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Behind the scenes

Restoring London's last music hall

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Archive feature

The cabling of the Golden Gate Bridge was a source of much fascination in the summer of 1936

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this**issue**

Volume 297
Issue No.7878
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news

opinion

features

our**opinion**

Mixed signals

It's been a tempestuous few weeks for *The Engineer*, as we try to interpret the mixed signals about the future of the Hinkley Point project (see p14), take in what may be the birth of medical neuroelectrical engineering with the news of GlaxoSmithKline's tie-up with Google parent Alphabet and, as we close this issue, marvel at the narrow escape of the passengers and crew of the Boeing 777 that crashed at Dubai Airport.

Meanwhile, the uncertainty about the UK's proposed exit from the European Union continues to reverberate, although there are some indications that overseas companies will continue to put their trust in the UK's workforce.

As is traditional in this online issue for our August hiatus between print editions, we're aiming to bring you something slightly different. Our interview gives readers a glimpse into the near future, with electronic devices that incorporate paper as a functional and structural component. Its inventors, Portuguese couple Elvira Fortunato and Rodrigo Martins, believe it could enable a new generation of recyclable, disposable functionality such as solar-powered food packaging that senses when its contents are safe to eat and informs the consumer accordingly, and 'intelligent' ticketing that updates itself.

In our cover feature (p16), we take a look at the remarkable survival of one of the UK's architectural gems, Wilton's Music Hall in London's East End, and the innovative civil engineering project that has rendered it safe and gave it 21st century facilities, while retaining the tumbledown appearance that contributes so much to its unique atmosphere.

> "Future electronic devices could incorporate paper as a functional and structural component"

Of course, we also bring you our usual news coverage and columns.

Our print issue returns in September with a cover feature that will explain how the aerospace sector is contributing to the thrilling ocean races of the Americas Cup, and learning more about its own technologies in the process.

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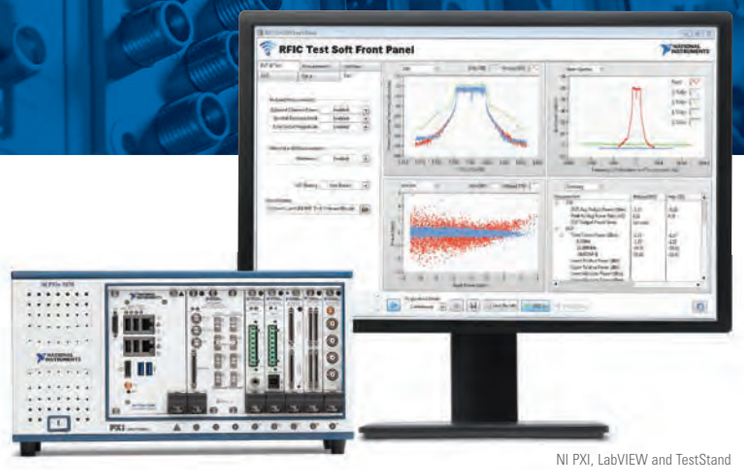

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Couriers tool up to map London air pollution

AEROSPACE

Rocket into orbit around Jupiter

Uk-built liquid-fuelled rocket engine involved in solar exploration mission

STUART NATHAN REPORTS

A Leros-1b liquid-fuelled rocket engine made by Moog-ISP has been pivotal in placing Juno, NASA's solar system exploration mission, into orbit around Jupiter.

The British-made rocket, one of the most crucial components of the orbital insertion manoeuvre, worked perfectly despite the ferocious radiation levels close to Jupiter.

The spacecraft can now begin a series of observations of the conditions below the planet's cloud systems and into the interior structure of the solar system's largest planet.

The Juno mission is designed in part to test theories about the early history of the solar system: it is believed by some that Jupiter originally formed much closer to, or further away from the Sun, and gradually moved to its current orbit. Juno carries eight instruments that will look down onto the planet from its orbit, which is designed to avoid the highest radiation regions of Jupiter, and measure its gravity; the abundance of oxygen and hence water in its composition; its magnetic fields; and determine the composition of its atmosphere and lower layers. It will also take the closest images of Jupiter yet obtained when it moves into a smaller orbit in October, a few thousand kilometres above the top of its atmosphere. The water levels are key to determining where the planet – believed to be the oldest in the solar system – formed.

The orbital insertion depended on the main engine of the 20m-diameter spacecraft, a Leros-1b rocket engine made by Moog-ISP of Westcott in Bucks. Leros-1b has a history dating back to the Mercury missions of the late 1950s and early 1960s.

The Leros-1b is an apogee engine, which fires at the point in a spacecraft's elliptical orbit when it is furthest from the planet, bringing its orbit closer to the planet. It's most typically used on geostationary communications satellites to change the shape of their orbits from elliptical to circular, generating 635N of thrust.

The engine is essentially an off-the-shelf item, said Ian Coxhill, Moog-ISP's chief engineer, although each engine is tuned for the specific thrust required for its mission and fitted with certain critical components to ensure it can meet its requirements. Moog builds about four Leros engines per year, mainly for commercial telecommunications satellites, although it has developed a variant version for ESA missions and is looking at a further development using different propellants to obtain twice the thrust, Coxhill added.

The engine has already played one crucial role in Juno's mission in 2012, when it put the spacecraft in 'slingshot' orbit around the Earth, using its gravity to set it on its course to Jupiter. On 5 July 2015 it fired again, under the control of a pre-programmed system, to brake the spacecraft to place it into orbit. The engine had to burn for precisely 35 minutes; any error and Juno would have skipped off Jupiter's atmosphere into deep space. There were concerns that intense radiation could have interfered with Juno's electronics, but its vital components are shielded behind titanium.

"It seems to have performed perfectly," said Coxhill. "We're told there was only 0.3 per cent difference between the predicted performance and the result."

The Juno mission is designed in part to test theories about the history of the solar system

MANUFACTURING

Forging partnership for nuclear SMRs

Sheffield Forgemasters collaborates with US small nuclear reactor specialist

STUART NATHAN REPORTS

Forging the trial reactor pressure vessel head

Image: courtesy of Sheffield Forgemasters

Sheffield Forgemasters is to work with US small modular nuclear reactor (SMR) specialist NuScale Power to develop manufacturing techniques for its reactor technology.

The two companies have announced that Forgemasters is to make a trial reactor vessel head for NuScale's SMR design by the end of 2017, as part of a £4m project funded by Innovate UK.

NuScale's technology is based around 50MW reactors (around 5 per cent of the generating capacity of a typical civil reactor) that are intended to be deployed singly or in clusters of up to 12 units. The advantage of this technology is that the reactors are designed to be made on production lines in factories, more cheaply and efficiently than the huge facilities required for conventional reactors.

The reactor head component is a forging about 2.75m in diameter and weighing around 9.5 tonnes. None of the NuScale SMR reactors have yet been made, although the company said that it is pursuing the development of a first plant in Idaho; and NuScale is working closely with Forgemasters on the geometries that the reactor head, which houses the system that operate the control rods that moderate the nuclear reaction and the outlets for the steam generators, will require.

Forgemasters has expertise in techniques such as near-net forging, where the approximate shape of a complex component is made by shaping it over a die before it is machined to its precise shape. This is in contrast to the way that conventional reactor heads are made, where the steam generator outlet pipes are typically forged separately from the main domed 'lid' of the reactor and attached using highly specialised welding techniques to ensure a completely flawless joint.

"Sheffield Forgemasters' skill, expertise and heritage is known the world over," said Tom Mundy, NuScale's managing director for the UK and Europe, speaking at a conference on the so-called 'Northern Powerhouse' strategy. "Working together now is, I hope, the starting point of a lasting relationship that will ultimately see UK-manufactured SMRs generating clean reliable power for the UK grid by the 2020s."

For Forgemasters, chief executive Graham Honeyman said: "NuScale's design is one of the most advanced in the world and this forging project will allow us to prove yet again that UK manufacturing is at the leading edge of global technological advancement.

"The efficient factory manufacture of major components [for SMRs] will be crucial to seeing them deployed cost-effectively and Sheffield Forgemasters has an unparalleled track record in the production of civil nuclear forgings of this size."

EDUCATION

Planning for an engineering life after GCSEs

Post-16 standards to be set by professionals

JON EXCELL REPORTS

The government has unveiled plans to create new post-GCSE options that are designed to encourage more young people to consider a career in engineering.

