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# the ENGINEER

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# Eye robot

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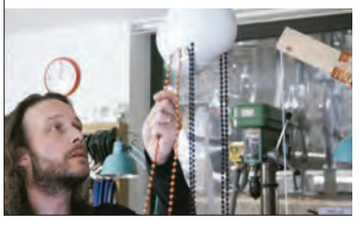

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Chernobyl's giant new shield is slid into place over the infamous damaged reactor

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# Rage on robots

Earlier this month, Bank of England governor Mark Carney strayed into unusual territory for a financier: warning an audience at Liverpool John Moores University that automation technology will put millions of jobs at risk in the years to come.

His comments provoked a predictably hysterical response from the mainstream media. "Robots to steal 15 million of your jobs" screeched the *The Daily Mail*, while *The Daily Express* briefly forgot about its hatred of immigrants and warned that "androids" now posed the biggest threat for "Brit" jobs.

In fairness, although the tabloids only picked up on one aspect of what was a wide-ranging speech on the economy, Carney's comments were only marginally less apocalyptic than the papers would have us believe. Discussing the uneven gains enabled by advances in technology, he more or less handed tabloid sub-editors their headlines on a plate when he warned that: "Up to 15 million of the current jobs in Britain could be automated over time."

The transformative effects of automation – both positive and negative – are always an emotive topic. And there's little doubt that the technological revolution we're living through will ultimately render many human jobs redundant. Indeed, with some news outlets now experimenting with automated news-writing technology, there's an outside possibility that *The Engineer* of the future could be written by robots.

> "We should be optimistic about high-skilled opportunities created by the march of the robots"

But as we've long argued on *The Engineer,* while it would be foolish to completely ignore the risks, we should be optimistic about the high-skilled opportunities created by the march of the robots.

Take the medical advances made possible by the development of the eye surgery robot featured in this issue's cover story (p14). Currently undergoing trials in the UK at Oxford's John Radcliffe Hospital, this teleoperated technology, which enables human surgeons to operate with previously impossible levels of precision is a perfect example of how robots can advance, not extinguish human expertise.

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SPACE

# Beagle eyed: Mars lander 'did not fail'

## Simulated and real images show Beagle 2 unfurling three solar panels

STUART NATHAN REPORTS

Analysis of images of failed British spacecraft *Beagle 2*, which was believed to have been destroyed after a crash landing on Mars in 2003, suggest the mission came close to success.

Combining computer simulation with high-resolution imaging, a team from De Montfort University in Leicester has determined the lander fully unfurled at least three of its four solar panels, and may even have taken data from the Martian surface for several months, but was unable to transmit information back to Earth or receive instructions. There is even a tantalising (but very slim) chance *Beagle 2* may still be operational today.

*Beagle 2* was part of the European Space Agency's Mars Express mission and was equipped to sample the Martian surface soil and atmosphere, and analyse the samples for chemical compounds that might indicate the presence of past or current life. It was intended to transmit back to Earth on Christmas Day 2003 but no signal was received and the tiny static lander (about the diameter of a bicycle wheel) was assumed to have been destroyed and its parachute and airbag landing system deemed a failure.

In 2015, however, NASA's Mars Reconnaissance Orbiter received images from its HiRise camera that revealed *Beagle 2* was in fact intact on the surface. The news came too late for the project's principal investigator, Prof Colin Pillinger of the Open University, who had died the previous year. The images showed that not all of the four solar panels on the lander had deployed, but were not clear enough to give any more information.

The De Montfort team, led by Nick Higgett, used 3D modelling to simulate how sunlight would bounce off the panels in various states of deployment, and compared these simulations to the original HiRise images.

"In order to do this, our visualisation specialist Teodora Kuzmanova had to create a physically accurate 3D model of the *Beagle 2* Mars Lander with surfaces that would accurately reflect virtual sunlight," explained Higgett. "The angle of the sun had to be simulated along with the position of a virtual camera that could take pictures equivalent to NASA's Reconnaissance Orbiter. Finally, these images had to be pixellated to match the resolution of the Orbiter's images."

Former *Beagle 2* mission manager Mark Sims, who is now professor of astrobiology at the University of Leicester, had the idea of combining modelling with imaging to analyse reflections.

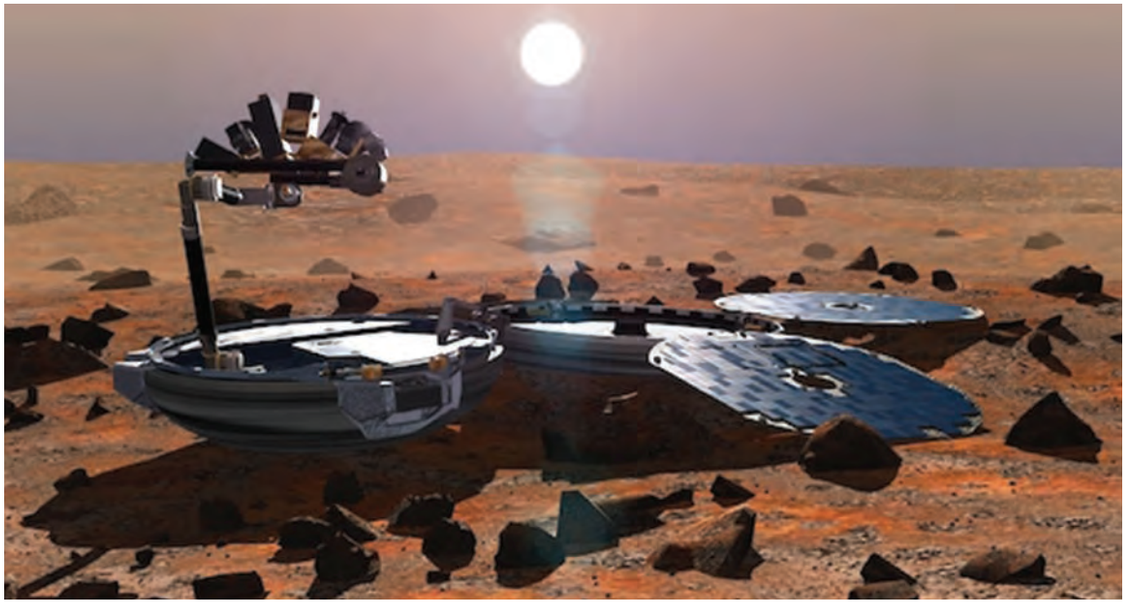
"The work shows, frustratingly, that *Beagle 2* came so close to working as intended on Mars," he said.

The closest matches between simulations and real images indicate that three panels deployed fully and the fourth may have deployed partially. The failure to communicate may have been due to the partially deployed panel obstructing the lander's antenna, or possibly to an electrical fault incurred during the rough landing.

The researchers, working with colleagues at Leicester university, believe the lander may have entered surface operation mode and, with three panels open, would have had sufficient energy to begin its pre-programmed operations and collect data. Experience of other landers suggests it may have worked for hundreds of days, but could not send any data to the orbiting Mars Express satellite.

And the longer-than-expected lifetimes of some NASA landers suggest the faint possibility – albeit dismissed by Sims, who accepts that he will never know what happened to the craft – that *Beagle 2*'s systems may still be operational.

The Beagle 2 lander, believed to have been destroyed after a crash landing on Mars



HEALTHCARE

# Implant offers hope for paralysis cases

## Chinese/Swiss research creates 'brain-spine interface' to bypass spinal injury

STUART NATHAN REPORTS

The implant bypasses the injured part of the spine

Research in China, carried out by neurologists and surgeons from the Swiss Federal Institute of Technology in Lausanne, has demonstrated an electronic implant that has helped restore leg movement in a monkey that had been paralysed by a spinal injury.

The implant works by bypassing the injured portion of the spine and sending signals directly from the brain to the intact nerves below the injury.

The researchers, led by EPFL neuroscientist Gregoire Courtine, call the implant the 'brain-spine interface'. It consists of several components and takes advantage of the fact that, even when spinal-cord injury causes paralysis, the motor sections of the brain remain intact and still produce the signals that in an uninjured vertebrate would order muscles to flex and relax. The nerves and muscles in the paralysed limb are also generally intact but unable to communicate with the brain because of the spinal injury.

"To implement the brain-spine interface, we developed an implantable, wireless system that operated in real time and enabled a primate to behave freely, without the constraints of tethered electronics," Courtine explained.

