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# DEPARTMENT OF ENGINEERING NEWS



UNIVERSITY OF CAMBRIDGE

# In this issue



Cover image: James Macleod: Graphene-IPA Ink, First Prize in the ZEISS Photography Competition 2016.


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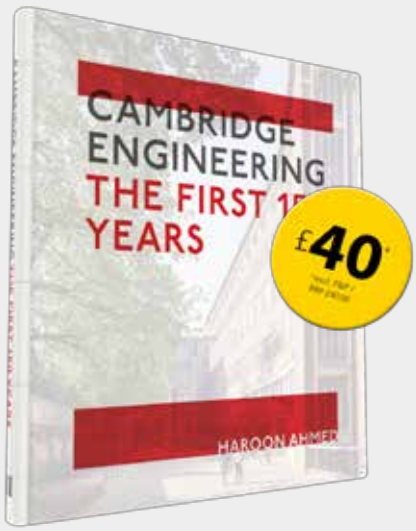
# Welcome

**In the hurly burly of the Department of Engineering, it can be hard to catch one's breath to take stock – the newsletter provides the perfect moment to reflect on how things are going.**

This edition shows a reassuring range of extraordinary engineering achievements across a wide range of fields, with a wonderful display of images from the ZEISS Photography Competition and a fine crop of prizes and awards. But of all these stories, I was particularly inspired by those about our young engineers and a distinguished veteran engineer, who are linked by a common thread of ingenuity and inventiveness: Keno Mario-Ghae is the NMI 'Young Engineer of the Year'; Dr Jenni Sidey is the IET 'Young Women Engineer of the Year'; Heba Bevan's invention from her time as a student has been selected for export by the Department for International Trade; and then Dr John C Taylor OBE, a prolific inventor whose company has won four Queen's Awards, has donated £2.5 million for a Professorship of Innovation. It is wonderful to see this spirit of creativity connecting through the generations and into the future.

These connections remind me to thank the alumni that have recently been in touch about wishing to leave a bequest in their will in support of the Department of Engineering. We have had a number of enquiries of this nature in recent months and I'm heartened that our alumni are starting to think of supporting us in this way. Remembering the Department in your will is a fantastic way to support our long term future and we are incredibly grateful for each and every bequest. If you would like further information on how to go about leaving a bequest to the Department, please contact Georgina Cannon at georgina.cannon@admin.cam.ac.uk in the Development Office or Philip Guildford at director-of-research@eng.cam.ac.uk in Engineering.

**Professor David Cardwell FREng**




## Cambridge Engineering The First 150 Years

"The history of engineering told in this book shows that Cambridge Engineering has come a long way in nearly 150 years. Its reach and impact continues to accelerate. Even my wildest predictions for the next 150 years are likely to fall short of what this unique international community of engineers will achieve."

Ann Dowling | November 2016
Dame Ann Dowling is President of the Royal Academy of Engineering and was Head of the Department of Engineering from 2009 to 2014.

**Copies can be bought at:**
tmbooks.com/cambridge-engineering-hb.html

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↑ Mixed reality for infrastructure

# Virtual infrastructure models

## From computer to workspace

**Engineers will soon be able to visualise Building Information Models (BIMs) in full scale at their offices or superimposed on the real structure at construction sites, thanks to technology developed by the Department's Construction IT laboratory in collaboration with Trimble and Microsoft.**

The new mixed reality technologies for visualising fully textured infrastructure models in the office and schedule-loaded BIMs on site were recently shown at BETT, a major technology show in London by partner Microsoft.

Using the Bridge Inspector HoloLens app created by the Cambridge team, engineers are able to inspect the condition of infrastructure in their office as if they were standing on site in front of the real asset.

Dr Ioannis Brilakis, Laing O'Rourke Lecturer in Construction Engineering, has been pioneering the as-is virtualisation of existing infrastructure assets since 2005.

"Bringing a bridge to life at full scale while still being aware of your surroundings is a major time saver for experienced inspectors," he said.

The research behind this work, conducted by PhD student Philipp Huethwohl, will revolutionise the way we inspect major structures in the future.

The Progress Monitoring HoloLens app on the other hand, also created by the Cambridge team, allows engineering to bring four dimensional design models to site and intelligently superimpose them on the real structure. The app allows construction inspectors to both visualise progress and automatically detect building elements that should have been built at the time of their visit but are missing.

"All elements missing are marked as behind-schedule automatically in the 4D model simply by looking at them during an inspection visit," said Marianna Kopsida, who is the PhD student responsible for this project.

The team's current research focuses on how to guide inspectors in these massive models and centre their attention on the elements most relevant to their inspection task-list.

"This is all about productivity and improving workflows", said Dr Brilakis, which is a prerequisite for enabling industry wide technology adoption.

> "Bringing a bridge to life at full scale while still being aware of your surroundings is a major time saver for experienced inspectors.
>
> Dr Ioannis Brilakis

www.eng.cam.ac.uk/profiles/ib340


# IfM partner in new £50 million manufacturing research hub

**The Institute for Manufacturing (IfM) is part of a new research hub which will transform the way medicines and other high-value materials are made.**

The Future Continuous Manufacturing and Advanced Crystallisation (CMAC) Hub has been set up to develop innovative manufacturing processes for today's high-value products – including medicines – which are estimated to generate £50 billion each year for the UK economy.

The hub's research team is supporting industry in moving from 'batch crystallisation' to 'continuous crystallisation'. This is a more dynamic process which allows manufacturing to take place within smaller, more cost-effective facilities using smaller quantities of expensive ingredients and less energy, with more control over the final product quality and performance.

> We will be building on our current work looking at how digital supply chains can connect patients and consumers using sensors, diagnostics and smart packaging with the digital factory.
>
> Dr Jag Srai

Under the leadership of Dr Jag Srai, Head of the IfM's Centre for International Manufacturing, Cambridge researchers will be looking at how these new technologies and processes will transform the supply chains for medicines and other high-value products.

Dr Srai said: "Continuous manufacturing and digital supply chains have the potential to make truly personalised products and medicines a reality. We will be building on our current work looking at how digital supply chains can connect patients and consumers using sensors, diagnostics and smart packaging with the digital factory."

The hub, led by the University of Strathclyde, is one of six in the UK which will share £60 million of government funding as part of the Government's industrial strategy.

Announcing investment in the new hubs, Universities and Science Minister Jo Johnson said the funding 'will lay the foundations to allow industry and the UK's world-leading universities to thrive for years to come'.