Based on recommendations made by a panel led by Lord Sainsbury, the proposed reforms have been hailed by the Royal Academy of Engineering as the most significant transformation of post-16 education since A-levels were introduced 70 years ago.

Lord Sainsbury's review found that young people considering a technical education today must choose between more than 20,000 courses provided by 160 different organisations. A young person pursuing an engineering career has a choice of 501 different courses.

The review recommends simplifying the current system so that technical education is provided through 15 routes, with standards set by industry professionals. Acting on the review, the government has published a Post-16 Skills Plan that pledges to implement all of the Sainsbury panel's proposals where budgets allow.

The plan will enable students to choose whether to take technical or academic qualifications after their GCSEs. Those opting for a technical route will be able to choose between a two-year college course – with standards and content led by employers – or an apprenticeship.

Paul Jackson, chief executive of Engineering UK, said the proposed introduction of a 'transition year' to give young people the opportunity to focus on bringing their skills in key areas up to the required standard is particularly welcome.

Newsinbrief

World stage

Solar Impulse 2 (Si2) has concluded its 17-stage circumnavigation of the world with a successful landing in Abu Dhabi. Piloted by Bertrand Piccard and André Borschberg, Si2 broke 19 world records, including the longest solar-powered flight and, for Borschberg, the longest uninterrupted solo flight for a 118-hour leg between Japan and Hawaii.

Vacuum of space

UK researchers will be able to test and develop space propulsion technologies at a new National Propulsion Test Facility. The UK Space Agency is investing £4.12m in the new facility in Westcott, Bucks. Government funding will help create a new vacuum facility at the Westcott propulsion test site. When used with rocket-firing test cells, this will allow the simulation of high-altitude testing of thrusters.

Taking orders

Organisers of the Farnborough International Airshow have confirmed that the five-day trade exhibition generated orders and options worth $124bn. FIA16's internal order tracker recorded a total of 856 aircraft valued at $94bn, 1,407 engines worth $23bn and other deals totalling £7bn. Virgin Atlantic concluded the acquisition of 12 Airbus A350-1000s.

Lacking confidence

Manufacturers' business confidence has been shaken following the June referendum on Britain's membership of the EU. This is the conclusion of a report from EEF and BDO, which shows every region in England and Wales suffering a decline in optimism, with the biggest falls seen in the South East and London and Wales.

ROBOTICS

Going the last mile for Londoners

Fleet of autonomous delivery robots begins trials in Greenwich

ANDREW WADE REPORTS

London's streets will soon be home to a fleet of the world's first autonomous delivery robots, as Starship Technologies begins trials in Greenwich.

Established by Skype co-founders Ahti Heinla and Janus Friis, Starship has been testing its six-wheeled robots across 40 cities since the end of last year, clocking up about 5,000 miles without incident. The next phase of the programme will see the company team up with partners including Just Eat and Hermes to begin 'last-mile' deliveries of food, groceries, and parcels.

Travelling on paths at approximately 4mph, the battery-powered robots are designed to operate in a two- to three-mile radius. They mainly use off-the-shelf components that include GPS and a nine-camera computer vision suite, all overseen by proprietary software. The robots map their surroundings as they travel, with the level of autonomy increasing the more time they spend in a designated delivery area.

"The robot will be operating in a neighbourhood, say nine square miles," said Henry Harris-Burland, Starship's marketing and communications manager. "In order for the robot to drive autonomously within that neighbourhood it would have to map the area. It uses computer vision to do that, meaning it analyses straight lines from its nine cameras, and it's analysing thousands of lines every second, which builds a 3D map of the environment around it. After it's built that map it can then operate autonomously in that neighbourhood."

According to Starship, the goal is to achieve 99 per cent autonomy, with one human overseeing 100 robots. If a robot gets into a situation where intervention is required, the operator can step in and take control remotely.

"We don't actually want 100 per cent autonomous driving," said Harris-Burland. "We always want a human overseeing the robot and its journey, and intercepting if needed."

> "We always want a human overseeing the robot and its journey"
>
> Henry Harris-Burland, Starship

The robots are also equipped with a sensor suite for obstacle detection, allowing them to navigate around pedestrians. Under normal circumstances, while travelling on pathways, this 'situational awareness' bubble extends to about 7–10m.

The robots will have to map the area to drive autonomously

AEROSPACE

Delivery by drone

Amazon set to test component elements of its UAV Prime Air delivery service

Online retailer Amazon will begin testing its delivery drones in Britain after receiving permission from a cross-government team, including the UK Civil Aviation Authority (CAA).

The agreement gives Amazon a green light to trial three components for its Prime Air delivery service: beyond line-of-sight operations in rural and suburban areas; sensor performance for obstacle identification and avoidance; and flights where one operator oversees multiple autonomous drones.

"This announcement strengthens our partnership with the UK and brings Amazon closer to our goal of using drones to safely deliver parcels in 30 minutes to customers in the UK and elsewhere around the world," said Paul Misener, Amazon's vice-president of global innovation policy and communications.

Amazon's fleet of unmanned aerial vehicles (UAVs) will weigh around 25kg each and be capable of delivering packages weighing roughly 2kg. **AW**

The UAVs will deliver 2kg packages

CARBON CAPTURE

Counting costs of competition scrappage

Report suggests big delay in UK's CCS deployment

STUART NATHAN REPORTS

The government's decision to scrap the UK's carbon capture and storage (CCS) technology development competition could increase the cost of meeting the country's carbon emissions targets by 2050 by £30bn, according to a report from the National Audit Office.

The competition was scrapped in former Chancellor George Osborne's autumn Spending Review last December. Work on the two competing projects, White Rose in Yorkshire and Peterhead in Scotland, both ceased before their final designs were submitted.

The National Audit Office (NAO) prepared the report as part of a briefing for the Environmental Audit Commission. It said that cancelling the competition would delay CCS deployment in the UK by a decade, and that the Treasury and DECC failed to quantify the cost of this delay.

The NAO also warned that the decision was likely to reduce the confidence of investors in government technology schemes in future. The cancellation of the competition means that there is "no viable way to achieve deep emissions reductions from the industrial sector in the near future", the report concludes.

CCS technology has been put on hold

CCS Association chief executive Luke Warren said that the move will increase energy bills. The Energy Technologies Institute has shown that a 10-year delay to CCS could add £1–2bn to consumers' bills every year throughout the 2020s.

Scottish Carbon Capture and Storage (SCCS) said that the cancellation revealed a "baffling" lack of foresight and coordination between government departments.

"After the Paris COP21 climate agreement for advanced economies to become zero-carbon by 2050, it is clear that CCS is unavoidable," said Prof Stuart Haszeldine, SCCS director. "CCS has immense value across an entire economy. It is not about expensive electricity, it is about the sustainable use of fossil-fuel wealth."

ROBOTICS

Rats are all heart for fish-like robot

Development seen as stepping stone towards biomechanical human heart

STUART NATHAN REPORTS

Researchers from Harvard University have made a biomechanical fish-like robot whose metallic skeleton supports living muscle cells.

The robot, whose development is seen as a stepping-stone towards engineering a biomechanical human heart, is comprised of a silicone skin enclosing cells cultured from rat hearts, with a gold support structure.

Research leader Kevin Kit Parker has been building biomechanical hybrid structures for some years, after initial work on growing films of heart muscle cells on silicone films. His first was a jellyfish-like 'medusoid' in which the cells were induced to contact using an electric current, forcing the cup-shaped silicone structure to contract and expel some water. Moving to stingrays, the latest project incorporates some genetic engineering into the mix too.