The interface has two implants: one attaches to the region of the motor cortex responsible for signals that control the leg; the other, a network of electrodes attached directly to nerve fibres, is implanted on the surface of the spinal cord in the lumbar region, beyond the lesion that caused the monkey's paralysis. The brain implant picks up the electrical signals produced by the cortex's nerve cells and transmits them to an external computer, which decodes the electrical spikes and send signals, again wirelessly, to the lumbar implant ordering the previously inactive muscles to contract. The signals are only of the order of a few volts.

"We understood how to extract brain signals that encode flexion and extension of the leg with a mathematical algorithm," Courtine said. "We then linked the decoded signals to the stimulation of specific hotspots in the spinal cord that induced the walking movement."

The experimental subject, a rhesus monkey, had a type of spinal lesion that normally self-corrects after a few months, but the team believes that the implant would also work with more severe injuries (albeit possibly requiring the use of pharmaceuticals). No physiotherapy or training was required to help the monkey; it started walking as soon as the implant was activated, according to Erwan Bezard, a neuroscientist from Bordeaux University who oversaw the experiment.

And neurosurgeon Jocelyne Bloch of Lausanne University Hospital said: "The link between the decoding of the brain and stimulation of the spinal cord is completely new."

NANOTECHNOLOGY

# Team focuses light into space of single atom

## Gold nanoparticles can create tiny optical cavity

STUART NATHAN REPORTS

Researchers from Cambridge University and the Center for Materials Physics in San Sebastian, Spain, have developed a 'magnifying glass' that can focus light down to the scale of a single atom. The invention has the potential to unlock light-catalysed chemical reactions and to be used in opto-mechanical data storage devices.

Previously, it had been deemed impossible to focus light into a spot smaller than its wavelength.

The Cambridge-led team used conductive gold nanoparticles to create an optical cavity so small that a single molecule could fit inside. Called a 'pico-cavity' by the researchers, this consisted of a bump in a gold nanostructure the size of a single atom, and confined light to a space less than a billionth of a metre across.

Constructing the pico-cavity involved building a structure with single-atom control. The team sandwiched a layer of a self-assembling organic molecule, biphenyl-4-thiol, between a film of gold and a gold nanoparticle, with the whole assembly cooled to -260°C to reduce the speed of the atoms' motion. They used lasers to move individual atoms in the nanoparticle, which also enabled them to observe the atoms' motion in real time.

"Even single gold atoms behaved like tiny ball bearings in our experiments, with conducting electrons roaming around, which is very different from the quantum life where electrons are bound to the nucleus," said project director professor Jeremy Baumberg of the Nanophotonics Centre at Cambridge's Cavendish Laboratory.

## Newsinbrief

### UK signs climate deal

The UK government has ratified the Paris Agreement on climate change, which aims to keep global warming well below 2°C. Greg Clark, secretary of state for business, energy and industrial strategy, said: "The Paris Agreement sends a clear signal that cutting emissions globally not only will help countries respond to the impact of climate change but is also compatible with economic growth."

### Remote laser cutting

A team led by OC Robotics has used remote laser-cutting technology to dismantle redundant equipment inside a nuclear facility. In August, the project cut up a steel dissolver vessel at Sellafield using a laser integrated with a highly flexible remote-controlled robot arm. The operation proved the value of laser-cutting technology, combined with robotics, for handling hazardous decommissioning tasks.

### Low-emission go-ahead

Transport secretary Chris Grayling has confirmed a £290m investment in low-emission vehicles, including cleaner buses and taxis. Less-polluting buses will be put into service and engines retrofitted to reduce nitrogen-oxide emissions. The investment is claimed as a major step towards the government's aim for nearly all cars and vans to be zero emissions by 2050.

### Simulated snow

Ford has launched an environmental test centre that can simulate scenarios from arctic snowstorms to the thin air of a mountain pass. Based in Cologne and set for operation in 2017, the multimillion-euro centre will enable engineers to work on up to nine vehicles at once, testing comfort, safety and operational capabilities.

AEROSPACE

# Supersonic flight is back on the tarmac

## US manufacturer Boom Technology works with Virgin Galactic on the project

JASON FORD REPORTS

The first independently developed and privately funded supersonic jet has been unveiled in the US.

Boom Technology's XB-1 Supersonic Demonstrator is designed to cruise at Mach 2.2 and is a one-third subscale prototype of a supersonic passenger airliner proposed by the Denver-based company.

"Concorde's designers didn't have the technology for affordable supersonic travel, but now we do," said Blake Scholl, chief executive officer and founder of Boom. "We're proud to unveil our first aircraft as we look forward to first flight late next year."

According to Boom, a subsonic flight test of the XB-1 – dubbed Baby Boom – will be conducted east of Denver and supersonic test flights will be performed near Edwards Air Force Base in Southern California, in partnership with Virgin Galactic's The Spaceship Company.

"I have long been passionate about aerospace innovation and the development of high-speed commercial flights," said Richard Branson, founder of Virgin Group. "As an innovator in the space, Virgin Galactic's decision to work with Boom was an easy one. We're excited to have an option on Boom's first 10 airframes. Through Virgin Galactic's manufacturing arm, The Spaceship Company, we will provide engineering and manufacturing services, along with flight-test support."

The XB-1 will fly with three General Electric J85-21 engines, plus avionics from Honeywell, carbon-fibre parts supplied by Tencate and composite structures fabricated by Blue Force in North Carolina. Final assembly and vehicle integration will take place at Boom's facility at Centennial Airport in Colorado.

Commenting on Boom's announcement, Kevan Kane, managing director of Technoset and member of Coventry & Warwickshire Aerospace Forum, said: "It was inevitable that supersonic flight would be revisited. They have wanted to do this since the end of Concorde.

"I am guessing that the [potential] issue would be noise pollution but, if we understand correctly, it [will fly] primarily across water, so it's not such an issue. I am sure a combination of current design methods and engine technology will overcome this problem.

"With recent global events, I am certain there would be massive demand for high-speed air travel, especially for business."


The XB-1 Supersonic Demonstrator is a one-third subscale prototype of a supersonic passenger airliner

MANUFACTURING

## LESS is more for Large Hadron Collider

### Laser-based process that modifies metal surfaces could reduce the LHC's 'electron cloud' problem

A laser-based process for modifying the surface of metals is to be used to enhance the performance of the Large Hadron Collider.

Jointly developed by researchers from Dundee University and the Science & Technology Facilities Council, the technology – dubbed LESS (Laser Engineered Surface Structures) – could increase the range of experiments possible on the LHC by helping to clear the so-called electron cloud: negative particles that can degrade the performance of the primary proton beams that circulate in the accelerator.

Current efforts to limit these effects involve applying composite metal or amorphous carbon coatings to the inner surfaces of the LHC vacuum chambers. However, these processes are expensive and time consuming.

As CERN prepares to upgrade the LHC to use proton beams that double the intensity of the current ones, it hopes to lower the electron cloud problem significantly. **JE**

MATERIALS

# Graphene adds to helmet safety and comfort

## Motorcycle helmets get Graphene Flagship input

ANDREW WADE REPORTS

Italian design company Momodesign has developed a graphene-coated motorcycle helmet claimed to both increase rider protection and enhance user comfort.

Created in partnership with the Italian Institute of Technology (IIT), the helmet is part of the EU's €1bn ($1.06bn) Graphene Flagship project, billed as Europe's biggest research initiative to date.

A graphene coating on the shell of the helmet enables better distribution of impact force, making the helmet less susceptible to damage, even in high temperatures.

"I started to read publications about graphene with curiosity and interest," said Marco Cattaneo, president of Momodesign, who claimed he was looking to "improve products in which safety is the most important aspect".

As well as safety, graphene's excellent thermal conductive properties help dissipate heat quickly across the helmet. This not only protects the inner materials from degradation caused by heat but provides a more comfortable user experience.

Application of the graphene coating takes place on an existing production line in northern Italy. Momodesign is planning an initial run of 3,000 helmets, which will be on sale at the end of the year for around £200.

The journey from concept to production took 18 months.

Andrea Ferrari, chair of the Graphene Flagship Management Panel and the Graphene Flagship's Science and Technology Officer, said: "This is an excellent example of what is at the core of the Graphene Flagship mission: to take graphene, related layered materials and hybrids from a state of raw potential to a point where they can revolutionise multiple industries, with a manifold return on the European investment, in terms of both technological innovation and economic exploitation.

