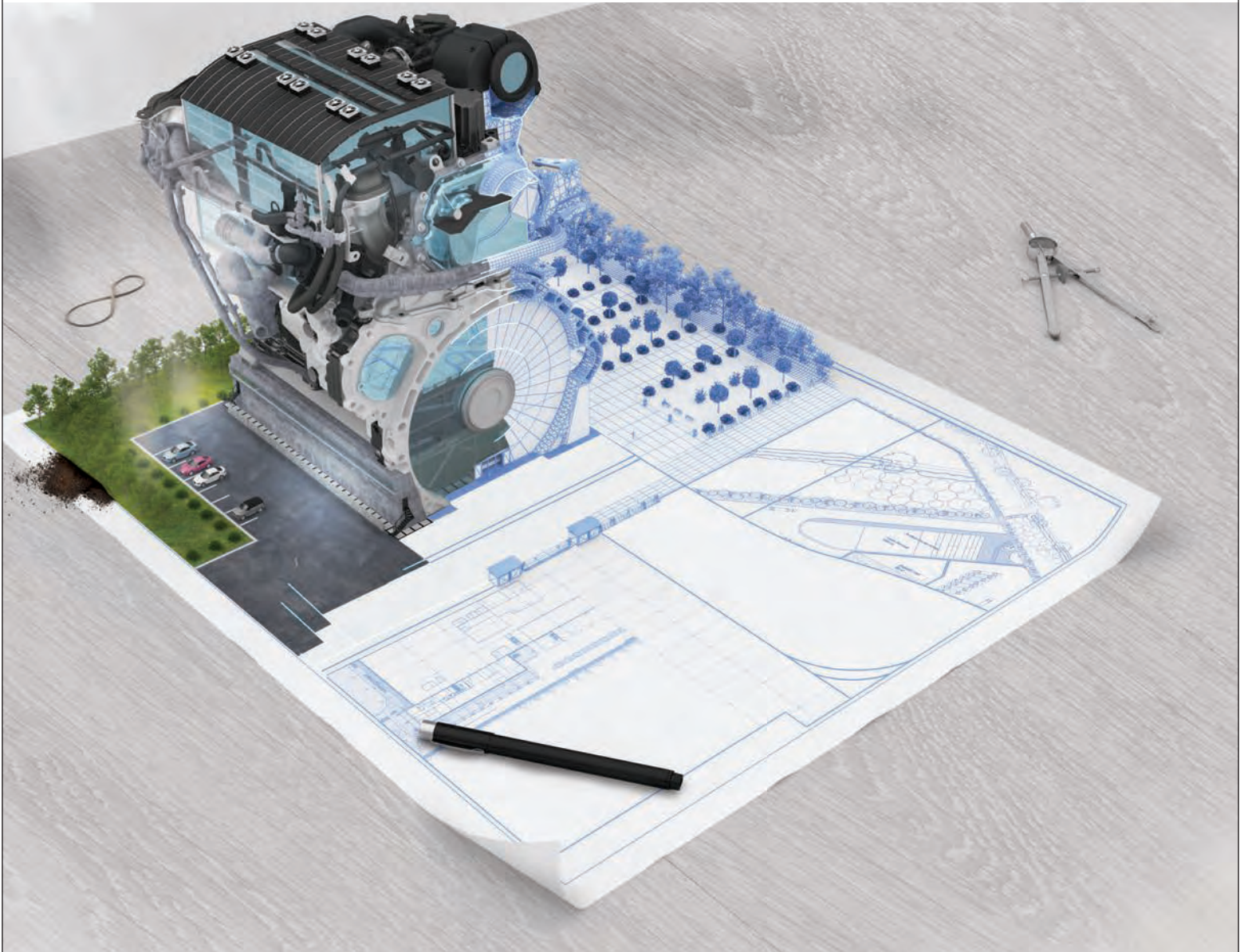
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Feb
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from the archive | ships

Wood and iron

Iron-clad warships were a new development that provoked intense scepticism in the 19th century

If any readers wanted a demonstration of just how long *The Engineer* has been running, and how much can change during that period, a long article from our archives shows both clearly. It discusses an issue that was of great concern to the defence of the British Empire, then at its height: whether the ships of the Royal Navy should be primarily made of wood or if they should be protected by a coat of iron.