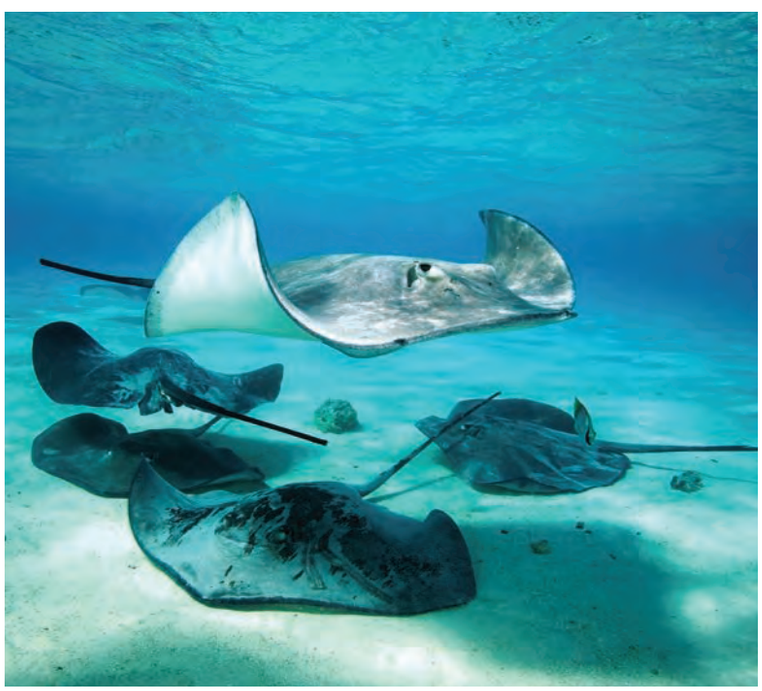
> "The cells only deflect the fin in one direction, with the spring action of the skeleton returning it to its original shape"

Using data gathered by another team studying how stingrays' muscles are arranged, Parker devised a springy gold skeleton as a support structure, and embedded a template of the protein fibronectin into a silicone sheet shaped like a very small ray (a tenth of the size of a living juvenile ray).

This template encouraged 200,000 cells taken from the hearts of embryonic rats to grow in a pattern radiating from the skeleton to the edge of the ray shape's fins. The team then infected the cells with a virus designed to implant a gene into the cell that would make them contract in response to the light of a blue laser. Another sheet of silicone completes the assembly.

Immersed in a bath of warmed nutrient solution, the robot is made to 'swim' by directing a laser onto each fin. Changing the frequency of the light speeds up the cells' contraction rate, allowing the robot's builder, post-doctoral student Sung-Jin Park, to steer it around the tank and through an obstacle course. The cells only deflect the fin in one direction, with the spring action of the skeleton returning it to its original shape; this simplifies the real ray's muscle structure, which has two muscle layers to control the fins' rippling motion. The research is described in a paper in the journal *Science*.

Parker is now turning his attention to a new biohybrid, whose nature he has not yet revealed, but his true goal is the bioengineered heart, he said.



The team studied how stingrays' muscles are arranged

MANUFACTURING

Production takes its medicine

Pharmaceutical company set to receive £92m to fund aseptic sterile facility in County Durham

GSK is investing £275m at three of its UK manufacturing sites to increase production and support delivery of respiratory and large molecule biological medicines.

The pharmaceutical company's site at Barnard Castle in County Durham is to receive £92m to fund the construction of an aseptic sterile facility that will support the manufacture of existing and new biopharmaceutical assets in GSK's pipeline.

Approximately £110m will provide a new facility for the manufacture of respiratory active ingredients in Montrose, Scotland, where the GSK manufactures active ingredients for respiratory, HIV and vaccine products.

In Ware, Herts, £74m will support further expansion of the company's new Ellipta respiratory inhaler through additional manufacturing capacity at the site.

With approximately 6,000 staff across nine sites, GSK said it views the UK as an attractive location for investment in advanced manufacturing due to factors. **JF**

MEDICAL

Project offers material impact on brain issues

Implant allows lasers to be used in diagnostics

STUART NATHAN REPORTS

People suffering from brain disorders could gain some benefit from a material implanted into the skull that allows lasers to be used in diagnostics and therapy without causing adverse immune responses.

Based on a ceramic that is used in bone implants, the transparent material has been developed at the University of California at Riverside as part of the international Window on the Brain project, which is developing a system by which therapy can be applied to the brain without the need for repeated craniotomies: operations that involve the removal of part of the skull.

The Window on the Brain project is intended to help improve the care of people with brain tumours, stroke damage, and neurodegenerative disorders. Rather than performing a craniotomy to directly access brain tissue, the idea is to place a single transparent implant of a rigid material that can still perform the skull's protective function but allow laser energy to be used to selectively heat tissue as part of a therapy programme, to destroy diseased or cancerous tissue, or cauterise damaged blood vessels.

The UC Riverside team developed a nanocrystalline, transparent form of yttria-stabilised zirconia and implanted it into the skull of a hamster, where, as they report in a recent paper in the journal *Nanomedicine*, it fused with the living tissue and caused no immune response.

The zirconia mineral is more impact-resistant and biocompatible than titanium, thermoplastic polymers and glass-based materials that have been developed by other members of the Window on the Brain consortium, making it "the only implant material that could conceivably be used in humans", the researchers claim.

The UC Riverside team worked on a series of laser-based diagnostics in order to measure white-blood-cell adhesion to the material implant, blood-vessel size and blood-flow rate directly from the living brain tissue with no ill-effects.

Succeed with flying colours

The South West's aerospace cluster offers some pertinent lessons for success that Brexit should not be allowed to obscure

The South West of the UK is being hailed as the second-largest aerospace cluster and aerospace manufacturer in the world after the US. Therefore, all eyes were on the recent Farnborough International Airshow in July 2016 as an indicator of how the news of Brexit may affect orders from overseas.

Despite rain stopping play a few times this year, Farnborough International Airshow 2016 weathered the storm and had an incredibly successful year, with the orders and options for aircraft, engines and supply-chain orders confirmed totalling US$124bn, with 70 per cent of those orders coming from outside the UK.

The companies I spoke to at the show had a positive outlook for the longer term as well, and two intermediaries, whose role it is to identify potential direct foreign investment into Britain, said since Brexit they have seen an increase in requests to look at the UK for investment.

Why is this and how do we encourage and maintain it? The keys to the success of the South West are its diversity, technical know-how and world-leading talent pool. Look at the make-up of the cluster here: there is the National Composite Centre that can design and rapidly manufacture composite technologies producing lightweight and strong state-of-the-art materials, pushing the limits of how aircraft can perform; computer modelling and simulation experts CFMS who can aid with the design of sophisticated new aircraft; Airbus's closed-circuit, low-speed wind tunnel, which is used for everything from real-world aircraft product development to Formula One aerodynamic applications; Bristol Robotics Lab, which specialises in autonomous and robotic systems; and the latest advances in virtual reality (VR) technology coming out of Bristol & Bath, allowing virtual training and testing to be completed in a safe and cost-effective environment (and one that doesn't disrupt an airline's normal operations).

It's little wonder that all 15 international aerospace giants, including Airbus, GKN Aerospace and Rolls-Royce, operate in the Bristol and Bath region. And this focus on cutting-edge research and development shows no sign of slowing. Take Airbus, which is building a VR suite and hi-tech wing development facility here. Put it all together and this aerospace powerhouse, which is the largest in Europe, provides 59,000 jobs for its skilled workforce and is worth more than £7bn.

So how do we grow this success post-Brexit? By doing what we've always done: innovating at every point along the aerospace supply chain and joining these companies up in a network that provides engineering excellence; and then building on it. To succeed we need to think not just of the end product or single things, but also about what the South West offers along the whole production chain.

> "We need to think not just of the end product, but also what the South West offers along the whole production chain"
> Barry Warburton

To help with this mission to stay ahead, local industries, along with the public sector, have developed iAero – a collaboration between the region's leading aerospace players to deliver a regional platform for innovation and growth. iAero is unique to the UK and it has been developed to offer an interconnected approach to innovation, R&D, skills and supply-chain development. The South West is leading on initiatives such as this, and we need to build on this form of cooperation to ensure the success of a long-term strategic approach to South West aerospace capability development.

We also need to capitalise on the fact that Brexit has the potential to open up new markets that aren't restricted by EU agreements. Aerospace has always been global, so it's important we look at the world stage and retain our focus on delivering tech-driven solutions to the problems that are facing the aircraft of the future.

Farnborough International Airshow is an advert for the UK aerospace industry, and it's a great one. Now, we need to keep demonstrating the collaborative nature of the region's business community, where interlinked sectors work together to develop new innovations and open up opportunities in new markets, to keep attracting those investors who service the global market, but do business from the UK. This is an opportunity we can't afford to pass up, and one that Brexit should not impede.

The Farnborough International Airshow had an incredibly successful year

Barry Warburton is aerospace and advanced engineering sector specialist at Invest Bristol & Bath

Keeping pace with a digital revolution

We lack the engineers with the necessary skills to stay in step with the opportunities and demands of the digital revolution

"It is vital for the health of the UK economy that young people develop digital and engineering skills"

Paul Jackson

Developments in engineering have a wide impact across the economy, particularly when it comes to digital skills, which link into all business areas. Employers are reliant on digital capabilities and workplaces need to keep pace with continued technological advances, in which the UK plays a leading role on the European stage.