"Over the next few years, we will see more and more products enabled by graphene reaching the market, thanks to the support of the Graphene Flagship project."

# PREVENTION

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MATERIALS

# GrapheneQ speaks volumes

## Graphene composite gives speakers 'better sound fidelity and battery life'

ANDREW WADE REPORTS

A Canadian start-up is developing speakers with graphene-based diaphragms that it said could greatly enhance both battery life and sound fidelity.

Based in Montreal, Ora Sound has created a proprietary nanocomposite formulation called GrapheneQ, consisting of over 95 per cent graphene combined with oxygen and other additives. According to the company, diaphragms made from GrapheneQ are compatible with existing speaker technology and deliver better frequency response and reduced distortion compared to other materials.

"Our production method will fit existing audio manufacturing processes," Ora co-founder Ari Pinkas told *The Engineer*. "Also, our method allows us to manufacture at scale.

"Ora's technology will be a fraction of the price of materials used today in high-end audio products – beryllium, CVD diamond, etcetera – while reaching the same sound-quality levels. Compared to low-end materials, it will be only slightly more expensive.

"It's also unproblematic when moulding it into different shapes such as speaker cones and domes."

Alongside improved sound fidelity, Ora claims speakers made using its lightweight graphene composite could enhance battery life by about half. With wireless speakers and headphones making up a growing share of the audio market, battery performance is increasingly important. Ora said it is in talks with some of the biggest OEMs in the audio industry.

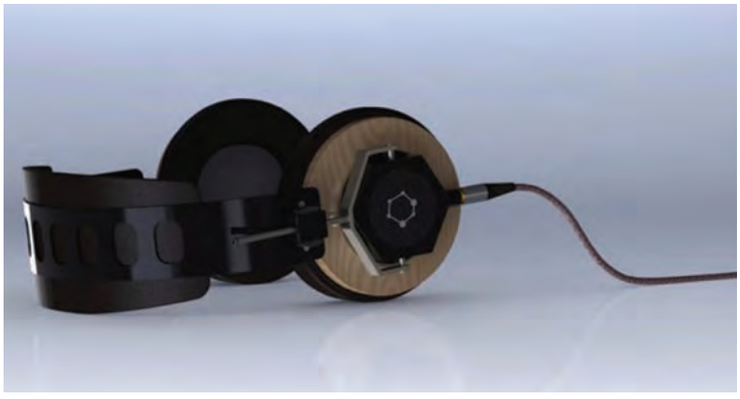
"By making theoretical calculations based on the material properties, we estimate we can consistently reduce power consumption by 40–50 per cent," said Pinkas. "While we have confidence in our calculations, we're in the process of having a third party evaluate this metric."

> "We estimate we can consistently reduce power consumption by 40–50 per cent"
>
> Ari Pinkas, Ora Sound

According to Pinkas, the promise of higher power output from a reduced footprint has also attracted the attention of smartphone companies, opening up potential in a market that shifts well over one billion units a year.

"They want smaller/louder speakers in their smartphones and tablets: something Ora can provide," he said.

The technology could be applied to speakers, smartphones and headphones



AUTOMOTIVE

## Fast-charging network

### Automotive giants team up for EV charging sites across Europe

Some of the biggest automotive names have formed a joint venture to deliver a network of ultra-fast charging sites across Europe.

BMW Group, Daimler AG, Ford Motor Company and Volkswagen Group with Audi and Porsche have signed a memorandum of understanding to create the high-powered DC charge network for electric vehicles (EVs). The infrastructure will provide power levels up to 350kW, with an initial roll-out of 400 stations beginning in 2017. According to the consortium, thousands of charge points covering continental long-distance routes should be available by 2020.

Initial rollout of 400 European sites

The network will be based on Combined Charging System standard technology, expanding the existing technical standard for AC and DC charging of EVs to the next capacity level for DC fast charging.

EVs that are capable of taking the full 350kW will be able to recharge at the stations in a fraction of the time it currently takes, regardless of brand. **AW**

NANOELECTRONICS

# Narrow carbon nanotubes alter state of water

## MIT researchers find big change in phase behaviour

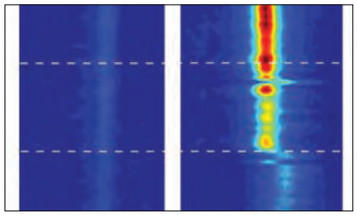
STUART NATHAN REPORTS

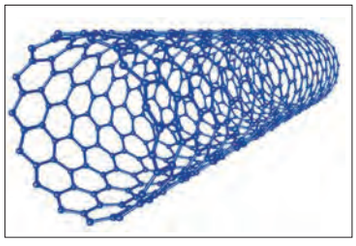
Confining water inside carbon nanotubes changes its physical properties to such an extent that it can become solid at 100°C. This discovery, while not fully understood, could lead to new advances in nanoelectronics.

It is well known that water freezes at 0°C and boils at 100°C, but these figures can change depending on the pressure exerted on the water.

Scientists have known for many years that confining water into small spaces can also change the phase-transition temperatures. However, the team at Massachusetts Institute of Technology has now discovered that, if the water is confined inside a cylindrical nanotube, these changes can be very large indeed.

According to research leader Michael Strano, the team expected to observe distortions of phase behaviour when confining water inside a nanocavity. However, they did not anticipate such a large effect, nor that the melting point would increase. In one experiment, the water was in a solid state at 105°C.





CNTs disrupt phases of water

The team used nanotubes that were extremely narrow (a little over 1nm in diameter) and open at both ends.

One unanswered question is how the water got into the nanotubes in the first place: carbon nanotubes are hydrophobic.

The state of the water inside the tube also remains a mystery. Although Rahman spectroscopy confirmed that it was solid, the researchers could not prove that it had the characteristic crystalline structure of ice.

"It's not necessarily ice, but it's an ice-like phase," Strano said.

Even very small changes in diameter caused a large difference in melting point; a +/- change of just 0.01nm raised the water's melting point by tens of degrees.

Again, the team could not explain this circumstance.

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# Fly high into our future

## The UK needs to stay ahead of the game in relation to its world-class capabilities in the aerospace sector

Without wings an aircraft simply can't get off the ground. It may sound an obvious point to make but is one worth reiterating because as a nation our capability to design and manufacture these complex and crucial structures is world class.

The challenge we face is how to keep it that way.

That's why we are constantly exploring novel wing concepts looking for the next generation of technological improvements. Much of the progress in the aerospace industry today involves incremental innovation. But we are also looking beyond that with disruptive ideas.

One of our clear drivers is performance. Future aircraft will require increased levels of performance, either improved aerodynamics or reduced weight.

So, at the heart of our work are requirements to reduce $CO_2$ output, cut fuel burn, shrink their noise footprints and hit increasingly stringent environmental targets. How might we do this?

A brilliant example is the folding wing tip. It has long been known by aerodynamicists that long, narrow wings offer a higher lift-to-drag ratio, which, in turn, improves fuel efficiency. But wings on a passenger jet are restricted in span by airport regulations. So why not try folding wing tips that could be extended before flight and then closed up again when back on the ground? It's early days but it is one idea we are experimenting with here in the UK.

A further challenge is how we go about delivering our products such as the wings against a massive growing worldwide demand for new aircraft. Our annual Global Market Forecast reveals demand for 33,000 additional passenger and cargo aircraft over the next 20 years. We have got to be able to meet that demand and deliver that product.

We can only do that by ensuring we deliver the technologies that can meet the rate requirement (how many aircraft are produced each month and year); the cost requirement (how expensive they are for us and our suppliers to design and build, as well as for the ultimate customer to buy); and the performance requirement (how these machines operate). In short, our wings and other vital components such as fuel systems and landing gear will have to be built faster, be cheaper and be easier to make and assemble.

That kind of initiative can only come with more spending on research and development to explore these new ideas.

Airbus currently invests around £400m on R&D in the UK each year. We are working with the Aerospace Technology Institute (ATI) on a wide range of projects covering our three prime areas of wing, landing gear and fuel systems. The ATI and the Aerospace Growth Partnership between government and industry means we have a strong financial foundation.