Wood had, of course, been the only material for shipping construction for centuries. It had become part of British mythology – ‘Heart of Oak’ is still the official march of the Royal Navy – and the need for the emblematic tree to provide the timbers for ships changed the appearance of the English countryside. The nation had fought off the Spanish Armada with wooden ships; and had protected the country from Napoleon. Why change now?

The reason the question was even being posed was largely down to one man: Isambard Kingdom Brunel. It’s worth pointing out that although he’s now universally praised as a genius and an iconic figure of British engineering, that wasn’t true of his own time. Brunel was an iconoclast whose projects pushed at the very edges of the available technologies, and, as *The Engineer*’s obituary of him makes clear, to his contemporaries he was seen as a foolhardy figure more notable for his failures and the great cost of his completed projects than his successes. But the completion of his final project, the enormous iron sailing steam ship *SS Great Eastern*, had focused attention on the future of shipping.

SS Great Eastern was enormous. By far the biggest ship ever built, it was 692ft long (211m) and weighed 18,915 tonnes – records that would only be surpassed in 1899 and 1901, respectively. It could travel from England to Australia with 4,000 passengers without refuelling. But it wasn’t an unqualified success: an explosion on the maiden voyage had damaged the ship, and Brunel’s death soon after cast a pall over the project.

The Engineer article (which oddly, or perhaps not, does not mention Brunel at all) begins by mentioning General Sir Howard Douglas, a veteran of the Peninsular War, expert of military strategy and

an authority on marine engineering. General Douglas, the article said, “has long been recognised as the principal literary champion of wooden ships of war”, and every time anyone had dared to suggest that iron should be used in their construction “he has uniformly exerted his influence, which is by no means inconsiderable, against the project”. Douglas had issued a pamphlet stating that: “Vessels constructed wholly, or nearly so, of iron were utterly unfit for all the purposes of war, whether armed or as transports for the conveyance of troops.” He even opposed the cladding of wooden ships in iron armour.

Stepping up to oppose the formidable General Douglas was Scott Russell, whose company had built the all-iron, double-skinned *Great Eastern* (and had gone bankrupt in doing so). Douglas was not impressed with the ship; in his pamphlet he had said that 68-pound solid shot “would pass straight through the *Great Eastern* with tremendous effect, and this perforation could not be plugged up”. Moreover, he claimed the ship was “an awful roller, and has never attained anything like the calculated speed”, and that a thickness of iron of eight inches would be needed to proof the hull against shells and solid shot. Russell took umbrage. On balance, he

said, iron performed better than wood; iron ships would be stronger than wooden ships of equal weight; would be able to carry heavier weights; and would not catch fire. The *Great Eastern*, he insisted, rolled less than wooden ships, and had realised a speed of 14 knots on a transatlantic route.

The article points out that iron hulls could be repaired easily and fairly cheaply; shots striking at an angle tended to glance off, and they did not shatter into sharp splinters, which, in wooden ships, were a cause of terrible injuries to crew members.

The argument in favour of iron ships was a good one, the article concluded, with the matter of fire being particularly powerful; it notes that in a close engagement between wooden ships of the line, incendiaries could destroy both ships in less than five minutes. The developing expertise in metal shipbuilding would eliminate any drawbacks.

The argument had, in fact, been won two years before. HMS *Victoria*, launched in November 1859, was the Royal Navy’s last wooden ship of the line and the last wooden battleship to enter service, and the ironclads HMS *Warrior* and HMS *Black Prince*, launched in 1860, set the scene for the next iron-armoured wooden vessels. **SN** ©

“General Douglas has uniformly exerted his influence against the iron-clad project”