Whatever the impact of leaving the European Union (and EngineeringUK is part of the joint work to provide evidence-based advice to government to help secure the best possible outcome for the UK and UK engineering), digital skills are essential for the future of the UK economy. Whether it is data management, electronic payments, interactive apps or 3D printing, businesses of all sizes benefit from such developments, but understanding and accessing those technologies can prove challenging, particularly for smaller companies with limited budgets.

Interestingly, Barclays now has a large-scale programme that supports its customers, giving them the opportunity to learn about new technologies, helping to leverage data and innovation. Its Eagle Labs, supported by Digital Eagles, presents an approach to corporate social responsibility that is quite different from much of what we see elsewhere in that it offers its customers access to technologies and facilities that many larger businesses take for granted.

We are on the brink of a digital manufacturing revolution but – and this is despite a younger generation of digital natives – we lack the engineers with the necessary digital skills. Cyber security is another key area where digital skills aren't confined to digital industries but are a concern for individuals and industry alike. When it comes to digital, we need to boost skills across the UK. Barclays is looking to reach one million users of its digital driving licence by the end of the year and I hope that linking in with the Tomorrow's Engineers programme will help reach that target.

The recent Shadbolt review looked at computer science degrees and made some very sensible recommendations. One of the major difficulties with the pace of digital and technological advances is the feasibility of integrating the latest developments into undergraduate degrees. There seems to be some consensus among employers I speak to that the most logical way to develop these skills in young workers is via advanced apprenticeships, but that has its own set of challenges, which will only be overcome through more industry collaboration.

It is vital for the future health of the UK economy that young people in sufficient numbers develop the digital and engineering skills that employers need. That requires a concerted effort from across the community to work together to ensure those young people understand and are excited by the prospects in engineering.

To that end, Tomorrow's Engineers Week (7–11 November) aims to shine a spotlight on engineering careers in a way that young people, particularly girls, may have never considered before. I hope you and your company will get involved in some way. Could you feature as a media case study or make a short video about your job and sector? Maybe you'd be interested in answering schoolchildren's questions on how engineers solve problems? We want everyone in engineering to be involved. What will you do?

Paul Jackson
Chief executive EngineeringUK

Cyber security is a key area where the necessary digital skills are a concern for businesses and individuals alike

Mailbox

Thehottopic

Arguing the Point

The decision to postpone a decision on Hinkley Point C sparked an impassioned debate

Like many others within our profession (who, from their blogged comments are well-informed and competent), I once again have to shake my head in disbelief at what I see as the complete failure of our apparent leaders and betters among the great and good to deal with anything with a strong 'technology' content other than disastrously. Perhaps the most frightening comment is that the main components cannot be fabricated here as there are no facilities large enough or qualified to use IAEA-approved techniques. Can one imagine the stink if it was found that we can no longer manufacture nuclear submarine parts? I can already see the 'disgusted of Tunbridge Wells' admirals lining up to castigate a situation where life as we know it is no longer possible.
Michael Blamey

I for one am pleased about the delay in the hope that the government is finally looking at cheaper, perhaps more efficient reactors. The government would be taking a huge risk committing to the most expensive reactor ever built, the first of this type and completely untested anywhere else. There are also safety issues that other reactors just don't have. There has been much talk of other reactor types being offered to the UK, as well as the UK designing and building our own. Yes, a lot of experience has left the industry in the fallow years, but I'm sure a lot of them would return given the opportunity, the right encouragement and the idea that it might help to put the UK back into the top echelons of reactor-building countries. We must not get panicked into choosing the wrong route because of the possible threat of the 'lights going out'.
Mike Libman

Just like Mike Libman, I am also pleased the prime minister has intervened. To farm out such infrastructure in this manner is ludicrous and to look further ahead to possible new reactors at Sizewell and Bradwell built under similar schemes is basically giving foreign powers a gun to hold against the nation's head. We've built nuclear power stations before, why shouldn't we build them now? We could use a tried-and-tested design, and not be reliant on dubious foreign 'investment'. The prime minister and chancellor previously both held positions relating to national security, and must have had information to which George Osborne was not privy, although his sycophancy would have probably swept any 'inconvenient' facts under the carpet. We're not going to save our economy by contracting everything out to foreign consortia, and this talk of thousands of jobs being created is only verisimilitude – people employed in the construction will probably already be in that industry, and many of those would invariably be economic migrants. Jobs aren't suddenly created because somebody wants to build something – people move where the work is, just as the canals, railways and motorways were built by itinerant navvies. Hinkley C is a bad deal all round for the country. Build a couple of coal-fired plants (fuelled with British coal) to tide us over, then build some nuclear plants indigenously. It's that simple.
Phil Stannard

British nuclear engineering must be in a sorry state when we need to go cap in hand to the French and Chinese to design and build us a nuclear power plant. No doubt if it goes ahead it will also be operated by engineers from these countries so we won't need to worry about our lack of skills. Unlike the UK, France is desperate to maintain and develop its nuclear engineering skills base so this station is vital to them. I understand that the agreed strike price is £93 per kWh, which is three times the current rate. It will cost future generations a fortune to keep their lights on with all the profits going to France and China, and all to satisfy the government's climate policy. There are also national security issues that will need to be resolved. If we need nuclear power surely small modular reactors designed and made in the UK is the way to go.
David

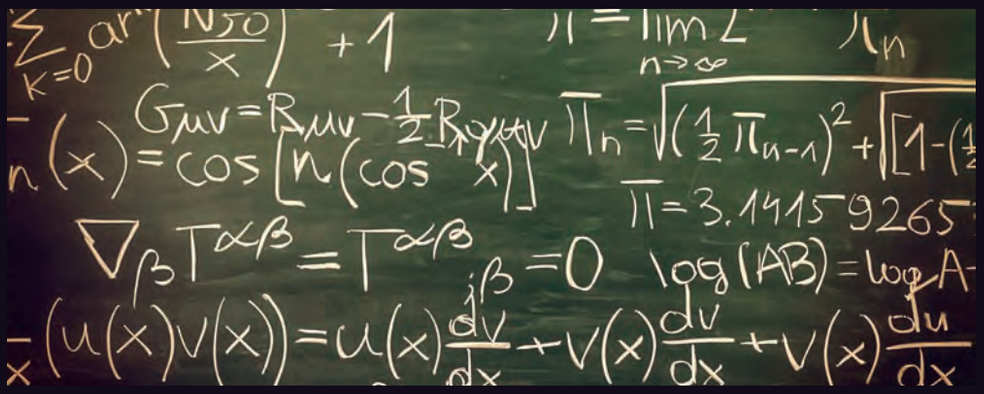
Building Hinkley C in its present form and cost is foolish. The proposed design does not work and is taking too long to build. Stop building new designs. Copy Sizewell B or the double version Sizewell C. The design works and exists.
M Trundle

It will be such a bad decision if this goes ahead. From the so-called investment 'in Britain', I bet 90 per cent of that figure won't even touch Britain's shores. Thirty-thousand jobs – not in Britain, but perhaps in France. Britain really has the talent and engineering capability to go for renewables, which is the ultimate end game. Let us skip the nuclear farce. What happens if everyone dumps EDF as a power provider? Will the public still have to pay for it? This would be another good subject to put to the vote by the public. Such public scrutiny might render the whole fog-bound farce much more visible. I am sure the public will make the right decision like it did with Brexit.
R Annett

The costs involved with an untried technology and risk of potential delays (isn't a similar French reactor being built in Finland way behind schedule and way over budget?) with a single monolithic machine seem daunting. As mentioned by others, small modular 50MW reactors that are plug and play have got to be the way to go. Also, thorium has been mentioned, which was a really promising and far superior technology to uranium largely pushed by British scientists. It was ditched decades ago because of the weapons requirements of the Cold War. If we are to have a renaissance in the British nuclear industry let's buy in the modular reactors to get us out of a hole and then move to thorium, which is more widely available and with fewer radioactive waste products.
Julian

Thesecretengineer

Our anonymous blogger questions the quality of a modern engineering education



Summer is here, the sun has shone for at least two days in a row, mittens and scarves have finally been discarded, and engineering students are looking for 'fill-in' jobs to help provide beer money during the holiday. Thus my mind turns to a fresh-faced hopeful who briefly joined me a year ago to help out with general drawing work.