Professor Andy Neely, Head of the IfM, said: "The work that Jag Srai and his team have been doing on pharmaceutical supply chains is genuinely ground-breaking and will play a key role in ensuring that the UK remains at the forefront of pharmaceutical and advanced materials manufacturing and innovative supply."

↑ Dr Jag Srai

Professor David Cardwell, Head of the Department of Engineering, added: "I'm delighted that the Centre for International Manufacturing is playing a pivotal role in this new hub which aligns with many of both the University's and Department's research priorities and with Cambridge's expanding healthcare and pharmaceutical ecosystem."

www.eng.cam.ac.uk/profiles/jss46
www.ifm.eng.cam.ac.uk
www.epsrc.ac.uk

Credit: diamond geezer

↑ Clangers

# Mice sing like jet engines to find a mate

**New research involving expertise from Dr Anurag Agarwal, Lecturer in the Acoustics Laboratory, has found that mice make unique high frequency sounds using a mechanism that has only previously been observed in supersonic jet engines.**

This is the first time that such a mechanism has been observed in any animal.

Mice, rats and many other rodents produce ultrasonic songs that they use for attracting mates and territorial defence. These 'singing' mice are often used to study communication disorders in humans, such as stuttering. However, until now it was not understood how mice can make these ultrasonic sounds, which may aid in the development of more effective animal models for studying human speech disorders.

Previously, it had been thought that these 'Clangers'-style songs were either the result of a mechanism similar to that of a tea kettle, or of the resonance caused by the vibration of the vocal cords. In fact, neither hypothesis turned out to be correct. Instead, mice point a small air jet coming from the windpipe against the inner wall of the larynx, causing a resonance and producing an ultrasonic whistle.

The new research co-authored by the Department's Dr Agarwal, and which involved researchers from Washington State University and the University of Southern Denmark, has been published in the journal *Current Biology*.

Using ultra-high-speed video of 100,000 frames per second the researchers showed that the vocal folds remain completely still while ultrasound was coming from the mouse's larynx.

Dr Agarwal said: "This mechanism is known only to produce sound in supersonic flow applications, such as vertical takeoff and landing with jet engines, or high-speed subsonic flows, such as jets for rapid cooling of electrical components and turbines.

Mice seem to be doing something very complicated and clever to make ultrasound."

"Mice seem to be doing something very complicated and clever to make ultrasound.

Dr Anurag Agarwal

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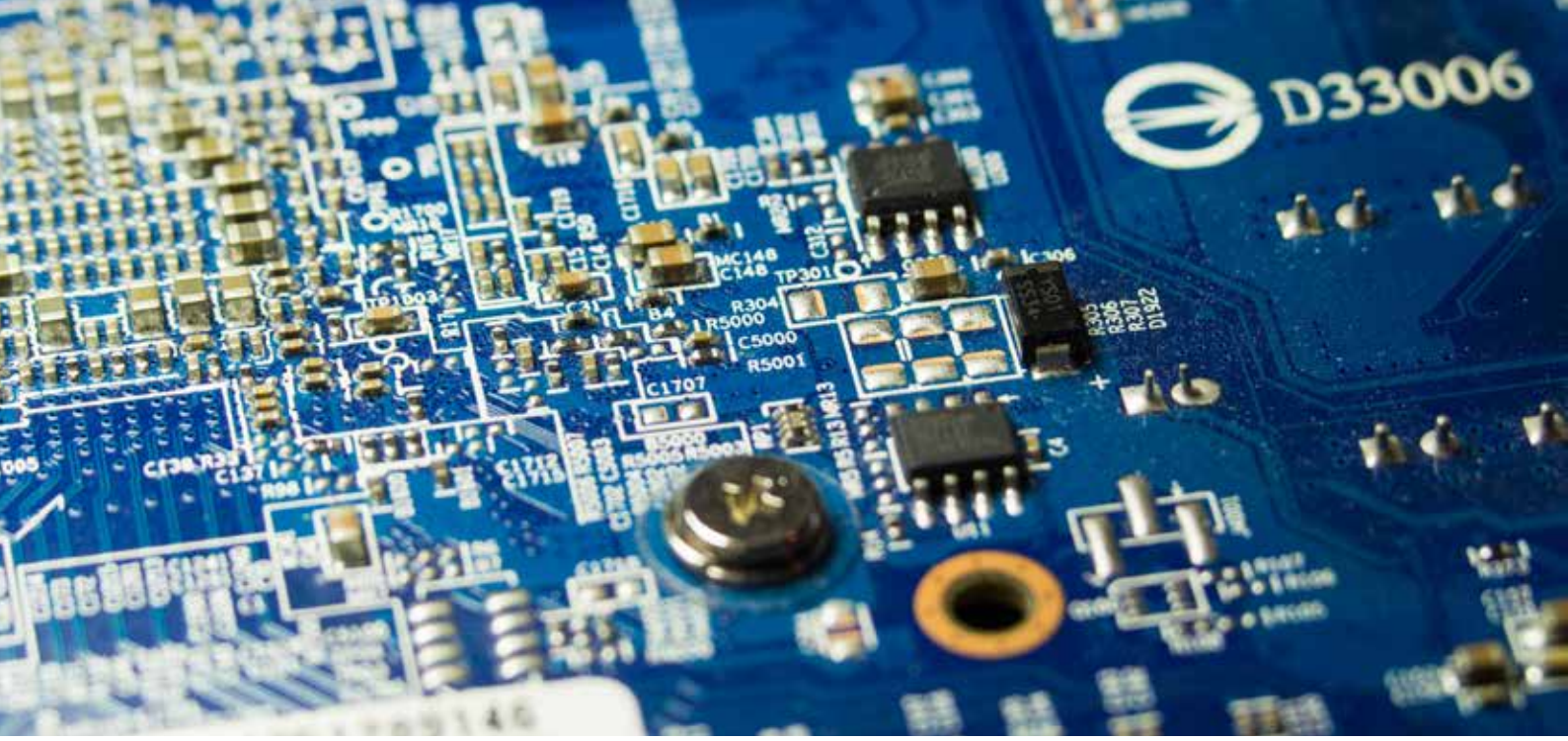


# Engineers design ultralow power transistors that could function for years without a battery

**A new design for transistors which operate on 'scavenged' energy from their environment could form the basis for devices which function for months or years without a battery, and could be used for wearable or implantable electronics.**

A newly-developed form of transistor opens up a range of new electronic applications including wearable or implantable devices by drastically reducing the amount of power used.