Our new cutting-edge wing integration centre is about to be built at Filton thanks to an investment of some £40m and will benefit Airbus, our suppliers and other partners. It is set to feature a range of modular equipment that enables several complex tests to be carried out at the same time.

A step change in automated production is coming to our factories too.

Some elements of robot-assisted assembly are necessary and desirable. But many improvements are primarily driven by the need to develop our highly skilled workforce, which today are increasingly more like data analysts rather than people who simply fasten pieces of metal together. They need a more sophisticated understanding of the data being generated and the technology being assembled.

Britain's powerful aerospace business has benefited hugely from the Aerospace Growth Partnership, which has brought together industry and government. The previous administration refreshed strategy around this vital component of UK plc and Theresa May's renewed enthusiasm for industry is to be welcomed.

A clear strategy around aerospace technology will provide us with an ability to improve the way we currently work with universities and other partners further down our supply chain to ensure we can deliver the right technologies at the right time for the future. Success, therefore, must be founded on collaboration. At a time of intense international competition, dynamic innovation and the greater mobility of skilled engineers, Britain must stay ahead of the game to maintain our position as the world's second-largest aerospace country.

At Airbus we call our work on all of this the 'wing of the future'.

It is to the future that the whole industry must look if we are to succeed


> "A clear strategy around aerospace technology will provide us with an ability to improve the way we work with partners"
> Mark Howard

Airbus currently invests around £400m on R&D in the UK each year

**Mark Howard is head of UK R&T business development and partnerships at Airbus**

# Mailbox

## Thehottopic

## Autonomous pros and cons

### Disruptive technology on the roads is still the source of much controversy on the part of readers

Let's be clear and frank about autonomous vehicles. How many people actually want them? Not me or any of my family or friends. The seriously dangerous fact is that certain organisations have been pushing such capabilities because they view it as an extremely profitable niche market in the short term. The really big concern for me and many others is that the recent fatal crash with a Tesla self-driving car and other incidents only go to prove that there is no way that such autonomous vehicles can cater for all the various use-case scenarios encountered on modern roads. I only wish OEMs, manufacturers and so on would realise that I and others are not prepared to pay for any vehicle containing such capabilities – we don't want it! Finally, at what point are manufacturers going to accept liability for failures in their product and face legal action, lawsuits and so on?
**Ian**

As an engineer and also a professional driver a thought has just occurred to me. How does a driverless car respond to being given way to or give way to someone else, as is often done as a courtesy across junctions, crossings and so on? How does such a concept work on single-track roads when either or both vehicles have to reverse and manoeuvre together? Can it recognise when the vehicle it confronts is less able to manoeuvre or reverse (perhaps it has a trailer or is larger)?
**Nick Cole**

I would suggest that car makers get the basic product right before they launch into further (unnecessary) complications such as 'driverless' cars. Things such as making the doors fit and seal to keep the rain out, ditto the windows. I don't think it's unreasonable to expect this on (even) the cheaper end of the car market; but it seems many makers still can't get this right.
**Graham Field**

Perhaps those persons commenting here should listen as I do to the radio traffic reports. If they did, they would realise just how much disruption is caused daily on major roads and motorways by 'accidents' caused by human drivers. While I agree that it is presently unreasonable to expect an automobile AI system to deal with off-road and single-track country lanes, it is obvious to me that autonomous vehicles on major routes will soon be a necessity, in order to prevent total gridlock.
**Tony Marshallsay**

Don't underestimate the ability of this disruptive technology – why would you own a vehicle if you could just pay a fee for it to turn up when you need it? And why not configure it with soft top, 4×4, load-carrying and dog-mover options?
**WynO**

This could be very disruptive. Why pay for parking when it might be cheaper to just let the car drive round in circles all day? Or just send it home. Or park it miles away. I can see a future with lots of empty cars clogging up the roads.
**Jonathan Bowen**

## Inyouropinion

### Come together

#### Our regular online poll asked for readers' views on the challenges of collaboration

The temptation to pick the 'low hanging fruit' is too hard to resist for most academic institutions. When facing choices, look for the well-funded team, not the project.
**Alex Vari**

Remove the opportunity for academic prima donnas to get into the team or, if they must be there, appoint a product champion who has absolute authority to over-ride all attempts to de-rail progress (there will be many). Get the customer(s) onside early: and keep them there. Watch out for patent agents seeking to cream off the profits. Failing this, find the individual with the most knowledge, lock him/her in a room and don't let them out until they have produced at least 'back-of-an-envelope' drawings and so on.
**Mike Blamey**

A very, very senior CEO recently told me that the big mistake that companies make is that they do not put enough 'people-effort' into the industry side of the equation. I'll save the full details for something I am working on but, in essence, too many companies think that they can put in one person's effort in return for 100 people's output. In most projects, IP is red herring.
**Michael Kenward**

I have worked on several collaborative products involving big players in the automotive industry, and on every project the biggest problem was sharing information, as each 'partner' wanted to put in the minimum and take out the maximum. Company loyalties always overcame the team loyalties of the people working on the projects. After all, who paid their wages?
**20 Cent**

How to organise and coordinate the product development, and the commercialisation of research and radical inventions involving universities, industry partners, government organisations and other public organisations – this is the biggest problem.
**Vinod Rajan**

**Join the debate theengineer.co.uk**

# Thesecretengineer

## Our anonymous blogger considers the huge challenge of attracting and inspiring the next generation of engineers

I have previously made references to various high-profile projects and engineering in the media, generally based around my own views and what I find interesting.

Such egocentric musings would probably be frowned upon in the wider world but, assuming these jottings actually have a remit, I am required to reflect the thoughts and feelings of 'one of you'.

As such I must initially look to myself as a vaguely representative source of the raw data. Whether I actually count as 'typical' regarding the members of our profession isn't for me to say. Certainly, as one would expect, I do not speak for all. The advantage though is that it invokes debate and, I hope, interest.

Although I generally try to pick up on the *topic dejour* or reflect on a matter that has recently arisen at work, it is useful to try to fine tune the process with first-hand feedback. Thus I lurk in the ethereal halls of *The Engineer*'s website and try to gauge the atmosphere.

From this I have noted that there seems to be a sharp divide regarding inspiration for taking up engineering, not only for those of us already within the profession but also for what should be promoted to encourage the next generation.

This seems to be a reoccurring topic, although not directly addressed by me before. As with pay and status though – all the time it remains as a significant area of discontent it is difficult to avoid.

For the reasons given above, my start point has to be 'what drew me into engineering?'. The answer being the Moon landings, Concorde, Thrust 2, the Space Shuttle, turbocharged Formula One cars and so on. A historical hinterland of past exploits along similar lines reinforced this with, to my eyes, exotically dangerous machines achieving great things in the hands of heroes and heroines. The high speed and high-octane power excited from an early age and has never left.

I have been fortunate, given this, to have been involved in the design of various machines that have something of these qualities to them; although a large part of my career has been involved with the altogether more mundane.

That doesn't matter though, as it is merely the hook and all the time I am able to work there is the hope that one day I will be a part of a team that writes as large in the history books as those I idolise. Through hard work and application, inspiration becomes realistic aspiration.

If I try to look wider from my own personal view, I wonder if the current generation of iPhones inspire in the same way? I have never felt anything but cold ambivalence for such devices and even the many who get extraordinarily excited about them seem to be so purely because of size and application – rather than how it is achieved or the reality of the technical advance it represents.

What too of the more philanthropic endeavours? I deeply admire and respect those who seek to bring water to the poorest areas of our world, or who devote their lives to improved prosthetics. In fact, I would be immensely proud if I had any involvement in these or a thousand similar projects. The problem is, it just doesn't excite me.

Is any of this important? I think it is because if anything is to be done about the perennial problem of attracting teenagers, and young women, into engineering then a dialogue needs to be started. Bemoaning the state of our profession is fine but it achieves nothing. Engineering is a calling and if we are to attract new blood then we need to understand what draws us into it. If the question is "what inspires people to be an engineer", then surely the best person to answer is an engineer?