Sam came to us after completing his first year of an engineering design degree at Red Brick University PLC, backing this up with a strong initial showing in design technology at school. Bright and personable, willing to put the time in and make the effort, Sam was all right. However, when he started to take on small work packages, the wheels soon fell off the wagon.

I admit that I was basing my expectations on my dim memory of college courses in the past, but even so I was not prepared for the stunning lack of knowledge regarding what I consider to be the fundamental basics of engineering. Sam's response after I had spoon-fed him yet another nugget of information would invariably be that he had not been educated regarding this particular aspect before. Personally, I have no reason to doubt him and felt he had been let down by the educational establishment.

To pick one example, I was startled to hear that he had no idea about standardisation of fasteners. I am not talking about keeping the number of different fasteners for any given product down to a minimum. Rather it was literally the concept of there being a set number of thread types and sizes readily available, from which to choose the one best suited for any given application. I have wracked my brain to try to remember when I first became aware of this and to be fair it was probably around age 14 when I started messing about with cars. Even given such extra-curricular activities, I am fairly sure we covered the basics of these things in the first year of my ONC course.

It is hard to imagine that without the most basic grasp of standardisation and economy of scale anyone could stand the slimmest of chances for starting a career in engineering – let alone engineering design. If you dissect this further it means that without the knowledge of standard, tightly defined, thread sizes he cannot even have had the instinctive understanding that says 'a nut of thread X will always fit with a bolt of thread X'. Take a moment to consider how fundamental that is, and to not know that after completing one year of an engineering degree.

I quizzed young Sam on what he had covered at school and at university, and this revealed that he had done some drawings on CAD and created rendered images. He had also completed a project making a hand tool and covered basic dynamic and stress calculations. These are all important areas but, to use a civil engineering-based simile, it struck me as being like constructing the first floor of a tower block without ensuring the foundations were in place.

Admittedly this is from a sample size of one but if I am to speak as I find then, although I am no academic, this structure to the education of our up-and-coming engineers worries me. Most importantly, I feel it lets them down. It may be that he'll cover such things in his next year. However, there was a massive hinterland that he could have drawn upon while learning about the more in-depth stuff (such as stress calculations), and thus built up an inherent understanding of the practical applications and consequences of what he was learning. Also, I wonder how 'fit for purpose' our enthusiastic graduates are once they've left the the halls of academia? Still, on the up side, at least it doesn't look like I'll have to retire anytime soon.

The secret life of a London music hall

London's last-surviving Victorian grand music hall has undergone an unusual restoration designed to keep its raffish decay intact.
Stuart Nathan reports

Wilton's Music Hall is described in its publicity material as 'London's hidden stage'. It's not hidden terribly well, in that it appears on maps, and there are signposts to it, but visiting it still has something of the feel of stepping into another world.

To reach it, you turn your back on the ramparts and gates of the Tower of London, and its attendant steel and glass towers, and walk along streets where office buildings give way to blocky city car parks and then to older brick commercial buildings, well-worn pubs and corner shops. With an elevated section of the Docklands Light Railway echoing and rumbling on one side, you turn down Graces Alley (which has the look of a turning that won't be there the next time you try to find it), and you're faced with what looks like a row of diminutive terraced houses of old, yellow brick with peeling paintwork on wooden window frames opposite a set of railings that are barely holding luxuriant bushes at bay. On the other side of the vegetation are the unmistakable, slightly haunting, sounds of a school playground. If you were expecting a grand entrance like a West End theatre, there's none to be seen. And for a visit to somewhere described as being restored, nothing looks like it's in mint condition.

This, it transpires, is the point. Wilton's, London's last-surviving Victorian grand music hall, has always been hidden, and it's not its location that's secret. Starting life as a bar that provided cabaret acts for its clientele of ships' crews from nearby docks, it was housed in those Georgian terraces that front Graces Alley. In the mid-19th century, the owner of the bar, Jon Wilton, bought the remaining three houses in the terrace and built a two-level auditorium across the back of the terrace, with the gallery supported by delicate-seeming, slender barley sugar twist columns that are the hall's most famous features (the twisted exterior conceals wrought-iron cores). Designed to hold 1,500 people in what must have been fairly uncomfortable conditions, under today's regulations, it can seat 300 in safety. There were several such establishments around the docks in Dickens' time and Wilton's is the only survivor.

The atmosphere inside the building could be described as charismatic dilapidation. Large chunks of plaster are missing, exposing the brickwork, especially around doorways. The floor of the upper level is made from slabs of paving stone, with daylight visible through the gaps. It looks one small step away from being derelict.

Appearance is everything, though. While Wilton's history is decidedly chequered and it certainly has been in danger of collapse, this is no longer the case. The building has just completed a most unusual plan of restoration that, while leaving it in a more robust state in terms of its structure and facilities, has been carefully calculated to leave that raffish decay intact. If it didn't feel like it was about to fall down around your ears, it wouldn't be Wilton's. The result is a decidedly 21st century building that looks and feels as though it hasn't been touched since the 19th century, and surely escaped the Blitz, the neglect of the old Docklands and the attention of property developers purely by accident.

Wilton's was a rough place; in one particular incident a heckler was beaten to death by an enraged performer (the judge deemed the victim to have deserved his fate, and the

01 Air-handling systems for the hall are installed unobtrusively on the roof

culprit was sentenced to two weeks in prison). Its gas lighting was one of London's wonders and a key component in its original ventilation system, but this was before the days of health and safety, and it may have contributed to its ruin. A catastrophic fire in the 1870s put an end to its first incarnation as an entertainment venue; it was a Methodist mission for a while, and later a rag warehouse, before its rediscovery in the 1960s (it was scheduled for demolition, but then-Poet Laureate and architectural historian Sir John Betjeman led a successful campaign to save it). It was listed in 1971, and gradually repaired as necessary simply to stop it falling down.

The current restoration programme, which cost £4m and began in 2006, was a unique civil engineering project because of the precarious nature of the building and the absolute need to keep the atmosphere intact. It was led by Tim Ronalds Architects, whose eponymous director had already worked on East End heritage projects at the Hackney Empire and the Ironmonger Row baths, and with engineers from the Max Fordham practice, whose clients include the late Zaha Hadid and refurbishment projects on the Royal Festival Hall and National Museum of Scotland.

"We often hear, when we take people around, 'I thought you said it was refurbished? It doesn't look like it'," said Luke Winterton, a multidisciplinary engineer from Max Fordham who worked on the project. "And, to be honest, on this project that's the best possible praise."

02 The hall seats 300 people on two levels

The key has been to keep the work hidden wherever possible, he said. There are a few places where this has been impossible, notably in the creation of a new studio, dressing rooms and prop-making workshops, but these tend to be in the end house of the terrace that was largely rebuilt in the 1980s and, in any case, is not open for public access. In all other places where new building was necessary and could not be hidden, it's very clearly new, with sharp junctions between the wear of decades and clean woodwork. A kitchen in this house has been designed to have a 'vintage' look, with restored light fittings, so when a window hatch is opened onto Graces Alley, patrons can be served pizza outside, and their view into the kitchen is in keeping with their experience of the rest of the building.

One of the most urgent tasks was to shore up the building's basement. Although it's not immediately >>

"Often when we take people around they say, 'I thought you said it was refurbished'. To be honest, that's the best possible praise"

Luke Winterton, Max Fordham

03 The 'Juliet balcony' overlooking the new studio space is a rare example of a brand-new structure

04 The barley-sugar twist columns have covers of cast iron

05 Skylights give the feel of outdoor space to formerly derelict areas

"Everything possible was preserved; broken fireplaces, chaotic Georgian brickwork, rotten window frames"

Tim Ronalds,
Tim Ronalds Architects

>> obvious from its location, Wilton's is close to the Thames, and the river water has seeped into the underpinnings. Combined with inadequate roof trusses in the hall that were pushing the walls apart, the effect was that the hall was gradually separating from the houses and effectively beginning a slow slide into the river.

The basement was given a completely new waterproof brick lining with modern plumbing and drainage installed, while walls that didn't join up were reinforced; where possible, by dowelling any collapsing brickwork rather than rebuilding it. The basement now boasts workrooms and a chilled cellar supplying the building's main bar – called the Mahogany Bar as it was in the hall's heyday, being the first in London to have mahogany fittings – and a new cocktail bar that has been shoehorned into the upper rooms of the original houses.