Using a similar principle to a computer in sleep mode, the new ultralow power transistor, developed by the Department's engineers, harnesses a tiny 'leakage' of electrical current, known as a near-off-state current, for its operations. This leak, like water dripping from a faulty tap, is a characteristic of all transistors, but this is the first time that it has been effectively captured and used functionally.

The results, reported in the journal *Science*, open up new avenues for system design for the Internet of Things, in which most of the things we interact with every day are connected to the internet.

The transistors can be produced at low temperatures and can be printed on almost any material, from glass and plastic to polyester and paper. They are based on a unique geometry which uses a 'non-desirable' characteristic, namely the point of contact between the metal and semiconducting components of a transistor, a so-called 'Schottky barrier.'

"We're challenging conventional perception of how a transistor should be," said the paper's co-author, Arokia Nathan, Professor of Photonic Systems and Displays.

"We've found that these Schottky barriers, which most engineers try to avoid, actually have the ideal characteristics for the type of ultralow power applications we're looking at, such as wearable or implantable electronics for health monitoring."

The new design tackles one of the main issues preventing the development of ultralow power transistors, namely the ability to produce them at very small sizes. As transistors get smaller, their two electrodes start to influence the behaviour of one another, and the voltages spread, meaning that below a certain size, transistors fail to function as desired. By changing the design of the transistors, the Cambridge researchers were able to use the Schottky barriers to keep the electrodes independent from one another, so that the transistors can be scaled down to very small geometries.

The design also achieves a very high level of gain or signal amplification. A transistor's operating voltage is less than a volt, with power consumption below a billionth of a watt. This ultralow power consumption makes them most suitable for applications where function is more important than speed, which is the essence of the Internet of Things.

"If we were to draw energy from a typical AA battery based on this design, it would last for a billion years," said Research Associate Dr Sungsik Lee, the paper's first author.

"Using the Schottky barrier allows us to keep the electrodes from interfering with each other in order to amplify the amplitude of the signal even at the state where the transistor is almost switched off."

Professor Nathan added: "This will bring about a new design model for ultralow power sensor interfaces and analogue signal processing in wearable and implantable devices, all of which are critical for the Internet of Things."

www.eng.cam.ac.uk/profiles/an299
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ALUMNI UPDATE

→ Keno with CUER solar car 'Endeavour' and a model of 'Evolution'.

# Keno Mario-Ghae lifts 'Young Engineer of the Year' Award

**Alumnus Keno Mario-Ghae has won The National Microelectronics Institute (NMI) 'Young Engineer of the Year' Award.**

Keno, who has a degree in Engineering and a Master's degree in Manufacturing and Management, was credited by the NMI judges for the difference he had made to Imagination Technologies in the relatively short time that he has been with the company.

At Imagination, Keno works as part of the MIPS-powered Creator Ci40 IoT kit and presented on it at the RIOT summit in Berlin in July 2016. He has worked on enhancing the usability of the development board and reducing the development time. He also spearheaded the adoption of 'LetMeCreate' libraries for the Creator kit, which have helped reduce the average time of developing a first project from days or weeks down to minutes.

Introducing the award, Derek Boyd, CEO of the NMI said that in his opinion the Young Engineer Award was the hardest of all the evening's 13 awards to win, with submissions for the award from up to 20 high-quality applicants.

Keno was part of Cambridge University Eco Racing (CUER) team from October 2011 and he ran the team during the 2013 World Solar Challenge. He has been working on developing solar energy for powering ovens and low-cost computers for the developing world.

Keno said: "I'm honoured and excited to have won Young Engineer of the Year Award at 20th NMI Awards. It means a lot and has already enabled me to meet and share ideas with great engineers and next generation engineers, and I look forward to more collaborations, potentially across industries."

> This award means a lot and has already enabled me to meet and share ideas with great engineers and next generation engineers across our industry and I look forward to more collaborations, potentially across industries.
>
> Keno Mario-Ghae

→ www.cuer.co.uk
Watch Keno's interview with NMI after he won the award: www.youtube.com/watch?v=2L6RnLDTDsE

Credit: ©judy_and_ed

# Reconditioning the brain to overcome fear

**New research involving neuroscientist Dr Ben Seymour has found a way of unconsciously removing a fear memory from the brain.**

Using a combination of artificial intelligence and brain scanning technology, the international research team's technique, published in the inaugural edition of *Nature Human Behaviour*, could lead to a new way of treating patients with conditions such as post-traumatic stress disorder (PTSD) and phobias.

Fear-related disorders affect around one in 14 people and place considerable pressure on mental health services. Currently, a common approach is for patients to undergo some form of aversion therapy, in which they confront their fear by being exposed to it in the hope they will learn that the thing they fear isn't harmful after all. However, this therapy is inherently unpleasant, and many choose not to pursue it.

The research team developed a method to read and identify a fear memory using a new technique called 'Decoded Neurofeedback'. The technique used brain scanning to monitor activity in the brain, and identify complex patterns of activity that resembled a specific fear memory. In the experiment, a fear memory was created in 17 healthy volunteers by administering a brief electric shock when they saw a certain computer image. When the pattern was detected, the researchers over-wrote the fear memory by giving their experimental subjects a reward.

Dr Seymour, one of the authors on the study, said the use of artificial intelligence (AI) image recognition methods now allow neuroscientists to identify aspects of the content of information represented in the brain.

"When we induced a mild fear memory in the brain, we were able to develop a fast and accurate method of reading it by using AI algorithms," he said. "The challenge then was to find a way to reduce or remove the fear memory, without ever consciously evoking it.

"We realised that even when the volunteers were simply resting, we could see brief moments when the pattern of fluctuating brain activity had partial features of the specific fear memory, even though the volunteers weren't consciously aware of it. Because we could decode these brain patterns quickly, we decided to give subjects a reward - a small amount of money - every time we picked up these features of the memory."

The team, which involved neuroscientists from Japan and the USA, repeated the procedure over three days. Volunteers were told that the monetary reward they earned depended on their brain activity, but they didn't know how. By continuously connecting subtle patterns of brain activity linked to the electric shock with a small reward, the scientists hoped to gradually and unconsciously override the fear memory.

Dr Ai Koizumi, of the Advanced Telecommunications Research Institute International, Kyoto and Centre of Information and Neural Networks, Osaka, led the research. She said: "In effect, the features of the memory that were previously tuned to predict the painful shock, were now being re-programmed to predict something positive instead."

The team then tested what happened when they showed the volunteers the pictures previously associated with the shocks.