# Robot surgery is easy on the eye

**The real-world R2-D2 has a much more important job than its fictional namesake: maintaining and restoring the eyesight of human beings.** Stuart Nathan reports

Everybody knows R2-D2. Such is the success of the *Star Wars* films that even those with no interest whatsoever in science fiction would recognise the little cylindrical robot on its three legs. They might even know that its stubby body houses a number of delicate manipulators for interfacing with external computers, and carrying out precise tasks. But they might be surprised to find that fiction has begun to leak into reality, because there is now a real R2-D2 that is designed to carry out the most precise tasks. And although the characters in *Star Wars* trust R2-D2 implicitly, the people who come into contact with its real-world namesake will have to invest an even greater amount of trust in it, because this robot's job is to maintain and even restore the sense most precious to human beings: eyesight.

The real-world R2-D2 is a series of trials being carried out by a surgical robot, the Preceyes surgical system (PSS) but unlike its fictional counterpart this is no clamp-handed humanoid looming over an operating table. Instead, the PSS is a tool intended to assist human surgeons in difficult and arduous procedures. Surgical-assistance robots such as this are a relatively recent addition to the operating theatre, as they are very expensive and not yet in particularly widespread use, but in some fields of surgery they are becoming more accepted and better known. In *The Engineer*, for example, we have written about the da Vinci robot, which is used particularly for minimally invasive abdominal surgery and increasingly for heart valve replacement. There are a little over 3,000 da Vinci robots in operation around the world.

Like da Vinci, PSS is a tele-operation robot: that is to say it has robotic arms tipped with mechanical manipulators that grasp surgical instruments and carry out the actual procedure; these are controlled by the surgeon using a joystick pad somewhat similar to those used in video games, with software intermediating between the control pad and the manipulators. The reason for this is to improve the precision of the movements of the surgical instruments and to impart a stability that is impossible for a human to maintain throughout the course of an arduous and intricate surgical procedure.

The PSS has been developed by Dutch company Preceyes, and is being tested and further developed for specific applications in the R2-D2 (an abbreviation for Robotic Retinal Dissection Device) trial, a long-term programme being carried out at the John Radcliffe Hospital in Oxford and in collaboration with Oxford University's Nuffield Laboratory of Ophthalmology. The trial, which consists of 12 operations, began this year with the first surgery taking place in September. The first phase of the trial, comprising six surgeries, is now complete. Phase two will begin in mid-2017.

**01** Prof Maarten Steinbuch, technical advisor at Preceyes

The first surgery, which we reported in *The Engineer*, involved the removal of a membrane around 100µm thick, which had grown over the retina of a 70-year-old man, distorting it and affecting his eyesight. This surgery, the first to be carried out by a robot inside the eye, was performed through a 1mm incision, and the surgical instruments had to be removed and reinserted into this incision several times throughout the surgery, even though, as the patient was under local anaesthetic and conscious throughout, his eyes were moving.

Prof Robert MacLaren, the surgeon in charge of the trials at the John Radcliffe, told *The Engineer* that the other surgeries in phase one were similar and also included repair of macular holes: tiny holes and tears that can appear in the retina with ageing. Repairing these also involves manipulating membranes on a very small scale inside the eye. Even though ophthalmic surgeons tend to be among the most dextrous of individuals, this type of surgery is extremely difficult because the movements needed inside the eye need to be both precise and controlled. Any hand tremor needs to be eliminated, and surgeons learn to slow their pulse and make the movements needed for the surgery


between beats to make sure that there is little chance of even the slightest deviation. The advantage of using the PSS for the surgery is that the intermediary software between joystick and manipulator eliminates those tremors and ensures the movements of surgical instruments are absolutely steady.

"It's really quite an odd experience at first," said MacLaren. "I could compare it to driving a car, and then switching to controlling it using your smartphone rather than using the wheel and pedals. In theory, of course, you know it would work perfectly well, but when you actually do it, because you've been doing it manually for so long and you're suddenly relying on computer assistance to help you, it just feels a bit strange. But to go back to the car analogy, you would find that the ride is smoother, you're going round corners with more stability and there are generally less bumps, and you find that you're more comfortable with it. As I got more experience with the robotic system it became much more natural. It's certainly been a most positive experience or I wouldn't have used it, and I've used it several times now."

**02** The PSS help surgeons operate with a stability that's impossible for humans to maintain

The Preceyes surgical system was initially developed as a collaboration between a mechatronics specialist and an eye surgeon. Gerrit Naus, chief operating officer of Preceyes, explained: "[Eye surgeon] Prof Marc de Smet, who is now our chief medical officer, was professor at Amsterdam Medical Centre, and he met [mechatronics specialist] Prof Maarten Steinbuch, who is a professor at Eindhoven University of Technology and is now also our technical adviser, and they together wrote a project proposal that was granted to build such a robot. The actual research project started about 10 years ago. Then, in 2012, we decided to build a company to fight blindness, and as part of that goal we wanted to take this proof of principle to a proof of concept that we could test in a clinical setting; that's how we have spent the last four to five years, to develop this actual clinical device that has been tested extensively in our labs

"I could compare it to driving a car, and then switching to controlling it using your smartphone rather than using the wheel and pedals"

Prof Robert MacLaren

and is in use right now in Oxford. It's an important milestone towards our goal."

The link with Prof MacLaren started when Preceyes won an innovation award at a major ophthalmology conference and exhibition in 2014, and MacLaren came second with his proposal to use gene therapy to treat eye disorders. "Of course our team already knew him," Naus said. "But that was a good point to start discussions. He said: 'I'm doing this gene therapy trial, but it's very difficult by hand and maybe you can help me.' Within a couple of months he had visited our laboratory and was very impressed, and a few months after that we had a contract with a company called Nightstar, which is developing a gene therapy."

Gene therapy is very suited to robotic surgery in this case, MacLaren explained, because of the stability issue. "The very best ophthalmic surgeons can maybe hold an instrument perfectly still inside the eye for about a minute," he said. "But after that, your back starts to hurt and you get achey and uncomfortable, and you are naturally going to start to get a bit of a wobble in the instrument. In gene therapy, we want to lift the retina in a controlled way and deliver the active ingredient by injecting it in a very slow way over perhaps 20 minutes. The robot will give us that stability; not just in the precise movements but also in being able to keep absolutely still."

Moreover, there is a definite need for gene therapies in ophthalmic conditions. Nightstar, the company with which Preceyes is collaborating, is developing a therapy for a disease called choroideremia, an inherited condition in which the light-sensitive cells of the retina degenerate. Inserting a correct version of the gene responsible could help to restore vision. Other eye disorders, also believed to be caused by faulty genes and currently with no treatment, are under investigation for gene therapy. "Right now, gene therapy is not an established therapeutic procedure," Naus said, "so there are many life science companies that are working on this, and other types of drug-delivery procedures. Surgeons need support administering these drugs at high reproducibility. We are helping them to get the drugs and the right dosage to the right target."

In fact, it could be said that the existence of the robots such as the PSS is a key reason that these targeted drug-delivery therapies are being developed at all. Naus said it's not so black and white, but added that Preceyes sees it as a beachhead into general ophthalmic surgery.

**03**

**04**

**03** Prof Robert MacLaren is in charge of the R2-D2 trials in Oxford

**04** The robot's arm and manipulator are controlled by seven motors

Naus is reluctant to reveal many technical details about the robot, but its arm and manipulator hand are controlled by seven motors within the body of the robot. One important difference from machines such as da Vinci is that the surgeon is at the site of the operation and not in a remote room. MacLaren added that this would not be practical for ophthalmic surgery in any case. "You could probably do it, but I certainly wouldn't want to," he said. "When the patient is under local anaesthetic and conscious, you need to talk to them during the operation to put them at ease, relax them and calm them down. Eye surgery is quite a scary thing to undergo. I often tell my residents [junior surgeons] and assistants that most of the anaesthetic my patients need comes out of my mouth. I don't think you'd want the robot just sitting there above the patient with a needle; there's a human factor that you really must not neglect."

Among the systems incorporated into the PSS to help the surgeon is an ability to switch quickly between assisted surgery and manual, and a function to scale the movement of the manipulator inside the eye. "When you're in the eye, you want to move very, very slowly. You would maybe want the manipulator to move a hundredth of the distance that you move the joystick, but when you're outside the eye you want to get away very fast, so the computer will change the scale," Naus said. MacLaren confirmed that this scaling is invaluable during surgery. He also found a movement limiter to be very useful. "When you first go into the eye, and using the scaled movement you reach a point beyond which you do not want the instrument to go, you press a button on the console and that sets a hard limit so when you go back in you can't move beyond that point. You don't feel any resistance on the joystick, but that doesn't matter because you are always within a safe limit."