The Engineer

SS Great Eastern focused attention on the future of shipping



Word of the issue

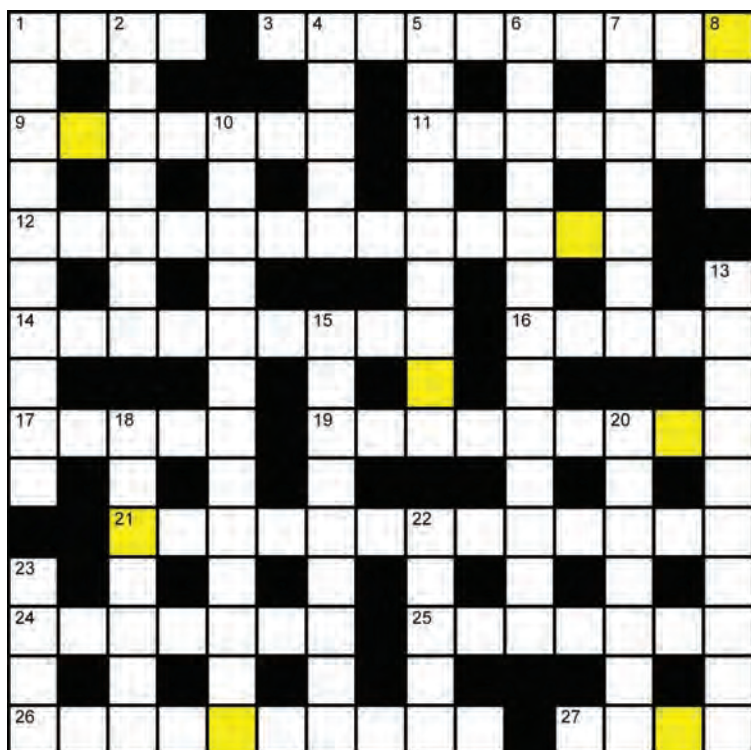
Anthony Poulton-Smith explores the origins of the word 'washer'

Ever wondered why something has been named a 'washer' when it clearly has nothing in common with 'washing'? For the engineer it has three practical applications: to prevent damage to a surface from a nut or bolt; as a spacer; and as a locking device. A simple item but nothing compared to the etymology of this six-letter noun. It is easy to find this coming to English from the Old French 'vis'. However, this was not used to mean 'washer' but either 'vice' or 'screw'. Both of these should be seen in the sense of 'tighten' or 'wind up' and related to the root of 'winch'. This terminology is all interlinked, with the whole assembly speaking about 'tightening' both as a whole and individually. Ultimately, this has the same root as Latin 'vinis' or 'vine', itself from 'viere', meaning 'to bind, twist'. Thus the climbing vine, which evolved to wind itself around and climb, eventually gave its name to the fastenings used today.

Big picture



In January 2016, technicians at NASA's Michoud Assembly Facility in New Orleans finished friction-stir welding the primary structure of the Orion spacecraft, which is set for a deep-space mission aimed at informing the agency's target of reaching Mars.



Prize crossword

When completed rearrange the highlighted squares to spell out a walkway beside a road. The first correct answer received will win a £20 Amazon voucher. Email your answer to jon.excell@centaur.co.uk

Across

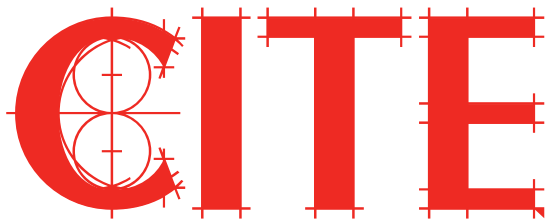
- 1 Place where merchandise can enter or leave a country (4)
- 3 Light invented by Sir Humphrey Davy (6-4)
- 9 Fine coatings of oxide on the surface of a metal (7)
- 11 In the shape of a coil (7)
- 12 Defeats totally (4,2,7)
- 14 An equivalent given in return (3,3,3)
- 16 Repair quickly and badly (5)
- 17 More than is needed (5)
- 19 Unusual (and often destructive) rise of water (5,4)
- 21 Desiring wealth and possessions (13)
- 24 Variety of mandarin orange (7)
- 25 Determined the sum of (5,2)
- 26 Alternately left and right with respect to a central point (4-2-4)

- 27 Organisation of countries producing petroleum (4)

Down

- 1 Hand tool for severing tubes (4,6)
- 2 Series of short sharp taps (3-1-3)
- 4 Chieftain in Africa or Arabia (5)
- 5 Displayed at a show (9)
- 6 Easily frightened (6-7)
- 7 Blamed for a wrongdoing (7)
- 8 Supporting column driven into the ground (4)
- 10 Organisation that preserves historic monuments and buildings (8,5)
- 13 Having parts that slide one within another (10)
- 15 Sessions of intensive instruction (9)
- 18 Disposed or enticed to (7)
- 20 Misbehaved badly (5,2)
- 22 Something given for victory in a contest (5)
- 23 Egyptian goddess of fertility (4)

January's highlighted solution was component. Winner: **Graham Verity**



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