"Remarkably, we could no longer see the typical fear skin-sweating response. Nor could we identify enhanced activity in the amygdala - the brain's fear centre," she continued. "This meant that we'd been able to reduce the fear memory without the volunteers ever consciously experiencing the fear memory in the process."

> "The challenge then was to find a way to reduce or remove the fear memory, without ever consciously evoking it.
>
> Dr Ben Seymour

Although the sample size in this initial study was relatively small, the team hopes the technique can be developed into a clinical treatment for patients with PTSD or phobias.

"To apply this to patients, we need to build a library of the brain information codes for the various things that people might have a pathological fear of, say, spiders," adds Dr Seymour. "Then, in principle, patients could have regular sessions of Decoded Neurofeedback to gradually remove the fear response that these memories trigger."

Such a treatment could have major benefits over traditional drug based approaches. Patients could also avoid the stress associated with exposure therapies and any side-effects resulting from those drugs.

www.eng.cam.ac.uk/profiles/mjd97

# Inside Big Ben

## Why the world's most famous clock will soon lose its bong

**Dr Hugh Hunt, Reader in Engineering Dynamics and Vibration, writes for *The Conversation* on the inner workings of England's most famous clock which will fall silent this year for repairs.**

The 'bonging' chimes that have marked the passing of time for Londoners since 1859 will fall silent for months beginning this year as part of a three-year £29m conservation project.

Of course, 'Big Ben' is the nickname of the Great Bell and the bell itself is not in bad shape – even though it does have a huge crack in it. The bell weighs nearly 14 tonnes and it cracked in 1859 when it was first bonged with a hammer that was way too heavy. The crack was never repaired. Instead the bell was rotated one eighth of a turn and a lighter (200kg) hammer was installed. The cracked bell has a characteristic sound which we have all grown to love, so maybe best leave it alone.

Instead, it is the Elizabeth Tower (1859) and the clock mechanism (1854), designed by Denison and Airy, that need attention.

Repairs to the tower are long overdue. There is corrosion damage to the cast iron roof and to the belfry structure which keeps the bells in place. There is water damage to the masonry and condensation problems will be addressed too. There are plumbing and electrical works to be done for a lift to be installed in one of the ventilation shafts, toilet facilities and the fitting of low-energy lighting.

### Marvel of engineering

The clock mechanism itself is remarkable. In its 162-year history it has only had one major breakdown. In 1976, the speed regulator for the chimes broke and the mechanism sped up to destruction. The resulting damage took months to repair.

The weights that drive the clock are, like the bells and hammers, unimaginably huge. The 'drive train' that keeps the pendulum swinging and that turns the hands, is driven by a weight of about 100kg. Two other weights that ring the bells are each over a tonne. If any of these weights falls out of control (as in the 1976 incident), they could do a lot of damage.

The pendulum suspension spring is especially critical because it holds up the huge pendulum bob which weighs 321kg. The swinging pendulum releases the 'escapement' every two seconds which then turns the hands on the clock's four faces. If you look very closely, you will see that the minute hand doesn't move smoothly but it sits still most of the time, only moving on each tick by 1.5cm.

The pendulum swings back and forth 21,600 times a day. That's nearly 8m times a year, bending the pendulum spring. Like any metal, it has the potential to suffer from fatigue. The pendulum needs to be lifted out of the clock so that the spring can be closely inspected.

The clock derives its remarkable accuracy in part from the temperature compensation which is built into the construction of the pendulum. This was yet another of John Harrison's genius ideas (you probably know him from longitude fame). He came up with the solution of using metals of differing temperature expansion coefficient so that the pendulum doesn't change in length as the temperature changes with the seasons.

In the Westminster clock, the pendulum shaft is made of concentric tubes of steel and zinc. A similar construction is described for the clock in Trinity College Cambridge and near perfect temperature compensation can be achieved. But zinc is a ductile metal and the tube deforms with time under the heavy load of the 321kg pendulum bob. This 'creeping' will cause the temperature compensation to jam up and become less effective.

So stopping the clock will also be a good opportunity to dismantle the pendulum completely and to check that the zinc tube is sliding freely. This in itself is a few days' work.

### What makes it tick?

But the truly clever bit of this clock is the escapement. All clocks have one – it's what makes the clock tick, quite literally. Denison developed his new gravity escapement especially for the Westminster clock. It decouples the driving force of the falling weight from the periodic force that maintains the motion of the pendulum. To this day, the best tower clocks in England use the gravity escapement leading to remarkable accuracy – better even, than that of your quartz crystal wrist watch.

www.eng.cam.ac.uk/profiles/hemh1
www.eng.cam.ac.uk/node/583

# Dr Jenni Sidey announced as IET 'Young Woman Engineer of the Year'


**Dr Jenni Sidey, Lecturer in Internal Combustion Engines, has received the 'Young Woman Engineer of the Year Award', and will play an ambassadorial role, promoting engineering careers to girls and young people.**

The trophy was awarded to Dr Sidey – the 2016 recipient – by the Institution of Engineering and Technology (IET).

Dr Sidey currently works on the development of the latest low emission combustion devices for use in the transportation and energy sectors.

"I'm enormously proud to be recognised by such a progressive programme promoting women in engineering within the UK," she said.

"The IET has worked hard to raise awareness of the lack of diversity within the engineering profession and I hope that, through receipt of this award and involvement in gender diversity initiatives, I can strengthen the IET's sentiment: to reach our technological potential, the UK's engineering workforce must be inclusive and diverse."

These prestigious engineering industry awards celebrate women working in modern engineering – and aim to help change the perception that engineering is predominantly a career for men by banishing outdated engineering stereotypes of hard hats and greasy pipes.

As well as highlighting female engineering talent, the IET Young Woman Engineer of the Year Awards seek to find female role models who can help address the UK science and engineering skills crisis by promoting engineering careers to more girls and women. Women currently represent only 9% of the engineering workforce in the UK (source: 2016 IET Skills Survey), the lowest percentage in Europe.

www.eng.cam.ac.uk/profiles/jams4
www.theiet.org
www.eng.cam.ac.uk/node/39
www.eng.cam.ac.uk/news/women-engineering-interview-dr-jenni-sidey
www-womeninengineering.eng.cam.ac.uk

## …and makes the shortlist to become an astronaut

Dr Sidey has been announced as one of 32 people competing for two astronaut positions at the Canadian Space Agency.

She made the shortlist following a rigorous selection process which lasts almost a year and involves several interviews, written exams and a range of physical and mental fitness tests.