> "Surgeons need support administering these [gene therapy] drugs at high reproducibility. We are helping them get to the right target"
>
> Gerrit Naus

Previous studies with other types of surgical robot have shown a correlation between surgical ability and frequent playing of computer games. Naus is quick to point out that the robot console is not a gamepad but has been specifically designed for this kind of surgery. MacLaren admits to playing PlayStation games with his children, but he didn't think that this experience was much help. "But eye surgeons tend to have very good manual dexterity. Some of my senior colleagues do watchmaking, and painting and sculpture is common," he said. "I think generally being used to operating inside the eye is probably a much more relevant thing."

However, MacLaren does admit that other parts of the system have similarities with computer gaming. For example, he uses virtual reality when observing the operating site through a head-up display connected to a microscope, which also displays additional graphics to assist with the operation. "We do need those extra optics," he said.

Phase one of the R2-D2 trial was mainly aimed at proving that PSS was safe to use in eye surgery and that it did assist the surgeon in carrying out his or her task. In phase two, MacLaren's team will be injecting therapeutic agents (drugs in this case, not gene therapy) under patients' retinas. "It's a fairly simple procedure, and we are used to doing it, but it will pave the way for the more difficult gene therapy technique," MacLaren said.

# Worth its weight in light

**Gravity is key to an invention that could replace dangerous kerosene lamps in the developing world.** Andrew Wade reports

When Jim Reeves was approached in 2009 to design a solar lantern for the developing world, he soon clocked that the concept was flawed.

"We quickly realised that the batteries and the solar panel contributed a fixed 60-70 per cent of the cost of micro-solar products," he told *The Engineer*. "So we started to question the premise of using batteries to store power."

Not only was the battery the first thing to fail, it was also the most expensive component, and not easily replaceable. On top of this, at the end of its life it would generally end up in landfill, adding to an already substantial environmental footprint.

Reeves and design partner Martin Riddiford knew that to hit the solar brief they would need to use lower-quality components, compromising the integrity of the product. Instead, they explored other ways to provide off-grid light that could replace the expensive and dangerous kerosene lamps still used by billions of people around the world. As with Newton's apple, a simple answer eventually fell to them.

Harnessing one of the universe's primary forces, GravityLight uses the kinetic energy from a 12kg bag of rocks or sand to drive a dynamo, which in turn powers an LED bulb. The brightness is six times that of a kerosene lamp, and each time the bag is raised, 20 minutes of light is produced.

"The progress that's been made over recent years in the efficiency of LED lighting technology started to bring the power required into the realm where simply raising a bag of rocks or locally found material could provide you with an energy reservoir that was a viable source of power," Reeves explained.

"The sort of elegance and simplicity of raising a bag of locally found weight had such appeal, because you're providing a fabric bag as the means to enable that mass to be coupled with the product."

The GravityLight Foundation has already received funding of £200,000 from Innovate UK, with additional support coming via the Shell Springboard programme. In October it was backed by Siemens Stiftung, the charitable arm of the German multinational that promotes sustainable social development.

Perhaps most impressively, £400,000 of early funding was raised through crowd-funding site Indiegogo, with GravityLight hitting its initial target in just four days. This helped finance a global field trial, with a first run of 7,500 units distributed across 26 countries, as well as among Indiegogo investors.

"We learnt vast amounts from that trial," said Reeves. "It showed up some incredibly surprising aspects and issues."

The team had assumed people would want to adjust the brightness in exchange for duration, and provided three settings as a result. But it found users had little interest in this, with lights invariably remaining on the same setting as when delivered.

"Learning that it wasn't a required function, we eliminated the feature," Reeves explained. "It was several parts, it was potential points of failure, it was complexity, and was simply not needed as a feature set."

Unsurprisingly, it was also found that children enjoyed swinging from the bag, so durability had to be improved. But overall the trial was a major success, with 90 per cent of users saying they would replace kerosene lamps with GravityLight if they could.

That first iteration required the user to pick the bag off the ground and physically lift it with their hands. This led to an unorthodox use pattern, with periodic darkness when the bag was being raised, and the height and strength required also creating a barrier for young, elderly, or disabled users. GravityLight 2.0 addressed this by introducing a pulley mechanism, which delivers persistent light.

"It does three things really," said Reeves. "It means the strength of the user is no longer coupled to the amount of energy they can deliver. We've given a mechanical advantage, so you pull down with a couple of kilos and you raise 12.

"We've decoupled the height issue, because it means if you're of lesser height you can pull on the cord and raise the weight far above your head. And, as a result, we're able to keep the light on continuously. So as long as you interact with GravityLight for about 30 seconds an hour, you'll keep that bag off the ground and have uninterrupted light for as many hours as you want into the evening."

01

Being aware that most off-grid households don't have access to scales, GravityLight essentially measures the weight for you. Small packets are provided with the kit, then filled with material and placed in the bag. When the maximum weight is exceeded, the light glows bright red. Removing one packet leaves the bag at optimum weight, with the LED operating at peak efficiency.

"The LED dictates the duration in combination with the gear train and generator, and the brightness is driven higher and higher the greater the weight, which is the other reason why you need to indicate when you've overloaded," said Reeves.

As well as providing light, the system can be used to charge AA or AAA batteries. The foundation is exploring the possibility of phone charging too, but the power requirements of smartphones mean this may not be practical with GravityLight. Power from the central dynamo can also be shared among up to four SatLights, auxiliary lamps that can be linked to form a mini home-lighting system.

"You can daisy chain these SatLights, and you share the brightness across the number of lights you have switched on at any time," Reeves said. "And there are other appropriate applications that are within that sort of power envelope. One of them is FM radio, which is used extensively across rural Asia and the developing world for delivering education. Coupled with the ability to provide lighting, you've really taken a big step towards enabling education."

GravityLight's power mechanism makes it suitable for emergency, as well as off-grid lighting, according to Reeves.

"One of the things we've come to learn over this journey is just how broad the application for GravityLight is… after Hurricane Sandy I think here were over eight million people in [the US] without power for a fortnight."

For now, however, the developing world remains the top priority. Having sized up the possibility of manufacturing in Africa, the team realised the infrastructure and supply chain were not quite mature enough. As a result, production is taking place in China, with assembly located just outside Nairobi, Kenya.

02

**01** TASK lighting is vital for enabling education in the developing world

**02** Advances in LED efficiency mean light can be generated with a relatively low power output

**03** Jim Reeves is co-founder and technical director of The GravityLight Foundation

"With GravityLight, assembly is the bulk of the creation of employment, and has relatively low investment and infrastructure required for an assembly line," said Reeves.

"We can control quality of materials and components at source, and explore the viability of assembling products locally, and if that can be made to work it's a model that could be replicated and rolled out in other markets where there's a need for GravityLight."

The product is being introduced across Kenya as part of a 50-stop roadshow. It's a country where 80 per cent of people don't have access to electricity, and where kerosene lamps are adversely impacting the health and finances of millions of people. By 2018 it's hoped that around 100,000 people will be using the technology, with gravity helping to light virtually every corner of the globe.

03

# New means of production

**Additive manufacturing guru on its shift from a mere method of prototyping to the production mainstream.** Jason Ford reports

Businesses that fail to engage with additive manufacturing will also fail to reap its benefits. If reading this line gives you a sense of déjà vu then don't worry, you read it before in High Value Manufacturing Catapult chief Dick Elsy's piece on additive manufacturing (AM) in the October 2016 edition of *The Engineer*.

In his article, Elsy talked about how leading figures from UK industry were joining up with academia and government to establish the UK Additive Manufacturing Steering Group, which is working towards the publication of a UK National Additive Manufacturing Strategy in 2017.

Similarly, if you've noticed a correlation between this author and a certain additive and rapid prototyping machine manufacturer and solutions provider based in the US then you would be right, but then there are very good reasons for Stratasys to have featured throughout 2016.

The company that introduced fused deposition modelling (FDM) in 1988 has evolved, with advances in technology and materials that have gradually taken additive from a successful method of prototyping to the point of being a means of production, be it for tooling, jigs and fixtures or for production parts.

The link between Elsy's piece and Stratasys can be found in the genial form of Dr Phil Reeves, vice-president of Stratasys Strategic Consulting.