"There were all sorts of strange spaces in the building; partly because the original construction was makeshift and there have been so many changes," Winterton told *The Engineer*. "You'd go through a door and suddenly find yourself in the open air. We wanted to keep that feeling." Judicious placement of joists and rooflights in the upstairs rooms allowed the engineers to create what feels like a mid-air conservatory, which even has a bar in one corner.

Ventilating the main hall was a considerable challenge as the heat from all the stage lighting and electrics, not forgetting the warmth and humidity created by 300 members of the audience, all have to be handled. The engineers installed air-handling systems hidden on the roof of the building, and hidden ducting behind the stage that draws away hot air.

"It was quite difficult because it's completely different from the original system," Winterton said. "There was an enormous gas chandelier with 300 burners hanging over the hall – it was called a 'sun-burner' – and the combustion of the gas drew air up into the ceiling where it was vented out through a chimney system. To our sensibilities, very unsafe indeed."

The roof structure did provide one opportunity. Although the hall has a curved barrel-vault system, this sits underneath a more conventional peaked roof, whose ridge runs the length of the hall. The space between the ceiling and roof has soundproofing, so the rumbling of the Docklands Light Railway doesn't disturb performances.

The original structure also allowed unobtrusive ventilation elsewhere. With new boilers and a modern heating system, the original fireplaces have become the outlets for ventilation shafts in the original houses.

The basement work also allowed voids to be created below the floor of the hall, accessed by trapdoors. These allow wiring for production-specific lighting to be installed unobtrusively. Safety rails on the balcony have an extra level that folds down when not in use and can be used as lighting anchoring points. Scaffolding poles in the walls that serve the same function are removable so that, when the hall serves as a location for music video shoots, it appears untouched. Also hidden away is a state-of-the-art fibre-optics data system, and an audio-visual system in the terrace house rooms, for more unconventional site-specific performances that are occasionally staged and for live music in the Mahogany and cocktail bars.

"The builders were quite confused at points," Winterton said. "There's a big patch of damp in the corner of the hall, up by the ceiling that's very visible. They asked us if they should fix it and we told them not to touch it."

Considering the list of materials used in the renovation, including 121 skips of debris, three tonnes of steel beams, 1,000m of reclaimed floorboards, nine tonnes of cement and 15 tonnes of lime plaster, it's all the more surprising how invisible the work is. There's only one tell-tale. Crawling across the walls are bright lines of new copper, which hold mineral-insulated electrical connections. Placed there because of the lack of voids in the walls, they retain a vintage feeling without compromising on services.

"Everything possible was preserved," said architect Tim Ronalds. "Broken fireplaces, chaotic Georgian brickwork, rotten window frames, fragments of plaster, disused roofs, old railway track built into the works in 1859, pulleys and cables from a door-bell transmission mechanism, ceramic electrical fittings, pipes for gas lighting, wooden mountings in the wall, holes deemed charming and abandoned birds' nests."

A large sink in a corner of the main hall may be a remnant of the hall's days as a mission. "We don't know how quite a few features got here," Winterton said, "but they tell the story of the building, so we wanted to keep them."

In one of the upstairs rooms is a short staircase leading to nowhere. You might almost expect a resplendent Victorian actor to appear, all whiskers, velvet and brass buttons. With the hidden modern technology of the restoration, Wilton's could probably arrange it.

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The appliance of paper science

Producing electronics is costly but that could change for some components thanks to a surprising source. Stuart Nathan reports

The price of electronics has been dropping steadily for decades. What were once luxury, high-tech articles are now commonplace, and microprocessors are being incorporated into ever-more numerous appliances and devices as the prefix 'smart' becomes almost oxymoronic for both consumer devices and, increasingly, industrial machinery and tools.

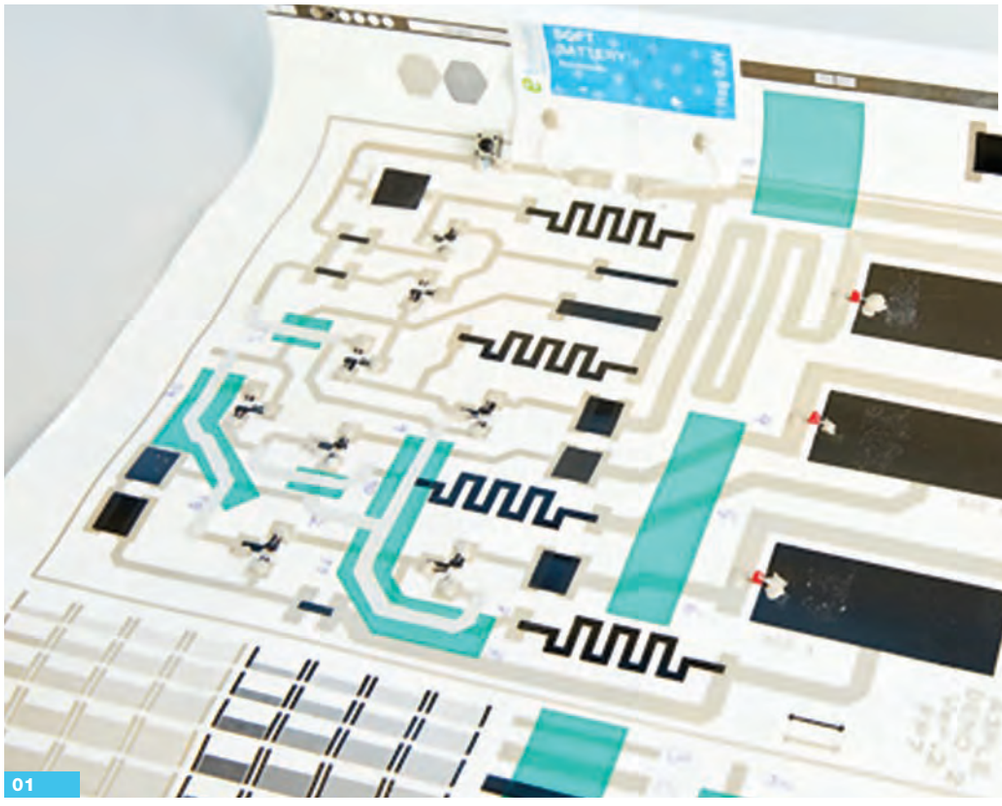
But there is still a choke-point because the price of making electronics cannot go below a certain level. The silicon and germanium-based materials of which transistors and their derivative products, microchips, are made have an associated cost, both in financial and environmental terms. No matter what economies of scale are employed by their manufacturers, they still require high-temperature processing and the use of chemicals that must be removed from factory waste or otherwise treated to render them harmless before discharge from the factory.

No matter how cheap they become, electronics cannot truly be regarded as disposable items; and although it is possible and desirable to recover high-value materials from scrapped electronics, they can hardly be regarded as fully recyclable either.

But that might be about to change at least for some categories of electronics – an entirely new category, in fact, where the inorganic semiconductor devices have been replaced with a familiar, but most surprising material: paper.

Prof Elvira Fortunato, a materials scientist and engineer at the New University of Lisbon in Portugal specialising in transparent electronics, realised early this decade that silicon was not necessarily needed in transistors. "There are three types of material needed," she explained at the recent European Patent Office Inventor's Awards in her hometown. "You need conductors: the metal leads, wires and contacts you see in electronic components. You need semiconductors, of course, to perform the actual functions of the component. But you also need insulators, sometimes called dielectrics, which are vital for the function of the components."