The Agency received 3,772 applications after its announcement last year that it would add two new astronauts to its roster. The Agency specified it was seeking individuals with 'an academic background in science or technology, excellent health, and a wide range of outstanding qualities and skills'.

Women make up 32% of the remaining field and engineering degrees are most widely represented.

"It feels great to have progressed this far in the selection process," said Jenni. "I'm so pleased to be a part of something with so many incredible Canadians. I'm looking forward to spending more time with them, regardless of the outcome."

Jenni is involved in several outreach activities and is one of the Department's ambassadors for Women in Engineering. She helped form Cambridge Robogals in 2014, an international, not-for-profit, student-run organisation that aims to increase female participation in STEM, through fun and educational initiatives aimed at girls in primary and secondary school. Her research interests are in the study of combustion with a focus on gas turbine technologies.

www.asc-csa.gc.ca/eng/astronauts/recruitment/map.asp
robogals.org/


ALUMNI UPDATE

# UtterBerry chosen for export to China

**UtterBerry®, the new smart sensing technology, invented by former Cambridge Centre for Smart Infrastructure and Construction (CSIC) student Heba Bevan, has been announced as the chosen advanced technology for export to China.**

Heba was invited by the Department for International Trade (DIT) to visit Shenzhen, Chongqing and Hong Kong recently as part of the UK-China TechHUB 2016 (a programme supported by the DIT). There she demonstrated the potential of the UtterBerry devices to the Chinese government and world-leading hi-tech companies and investors, including China Resources Group, Huawei and China Mobile.

UtterBerry, which has uniquely innovative, wireless, small and low-power capabilities, is being supported in China by the ARM Innovation Eco-system Accelerator - a company which helps SMEs and start-ups accelerate their business in China.

Heba developed and deployed UtterBerry while working on her PhD research with CSIC. Heba has also worked in engineering research and technical sales engineering for the leading global semiconductor IP company, ARM, in the UK and Silicon Valley.

Sherry Madera, Deputy Director General, DIT, at the British Embassy in China said: "I'm delighted UtterBerry has been selected as a champion of British technology excellence through the TechHub programme. DIT is dedicated to working with innovative companies to enter the China market and drive exports to this exciting high potential region. The TechHub programme is just one of the new initiatives we have launched in partnership with industry and the Chinese government. I wish UtterBerry and Heba great success."

UtterBerry consists of miniature, wireless, ultra-low power sensors combined with artificial intelligence and is designed for infrastructure monitoring. Its technology is unique in a number of ways, offering AI capabilities that enable it to be self-calibrating and capable of optimising data with sensors communication according to conditions, as well as achieving high levels of accuracy based on battery life that can last for years. The UtterBerry measures key data in real time.

Heba said: "I'm delighted that UtterBerry has been selected as a smart technology export to China. UtterBerry sensors are already being used at many major infrastructure sites in the UK including Crossrail, Thames Tideway and Tower Bridge and it will be wonderful to see them being used in cities throughout China.

"UtterBerry is the smart technology of today and it has the ability to transform the future of communications in the world of artificial intelligence and play a real part in the creation of the smart cities of the future."

> "I'm delighted that UtterBerry has been selected as a smart technology export to China. UtterBerry sensors are already being used at many major infrastructure sites in the UK including Crossrail, Thames Tideway and Tower Bridge and it will be wonderful to see them being used in cities throughout China.
>
> Heba Bevan

UtterBerry has already received awards for its innovations, including the 2015 Construction Excellence in London and the South East Innovation Award. The judging panel said: "The UtterBerry is a brand new technology… representing a quantum step in measurement sensors – not just providing data but also intuitively merging geo-technical with artificial intelligence."

↑ First prize, James Macleod: Graphene-IPA Ink

# Varied world of engineering shown off using photography and video

**It could be a crystal ball from a mythical age showing the swirling mists of time, but this image of graphene being processed in alcohol to produce conductive ink, has won the Department's annual photography competition.**

This was the first time that James Macleod, a 32-year-old technician at the Department, had entered the ZEISS Photography Competition. His is one of over 100 images that showcase the breadth of research taking place there.

Graphene is a sheet form of carbon that is a single atom thick, which can be produced by successively peeling thin layers off graphite using tape until an individual atomic layer is left. In the ink produced here, powdered graphite is mixed with alcohol then forced at high pressure through micrometre-scale capillaries made of diamond.

The competition, sponsored by ZEISS, international leaders in the fields of optics and optoelectronics, has been held annually for the last 12 years. The panel of judges included Roberto Cipolla, Professor of Information Engineering, Dr Allan McRobie, Professor David Cardwell, Head of Department, and Philip Guildford, Director of Research.

Second prize went to Toby Call for his photo showing an anode-respiring bacteria on a graphene coated carbon foam anodic surface. Biological conductive nanowires can be seen connecting the bacteria to the surface, from which researchers are able to measure current in a microbial fuel cell.

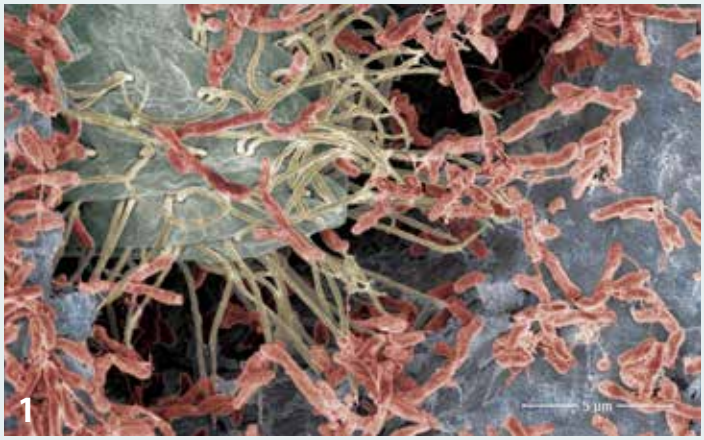
Simon Stent was awarded third prize for an image showing a 2km map of a power tunnel network in London. Due for completion in 2018, the network will channel up to six x 400 kV electricity cables underground, doubling power capacity to the city.