With over two decades of experience in advanced manufacturing, Reeves founded and was the managing director of Econolyst, an AM and 3D printing consultancy and research firm that was acquired by Stratasys in 2015 and slotted straight into the US company's Services Group to provide the foundation of the Strategic Consulting Division.

Stratasys currently holds over 800 patents and has an R&D budget of just under US$100m. Econolyst's remit is to help businesses and organisations understand and utilise AM, and to do so in a technologically agnostic way.

Like Elsy, Reeves is keen to see a wider adoption of AM but is equally well aware of the reasons why there may be reluctance to do so.

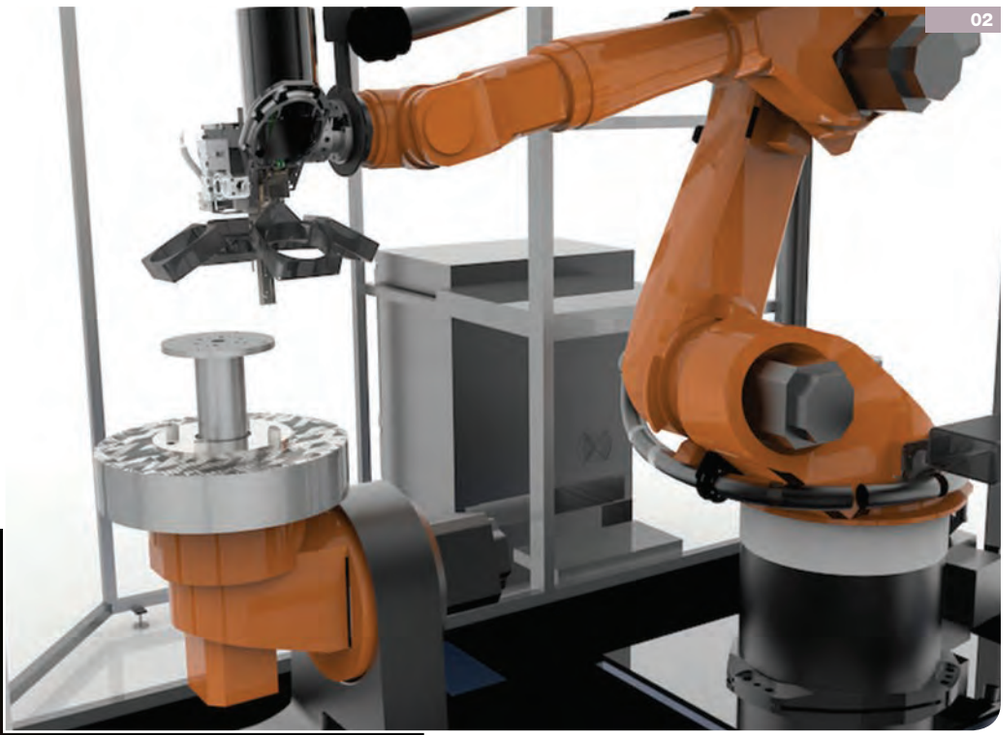
"You have to find a business application," said Reeves. "AM is not a technology that replaces existing technologies; you can't just shoehorn it in to replace moulding, machining or casting. You have to find some business benefit, some gain for the flexibility the technology gives you and I think that's where a lot of companies get really stuck."

01

"Additive manufacturing is not a technology that replaces existing technologies; you can't just shoehorn it in to replace moulding, machining or casting"

Another issue around implementation, said Reeves, surrounds the changing of fundamental practices in the day-to-day running of a business.

"To get the most out of AM you're going to change your process, you're probably going to change your raw material and you're probably going to change your design," he said. "All of a sudden you have changed all three basics and that is a real sticking point, I think, and that's where companies really struggle."



02

**01** United Launch Alliance uses ULTEM 9085 FDM thermoplastic in its rockets

**02** Stratasys worked with Siemens to develop a robotic composite 3D demonstrator

## CareerCV

### Dr Phil Reeves
Vice-president, Stratasys Strategic Consulting

**Education**

**1994–1998** Nottingham University Phd, manufacturing engineering
**1992–1994** B.Eng Prod (Hons) product design, Brunel University

**Career**

**Feb 2015 to present** vice-president, Stratasys Strategic Consulting
**April 2004–Feb 2015** Managing director, Econolyst Ltd
**June 1999 to April 2004** CEO, Engineering Forum
**May 1997 to April 1998** Senior research engineer, Innovative Manufacturing Centre

There is, said Reeves, the added factor of companies looking to their peers to see who makes the first move into AM as they'd prefer to be seen at the leading edge instead of the bleeding edge.

Remaining at the leading edge is a priority for Stratasys, which has recognised the need to diversify its offering and identify use cases that will help companies thrive with AM, a strategy that will require a good deal of collaboration between the company and stakeholders. According to Reeves, this means taking a machine, a material, software, process parameters and the business case, and wrapping it up as a potential solution for different industries.

"Take medical as a really good example [and] the idea of making medical models. Historically we were thinking – and other vendors were thinking – we'll just sell these machines to hospitals and they'll plug them into their scanners and print pre-medical planning models, and all will be fine in the world, but that's not the case," he said. "The surgeons want the model, they don't care about the technology. What they want is a robust, slick infrastructure to go from scan to model to operation. We've had to think: what is the package? It is servitisation, it's not 'here's hardware'. It's 'here's a solution'. That's where we're going, and, at the moment, we've got our aerospace, our automotive, medical, our tooling, jigs and fixtures, injection moulding, and now we're looking at how we expand that portfolio of vertical service offerings. What's the next area we go into... and what package does that industry need?"

As noted throughout 2016, Stratasys has been busy collaborating with Siemens and Kuka on the Robotic Composite 3D Demonstrator, but the company is no stranger to collaborative projects having worked – among others – with Boeing on the Fortus 900, and United Launch Alliance in implementing ULTEM on rocket components. For the latter project, ULA used Stratasys technology to develop enhanced, low-cost production tooling and reduce production costs for the Atlas V and Delta IV rockets' flight hardware. They did so by introducing the ULTEM 9085 FDM thermoplastic into its rocket design for the Environmental Control System duct system to replace metal pipes, which reduced the production cost by 57 per cent and took assembly from over 140 to 16 production parts.

With the same collaborative spirit, Reeves will now go to companies to identify constraints on the shop floor that can be overcome with AM. Helping Reeves along the way are strategic corporate acquisitions that include Interfacial Solutions, the company that developed Stratasys' polymers.

"We brought them in house, so we can turn around to the guys at what we now call Stratasys Advanced Materials and say: these are the properties and parameters I need of a material. Now, can you develop it, blend it, process it into filament, put it into machines – get the characterisation and settings on the machine – and get it back to me as a package because that's what the client wants? I don't know of any other company that has that in house."

Reeves added that for large OEMS that practise lean principles, optimised 3D printing for tooling can shave seconds off a production process, making the ROI into additive very favourable. This, however, will not be the case for a number of companies that are put off by costs incurred at the front end of the design process.

Reeves concluded: "The limitation is design tools and design data, that's what's stopping people... you need design software tools flexible enough to design around the benefits of additive – so honeycomb structures, topological optimisation, skeletal structures – there aren't many tools that do that, and certainly the workflow is very difficult. Yes, you can put things into an optimisation package but then you've got to take them out and put them into a CAD package, and then you've got to take them out and put them in a FEA package. That is an expensive and time-consuming process and that puts a lot of companies off.

"The other thing is data. In order to do that analysis and drive that front-end design we need credible material process data. It's only been in the past five years that anyone in our industry thought [that] we need to actually invest in the creation of robust data to drive the design process, so that's [also] constraining. It's about having the toolsets and having the data. Once we have them then I think the whole design community will embrace additive."