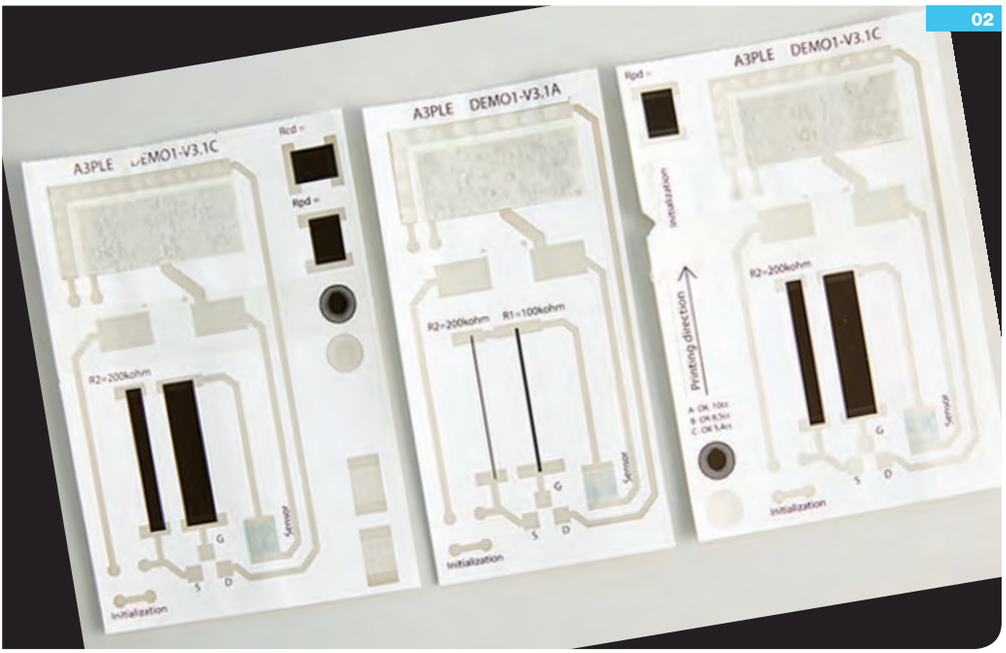
In many transistors, the dielectric is a thin layer of pure silicon sandwiched between layers of silicon that have been 'doped' with very small amounts of other atoms that have more or fewer electrons available in their outermost layers. Where there are extra electrons, these float around the atomic lattice structure of the silicon and can be moved by an electric current. Where there are fewer, they leave gaps that do not weaken the structure but provide another mechanism for charge to travel through the material. Manipulating the distribution and flow of free electrons and gaps across the insulating layer is the key to how transistors – and, by extension, all electronics – work. The insulating layer acts as a block to electron flow, and can also store electrons. Moreover, differences in charge on either side of the insulating layer influence the behaviour of the other layers through electrostatic attraction and repulsion.



01

"I thought there was a low probability it would work but we were very happy to find when voltage was applied, current flowed as it would in a conventional transistor"

Fortunato's key realisation was that the insulator and semiconductors do not have to be silicon. Initially, she and her husband Rodrigo Martins, a fellow material specialist at the same institution, were trying to embed electronics onto paper as a flexible support material. But, she reasoned, maybe the insulators could be a biopolymer like cellulose. This led to the theory that the paper itself could be made part of the support structure of the component. And could other semiconductors – for example, oxides of electron-rich transition metals – work across a layer of paper in the same way that doped silicon works across the pure material?



01 Transistor semiconductors are printed onto paper coated with a nano-layer of aluminium

02 A wide variety of electronic components can be printed

"To be frank, I thought there was a very low probability that it would work," Fortunato said. "It just seemed too simple." But working with her husband, Fortunato asked one of her graduate students to test the idea with a simple transistor design. "We were very happy to find that as soon as a voltage was applied, current flowed exactly as it would in a conventional transistor," she said.

The next stage of the research was to use the metal oxide semiconductors as ink. Suspending nanoparticles of gallium, indium or zinc in a liquid medium was simple, and the team adapted an inkjet printer to use these inks. The paper is coated with a nano-thin layer of aluminium, which acts as a conductor linking separate components, then the semiconductor components are simply printed onto both sides of the paper. Fortunato said: "We also need the aluminium to help dissipate heat generated as current flows through the semiconductor layers. This is very important in all electronics, but conventional electronics have some ability to dissipate heat; our materials cannot dissipate heat on their own."

Printing accuracy is vital, Martins said, so that the components on each side line up properly, but a wide variety of components can be printed, including photoelectric cells to power the electronics, sensors for organic molecules, and even display components such as alphanumerics, where a current makes a transparent layer of ink opaque. Systems as complex as RFID circuits are printable, he said, all with paper as the insulating component in the system.

One of the great successes so far of electronics is miniaturisation, which allows a large number of transistors to be put onto a single chip – this is the basis of microprocessors. Something similar is possible with paper electronics, Martins said. "If you coat the semiconductor inks onto single cellulose fibres, and cross them over each other, you make a transistor where they cross, and that will only be a couple of nanometres across. Such precision is very possible and allows you to construct complex circuits."

However, even Fortunato and Martins admit the limitations of their technique. A well as the heat dissipation issue, conventional silicon- and germanium-based electronics are more efficient and faster than those based on paper transistors. "We can't replace silicon and don't intend to; these systems will work alongside," Martins said. "Where they have a definite advantage is in applications where you need very large numbers of devices."

The materials are all cheap and readily available, and processing requires well-known techniques that do not need high temperatures, vacuum, ultra-clean environments or hazardous gases. "To recycle silicon, you need temperatures in excess of 120°C; with paper electronics, you can just burn it when you're done," added Martins.

The pair believe food packaging is likely to be the biggest initial application of the technology. Fortunato said: "You can incorporate sensors in the packaging to measure the concentration of gases inside the package that indicate microbial activity, and that will change a display element to indicate the contents are no longer safe. Current use-by information is effectively a guess. This information will come from unequivocal measurement."

Printed radio receivers powered by solar cells that function under artificial light could also trigger changes in price displays and similar techniques could be used to print tickets for flights or trains that update themselves when new information becomes available. Further ahead, moving graphics on newspapers might be possible. Whether we get to a technological version of the magical moving photos in Harry Potter movies is another matter.

CareerCV

Elvira Fortunato
Scientist and engineer
New University of Lisbon

Education

1991 MSc in semiconductor materials New University of Lisbon
1995 PhD in microelectronics and optoelectronics, as above

Career

1996 Demonstrator in Material Science Dept, New University of Lisbon
1998 Director, Materials Reseach Centre CENIMAT
2012 Full Professor, Material Science Dept, New University of Lisbon

Rodrigo Martins
Materials specialist
New University of Lisbon

Education

1977 MSc in Materials Science, University of Dundee
1982 PhD in energy conservation in semiconductors, New University of Lisbon

Career

Prof Martins is head of materials science at the New University of Lisbon, president of the Senate of the European Materials Research Society, and a member of the advisory boards of Horizon 2020 in advanced materials, nanotechnology and biotechnology

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Build the suspense

The cabling operation on the Golden Gate Bridge was the source of much fascination in the summer of 1936

Eighty years ago this publication reported on an icon of engineering, and one that remains as captivating today as it was all those years ago.

San Francisco's Golden Gate Bridge had been under construction since January 1933, and by the time a three-part feature appeared in *The Engineer* across July and August of 1936, the structure was nearing completion. Parts one and two had looked at the design, excavations and pier-building that the Golden Gate required, but the final instalment focused on the cabling operation of the giant suspension bridge.

According to our predecessors, by the summer of 1936 the spinning of the main suspension cables was three-quarters done, and there was "ample warrant for the official assurance" that the bridge's completion date of May 1937 would be met. With a total length from abutment to abutment of 8,981ft (2,737m), and a main span of 4,200ft (1,280m), the cabling of the bridge was an enormous undertaking.

"Each main suspension cable is made up of 61 strands, and, contrary to previous practice, the strands differ in size, depending on their respective positions in the cable – the number of individual wires therefore in the several strands ranges from 256 to 472 wires, and each wire is 0.196in in diameter."

In total, each cable consisted of 27,572 individual wires weighing 10,750 tons, with the two cables together containing around 80,000 miles of wire. After spinning, the strands were compacted by squeezing machines that used 12 hydraulic jacks to apply around 4,000lbs of pressure per square inch. The cables were also banded at regular intervals and then wrapped from the outside with an "envelope of steel wire".

Lessons had been learned from the George Washington Bridge that spanned the Hudson from Manhattan to New Jersey, completed just a few years earlier in 1931. Indeed, the same contractor actually provided the cables for both structures, with improvements made in the intervening period.

However, it was in the technique of the actual spinning where the Golden Gate far surpassed its East Coast contemporary.

The GW's spinning had involved carriages with single wheels making complete runs from one side to the other, stringing two wires in a given strand at about 650ft per minute. When work began on the Golden Gate, carriages were equipped with two spinning wheels. On top of this, a transfer station was set up in the centre of the span, so carriages only travelled halfway across the bay, swapping their wires with those of the carriage that had come from the opposite side, before returning to their own anchoring point. At any given time, a total of four carriages were operating, increasing the workrate even further.