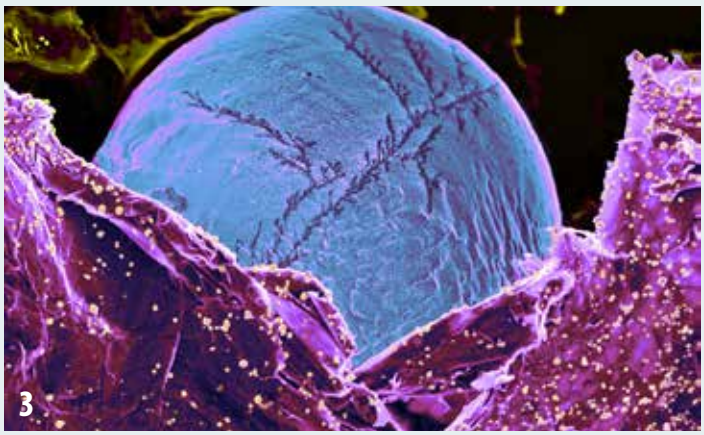
The ZEISS SEM prize went to Dilek Ozgit's image of a zinc-silver oxide battery anode that resembles a moon as seen on an alien world. It features a micron-sized single zinc sphere hiding behind reduced graphene oxide. Nanoparticles in the foreground are zinc redeposited onto the graphene.

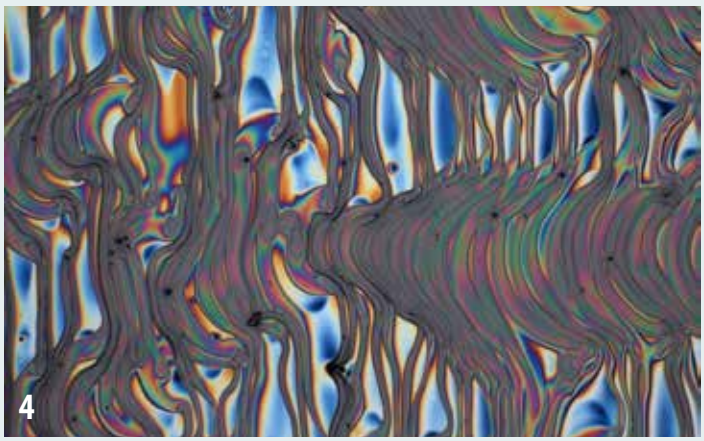
The Head of Department's prize went to a video, 'Reducing fuel consumption of Heavy Goods Vehicle' by Richard Stephens. The video, narrated by Richard, shows clips from a project investigating ways to reduce the fuel consumption of a heavy goods vehicle by lowering the aerodynamic drag of the trailer underbody. Using a high-speed camera, a lorry can be visualised as it moves through a fluid.

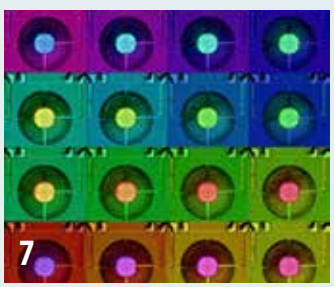
Mr Guildford said: "This year's entries form yet another collection of incredible images that offer us an insight into the varied world of engineering. These photos show how some scientific applications and processes can convey stark beauty. From tiny particles and microscopic images, to sections of tunnel on the Crossrail project in London, these photos represent the full spectrum of engineering."

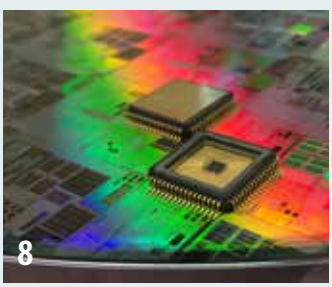
Some of the images submitted to the competition are tiny, and can only be viewed properly through a microscope, while others are on a much grander scale. Behind them all is a passion for the subject matter being studied by the photographer.











1: Second prize. Toby Call, Rhodo graphene anode

2: Ben Seymour and Aya Nawa, International Collaboration

3: SEM prize. Dilek Ozgit, Fractal Moon

4: Yoanna Shams, Printed and dried iron oxide nanoparticles on glass slide

5: Jack Alexander-Webber, Sputtered Cubism

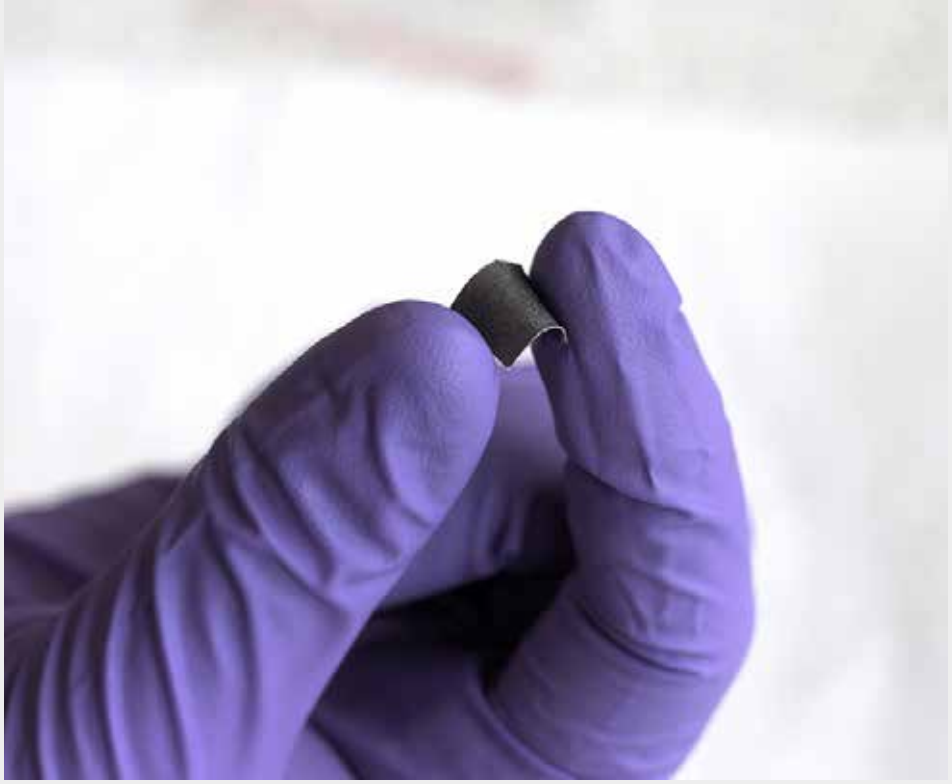
6: Tom Turmezei, Joint space lines

7: Andrea De Luca, A rainbow of micro-hotplates

8: Jiahao Li, Silicon Miracle

**The winning images and video entries can be viewed on the Department's Flickr and YouTube pages:**
www.eng.cam.ac.uk/Flickr
www.eng.cam.ac.uk/YouTube

# Environmentally-friendly graphene textiles could enable wearable electronics



Credit: Dr Sophia Lloyd

**A new method by Department researchers for producing conductive cotton fabrics using graphene-based inks opens up new possibilities for flexible and wearable electronics, without the use of expensive and toxic processing steps.**

Wearable, textiles-based electronics present new possibilities for flexible circuits, healthcare and environment monitoring, energy conversion and many others. Now, researchers at the Cambridge Graphene Centre, working in collaboration with scientists at Jiangnan University, China, have devised a method for depositing graphene-based inks onto cotton to produce a conductive textile.