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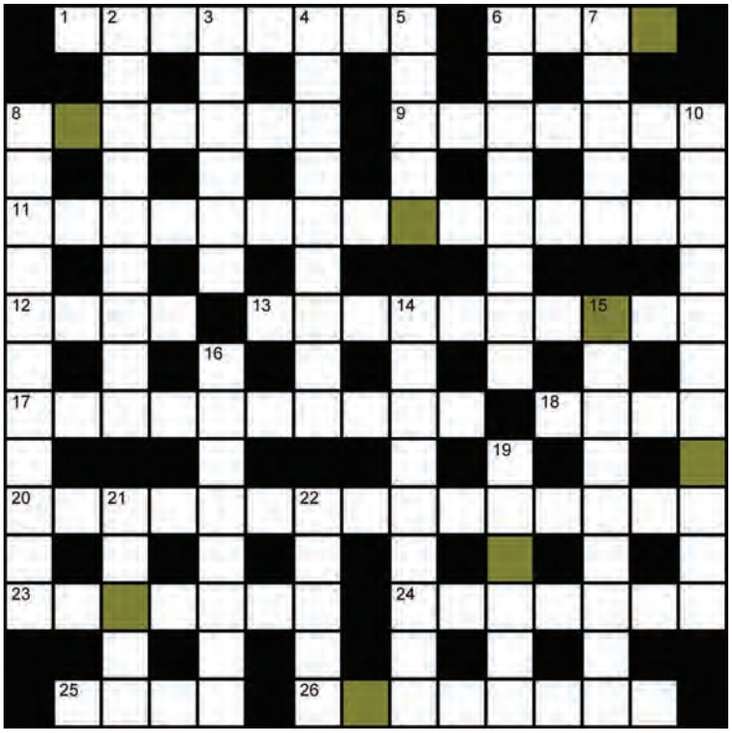
## Word of the issue

### Anthony Poulton-Smith explores the origins of the word ‘nut’

Having looked at the story behind the bolt recently, it seemed remiss of me not to look at the nut, which invariably accompanies same. It will come as absolutely no surprise to discover that initially the engineering nut was compared to the hard seed and its shell. Thus the term comes from the Proto-Germanic hnut and earlier from Proto-Indo-European kneu, the latter also being the origin of the Latin nux, which has come to us as ‘nucleus’ and thus ultimately ‘nuclear’. As the mating part for the bolt, the earliest record dates from 1610. Yet the term had been used for any small mechanical part for at least two centuries and thus the earliest ‘nut’ could have been any of the items heard today being described as a ‘widget’.

# Big picture

The radioactive remains of Chernobyl’s Reactor 4 have been safely enclosed after moving the plant’s New Safe Confinement (NSC) over a distance of 327m from its assembly point to its final resting place. The NSC completely encloses a previous makeshift shelter that was assembled immediately after the 1986 accident.



## Prize crossword

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

**Across**

1 Accidental discharges of fluid (8)
6 Social worker’s patient (4)
8 Compartment where a pilot sits (7)
9 Cord to hold whistle (7)
11 Path of a moving object that will lead to an accident (9,6)
12 After the expected time (4)
13 Made worse (10)
17 Unit of power equal to 746 watts (10)
18 Group of three (4)
20 Withdrawing from active service (15)
23 Protective structure along the coast (7)
24 Playing in opposition to (7)
25 In this place (4)
26 An obstruction that stands in the way (8)

**Down**

2 Moving staircase (9)
3 Caused to stay indoors (4,2)
4 Reaching a goal (7,2)
5 Beautician’s establishment (5)
6 Curl or twist together (8)
7 A series of steps (5)
8 British colonial financier and statesman in South Africa (5,6)
10 Battleship with similar big guns (11)
14 Resistors for regulating current (9)
15 Of a twisting force (9)
16 Spread or diffuse through (8)
19 Musical composition of three or four movements (6)
21 Wooden box (5)
22 Eskimo house (5)

Last issue’s highlighted solution was armature. Winner: **Christian Matthewson**

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Dec 1914

# Armour all at sea

## Diving armour resembles something from the mind of a slightly unhinged science fiction illustrator

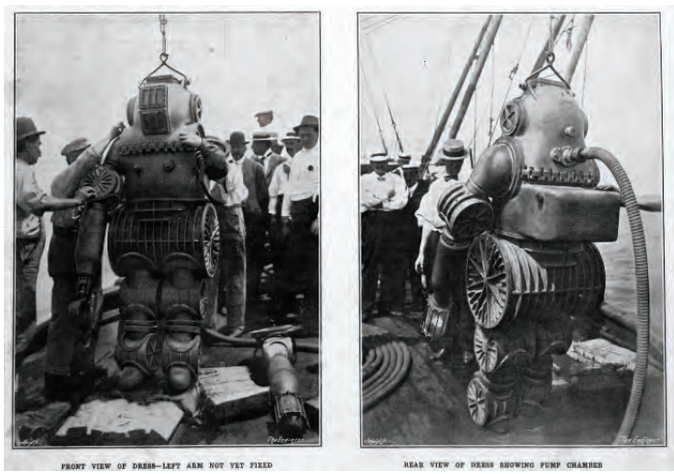
On the same edition of *The Engineer* as a report of the sinking of the German naval cruisers *Scharnhorst* and *Gneisenau* in the battle of the Falkland Islands, there is a page showing photographs of a most unearthly looking outfit. Resembling something from the mind of a slightly unhinged illustrator of the golden age of science fiction, it could be one of those endearingly blobby robots that threatened square-jawed heroes in 1950s B-movies. But, in fact, it's an early incarnation of an armoured suit to allow divers to work at great depths on salvage projects without having to undergo lengthy decompression and protecting them from the crushing pressure of deep water.

Designed by US inventor Chester E McDuffee, the suit was made from what is described as "an aluminium alloy of great strength, the composition being a trade secret". It weighed a total of 480lb when empty, but because of its displacement was extremely buoyant, and required an additional 115lb of lead in order to make it sink. Characterised by very large barrel-shaped hinges at the waist, knees, ankles and elbows, the suit looked extremely cumbersome but, according to *The Engineer*, allowed the user a great deal of movement while underwater. "The operators have declared that they were not hampered in walking freely on the bottom or in bending or moving their arms," the article said.

Prior to this, deep-sea diving had been done using flexible suits with a rigid helmet. However, the practical depth limit for such equipment was about 90ft and, because the air supply had to be provided at pressure, divers had to undergo decompression stops as they surfaced that could be longer than the time they spent at the bottom; this greatly increased the cost of deep-sea operations and led to the five-year research effort to develop the McDuffee suit.

The article related a test of the suit involving an experienced diver who had previously used flexible suits. He had since left the navy and, as is common with ex-servicemen, had put on some weight. The article said he weighed 214lb "and was what might properly be called stout". Despite this, he descended to 212ft in less than a minute, remained at that depth for 20 minutes and then was brought up "on the run" in less time than the trip down. He was taken out of the armour as soon as he was back on deck. "He was in his normal condition and regretful only that it was necessary to bring him up so soon" so that another diver could have a chance to test the equipment, the article recorded.

The armoured diving suit, seen here, was made from "an aluminium alloy of great strength"




The speed of ascent and immediate recovery was thanks to the rigid nature of the suit, which could withstand the pressure of water at the sea bottom without any need for high-pressure air, as would be necessary for a flexible suit. This meant that the diver could breathe air inside the suit at surface pressure, therefore eliminating the need for decompression during surfacing. Air was supplied via an armoured hose connecting the suit to the service ship at the surface, which also contained electrical cables: these powered the diver's intercom system and a removable hand-lamp.

The second trial was not without problems. Just after the diver was encased in the armour, the compressor overheated and the supply hose had to be reconnected to a smaller unit. This took about an hour, during which time the diver was in the armour in full sunlight and had to be cooled down with a water hose. During this time, the leather packing for the joints began to dry out. Nobody noticed this, and once the new compressor was working, the diver was lowered into the water. When he reached a 100ft depth, the compressor failed and was out of action for nearly five minutes, with the poor diver dangling unsupported. He breathed the free air in his suit, and was not inconvenienced, the report said. Once the compressor was reactivated he began descending again. Unfortunately, the joint packing had shrunk when it dried out, and once he reached 212ft, the suit started leaking. The water had reached his waist when he used the intercom to request to be brought back to the surface. By the time he came back to the top, all the excess water had drained out. *The Engineer* saw this as a positive. "It is easy to imagine what would happen to a diver in the elastic dress had the air pumps failed him at a depth of 100ft and his supply cut off for five minutes," it said.

The right arm was equipped with a mechanical hand; the left being fitted with a lamp or a hook. The hand was dexterous enough for the diver to be able to pick up a thin sheet of paper from a flat surface. It was sufficient for the tasks that a diver would be expected to perform at depth. "In regular salvage work the diver encased in the McDuffee armour would not be expected to tie knots or do anything of a kindred character," it said. **SN**

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