01

01/02/03 It was in the technique of spinning that the Golden Gate Bridge far surpassed the George Washington Bridge

02

03

"During a co-operating round trip of two carriages they were able to string a total of eight wires from anchorage to anchorage, while the four carriages duplicated that performance. Thus, in a given period, 16 wires were strung on the Golden Gate Bridge, as against four on the George Washington… On the GW the rate of stringing reached as much as 61 tons in the course of a day on a cable, while it was found possible to string 271 tons per diem per cable in the case of the Golden Gate."

Due in no small part to these novel spinning techniques, construction finished ahead of schedule the following April, with the bridge officially opening on 27 May 1937. Reports from our predecessors in 1936 heralded the fact that not a single death or even a permanent injury had occurred up to that point but, alas, that statistic was not to hold. Ten men perished as the bridge neared completion in 1937, when a platform that was attached to a rolling hanger on a track collapsed. Initially saved by the safety net in place beneath, the platform proved too heavy, and the net gave way. Just two of the 12 ironworkers survived the 200ft drop to the Pacific below.

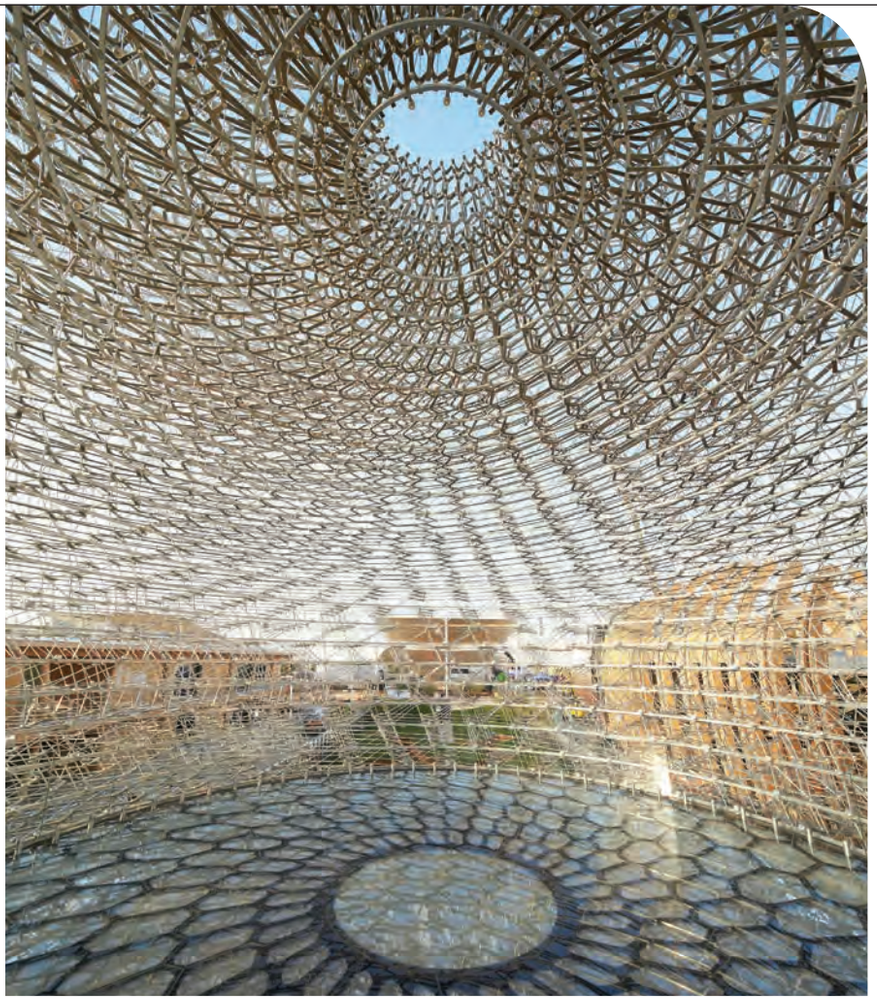
Over the course of the bridge's construction 19 other workers were saved by the nets, going on to form the infamous Half Way to Hell Club. The Golden Gate itself remained the longest suspension bridge in the world until 1964, and the tallest until 1998. While its dimensions may have been surpassed, its place in the public mind has not, and it remains arguably the most famous bridge ever constructed. **AW**

Word of the issue

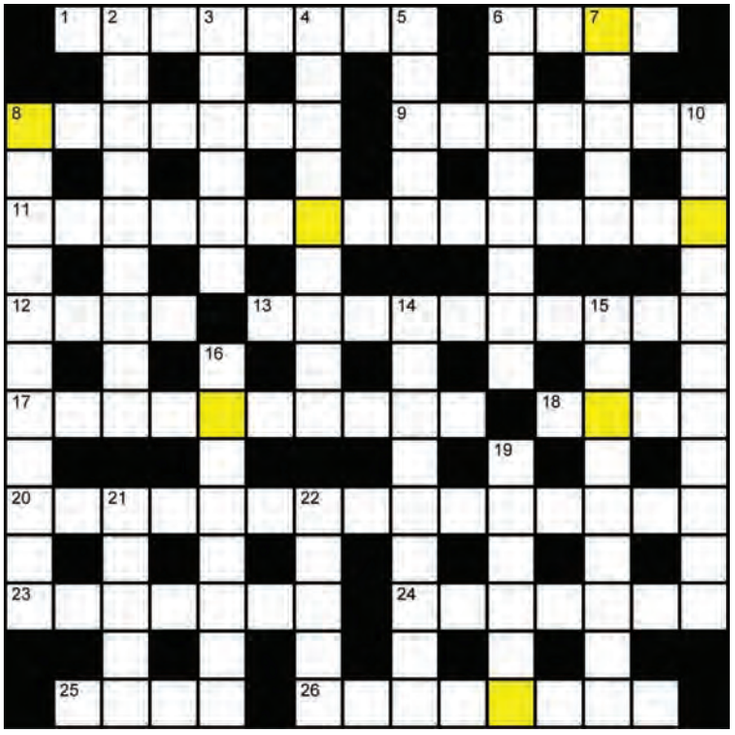
Anthony Poulton-Smith explores the origins of the word 'bolt'

The word 'bolt' is used in several senses: 'make a quick start', 'leave suddenly', 'eat quickly' and 'crossbow arrow' among them. Each of these came into use at different times – the diner unknown until the 19th century; sprint start and escape both of the early 13th century. This leaves the short arrow, itself from the Proto-Germanic bultas with the same meaning. Tracing the clues back further we get to Proto-Indo-European bheld, which had the same meaning as Lithuanian beldu meaning 'I knock' or as beldas 'pole for striking'. Thus the original 'bolt' should be seen more as a nail or peg. Later, the crossbow weapon would be named as such as it resembled the fastener, then 'bolt' became associated with speed, giving the other two uses. In an engineering sense, the 'bolt' has come full circle, first a simple peg, today an item engineered to fine tolerances but essentially the same thing.

Bigpicture



The Hive – a sculptural structure that formed the centrepiece of the UK Pavilion at the Milan Expo 2015 – has been shortlisted for the Structural Awards 2016. Simmonds Studio worked in collaboration with artist Wolfgang Buttress to create the beehive-inspired structure that contains 60,000 aluminium parts, formed in a structural system of 31 stacked layers of alternating radial and circumferential trusses. *Image: UKTI*



Crossword

Across

1 Incise using a diagonal line (8)
6 Impression in a surface (4)
8 Pivot about which a lever turns (7)
9 Serving during an intermediate interval of time (7)
11 Lacking complexity (15)
12 Famous safety lamp (4)
13 Hold in contempt (10)
17 Causing to stop operating (7,3)
18 Written proposal or reminder (4)
20 Made excessive corrections (15)
23 Structure that holds up or provides a foundation (7)
24 More sticky to the touch (7)
25 Traditional story accepted as history (4)
26 Liberality in bestowing gifts (8)

Down

2 Re-invests into a similar fund (5,4)
3 Scratch repeatedly (6)
4 Adding together (9)
5 Turn in the opposite direction (5)
6 Pocketbook (8)
7 Unit of weight for precious stones (5)
8 Lowest supports of a structure (11)
10 Built for a particular individual (4-2-5)
14 Optical telescope with a large concave mirror (9)
15 Wiring system (9)
16 Piece of treated fabric (8)
19 Mentally prepare (6)
21 Holding or containing nothing (5)
22 Shiny chemical element (5)

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