The work, published in the journal *Carbon*, demonstrates a wearable motion sensor based on the conductive cotton.

Cotton fabric is among the most widespread for use in clothing and textiles, as it is breathable and comfortable to wear, as well as being durable to washing. These properties also make it an excellent choice for textile electronics.

A new process, developed by Dr Felice Torrisi of the Cambridge Graphene Centre and his collaborators, is a low-cost, sustainable and environmentally-friendly method for making conductive cotton textiles by impregnating them with a graphene-based conductive ink.

Based on Dr Torrisi's work on the formulation of printable graphene inks for flexible electronics, the team created inks of chemically modified graphene flakes that are more adhesive to cotton fibres than unmodified graphene. Heat treatment after depositing the ink on the fabric improves the conductivity of the modified graphene. The adhesion of the modified graphene to the cotton fibre is similar to the way cotton holds coloured dyes, allowing the fabric to remain conductive after several washes.

Although numerous researchers around the world have developed wearable sensors, most of the current wearable technologies rely on rigid electronic components mounted on flexible materials such as plastic films or textiles. These offer limited compatibility with the skin in many circumstances, are damaged when washed and are uncomfortable to wear because they are not breathable.

"Other conductive inks are made from precious metals such as silver, which makes them very expensive to produce and not sustainable, whereas graphene is both cheap, environmentally-friendly, and chemically compatible with cotton," said Dr Torrisi.

Co-author Professor Chaoxia Wang of Jiangnan University added: "This method will allow us to put electronic systems directly into clothes. It's an incredible enabling technology for smart textiles."

The work done by Dr Torrisi and Professor Wang, together with students Tian Carey and Jiesheng Ren, opens up a number of commercial opportunities for graphene-based inks, ranging from personal health technology, high-performance sportswear, military garments, wearable technology and fashion.

"Turning cotton fibres into functional electronic components can open up to an entirely new set of applications from healthcare and wellbeing to the Internet of Things," said Dr Torrisi.

"Thanks to nanotechnology, in the future our clothes could incorporate these textile-based electronics and become interactive."

Graphene is carbon in the form of single-atom-thick membranes and is highly conductive. The use of graphene and related 2D material inks to create electronic components and devices integrated into fabrics and innovative textiles is at the centre of new technical advances in the smart textiles industry.

Dr Torrisi and colleagues at the Cambridge Graphene Centre are also involved in the Graphene Flagship, an EC-funded, pan-European project dedicated to bringing graphene and graphene-related technologies to commercial applications.

The research was supported by grants from the European Research Council's Synergy Grant, the International Research Fellowship of the National Natural Science Foundation of China and the Ministry of Science and Technology of China. The technology is being commercialised by Cambridge Enterprise, the University's commercialisation arm.

www.eng.cam.ac.uk/profiles/ft242
www.eng.cam.ac.uk/profiles/tc419
www.graphene.cam.ac.uk
graphene-flagship.eu

ALUMNI UPDATE

# Cambridge tech can track 100,000 items of clothing throughout the store

**It's one of the most frustrating experiences in shopping; you find an item you like but the shop doesn't appear to have it in your size. But now an alumnus and Cambridge entrepreneur says he has found the answer with a revolutionary stock control system.**

Dr Sithamparanathan Sabesan, who was a researcher in the Electrical Engineering Division and who is currently co-founder and CEO of PervasID, says his stock control system can provide intelligence to drive up sales.

According to PervasID, the Space Ranger 9100 system can replace the current 'passive tags' used in many stores. Though these tags are cost-effective and don't need batteries, they have a reliable detection range of only 2–3 metres and so require the shop assistant to check each item with a handheld reader.

Space Ranger uses a network of antennas located discretely at intervals across the shop floor and stockroom. A single radio frequency identification (RFID) reader can cover up to 400 m2 with almost 100% detection accuracy, allowing automatic monitoring of nearly all the tags and constant update of stock control.

PervasID says its system could be particularly beneficial for high street shops that have large and complex stock with a rapid turnover. It maintains records of stock levels, alerts shop assistants to popular items that are selling fast and gives information about other stores that have the item available. It has already been trialled by an unnamed, major high street brand, which installed the readers in a ~4,000 square metre retail store with about 100,000 tagged items. The system covers intake, storage, sales and fitting room areas over two floors.

Dr Sabesan said: "An advantage of having readers located on the ceiling is that movement of items within the store can be monitored in real time, highlighting clothes that are not displayed on sales floors, clothes that are tried on but never purchased, collections of items selected together, and it can track how the shopper moves through the store.

"All of this can be used to help the retailer improve the shopping experience. It also offers opportunity for up-selling by suggesting companion items and alternatives based on success with other shoppers."

The core technologies underlying PervasID's new products were developed by a team in the Department and commercialised through Cambridge Enterprise, which has worked with the founders since 2009. Cambridge Enterprise Seed Funds led a £720k investment round for PervasID which was announced in October 2016.

Gillian Davis, Cambridge Enterprise technology manager, said: "It is absolutely fantastic to see PervasID move into the next phase. The founders have worked so hard on this."

The potential for the PervasID system has been recognised by Victor Christou, CEO of Cambridge Innovation Capital (CIC). CIC invests long-term, 'patient capital' into companies in the Cambridge cluster, including PervasID, that have disruptive technologies and the potential to become significant players.

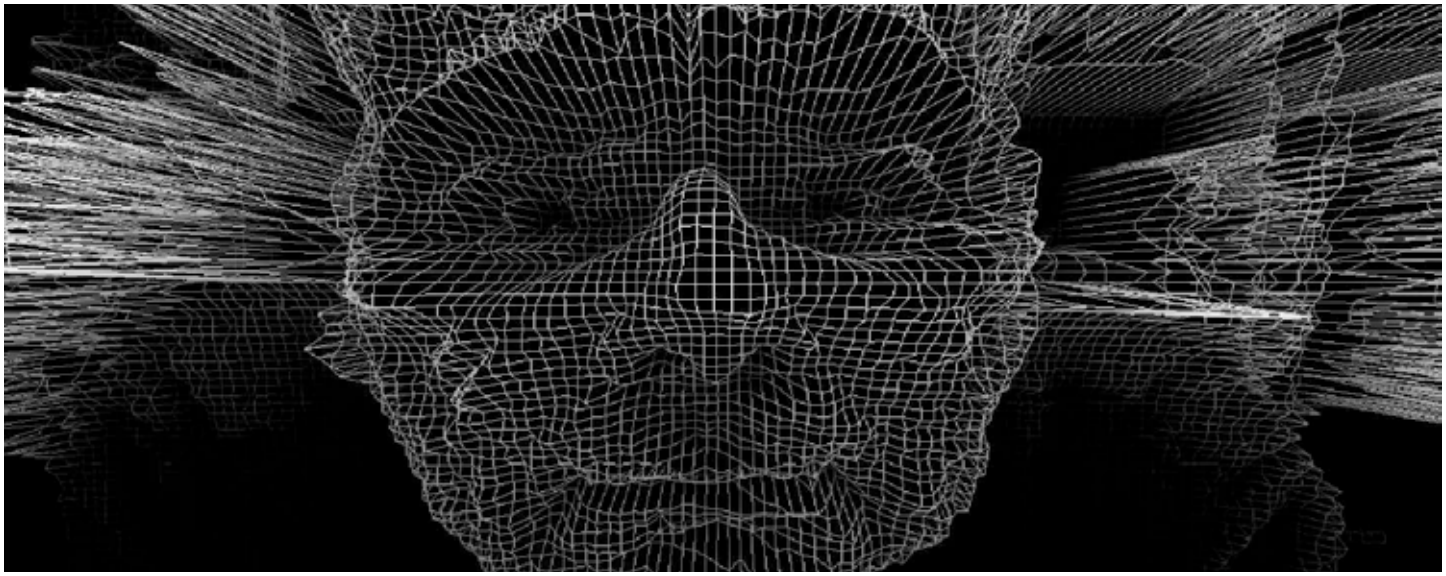
Christou said: "Low cost, long distance sensing of passive RFID tags is an unmet need in the retail and logistics industries. PervasID offers a new approach that facilitates a move towards the 'Internet of Things' while offering potential for a significant return on investment in the short term.

> "Movement of items within the store can be monitored in real-time, highlighting clothes that are not displayed on sales floors, clothes that are tried on but never purchased, collections of items selected together.
>
> Dr Sithamparanathan Sabesan

"The retailers that we have introduced to PervasID are excited by the potential of the technology to boost sales in their high street stores."

Space Ranger 9100 provides greatly extended coverage area compared to PervasID's current reader, requiring 60% fewer readers and significantly reducing the cost of installation. PervasID is also launching Gate Ranger 9100, a portal reader for strategic locations, such as entrances and exits and loading areas. This provides highly accurate portal solution with tag direction capability.

enterprise.cam.ac.uk
www.cambridge-news.co.uk/business/technology/cambridge-tech-can-track-100000-12161782
www.eng.cam.ac.uk/research/academic-divisions/electrical-engineering-0



Credit: thierry ehrmann on Flickr

## Artificial intelligence

# Computer says YES (but is it right?)

**Computers that learn for themselves are with us now. As they become more common in 'high-stakes' applications like robotic surgery, terrorism detection and driverless cars, Cambridge researchers ask: what can be done to make sure we can trust them?**

We are now in the era of machine learning. Machines can be trained to recognise certain patterns in their environment and to respond appropriately. Machine learning is a way to program computers to learn from experience and improve their performance in a way that resembles how humans and animals learn tasks.

Zoubin Ghahramani, Professor of Information Engineering, says that as machine learning techniques become more common in everything from finance to healthcare, the issue of trust is becoming increasingly important.

For example, faced with a life or death decision, would a driverless car decide to hit pedestrians, or avoid them and risk the lives of its occupants?

In May 2016, Joshua Brown had engaged the autopilot system in his Tesla when a tractor-trailer drove across the road in front of him. It seems that neither he nor the sensors in the autopilot noticed the white-sided truck against a brightly lit sky, with tragic results. According to Tesla this was the first known fatality in over 130 million miles of driving with activated autopilot. In fact, given that most road fatalities are the result of human error, it has been said that autonomous cars should make travelling safer. Even so, the tragedy raised a pertinent question: how much do we understand – and trust – the computers in an autonomous vehicle? Or, in fact, in any machine that has been taught to carry out an activity that a human would do?

"Machines can now achieve near-human abilities at many cognitive tasks even if confronted with a situation they have never seen before, or an incomplete set of data," said Professor Ghahramani. "But what is going on inside the 'black box'? If the processes by which decisions were being made were more transparent, then trust would be less of an issue."

Professor Ghahramani's team builds the algorithms that lie at the heart of these technologies (the 'invisible bit' as he refers to it). Trust and transparency are important themes in their work.

"We really view the whole mathematics of machine learning as sitting inside a framework of understanding uncertainty," he said. "Before you see data – whether you are a baby learning a language or a scientist analysing some data – you start with a lot of uncertainty and then as you have more and more data you have more and more certainty.

"When machines make decisions, we want them to be clear on what stage they have reached in this process. And when they are unsure, we want them to tell us."

One method is to build in an internal self-evaluation or calibration stage so that the machine can test its own certainty and report back.

Two years ago, Ghahramani's group launched the Automatic Statistician with funding from Google. The tool helps scientists analyse datasets for statistically significant patterns and crucially, it also provides a report to explain how sure it is about its predictions.

"The difficulty with machine learning systems is you don't really know what's going on inside – and the answers they provide are not contextualised, like a human would do. The Automatic Statistician explains what it's doing, in a human-understandable form."

Trust and transparency forms just one of the projects at the newly launched £10 million Leverhulme Centre for the Future of Intelligence (CFI). Ghahramani, who is Deputy Director of the Centre, explains: "It's important to understand how developing technologies can help rather than replace humans. Over the coming years, philosophers, social scientists, cognitive scientists and computer scientists will help guide the future of the technology and study its implications – both the concerns and the benefits to society."

Artificial intelligence has the power to eradicate poverty and disease or hasten the end of human civilisation as we know it – according to a speech delivered by Professor Stephen Hawking (19 October 2016) at the launch of the CFI.

www.eng.cam.ac.uk/profiles/zg201
www.eng.cam.ac.uk/profiles/aw665
lcfi.ac.uk


# Cambridge students spark international electric vehicle collaboration

**Cambridge University Eco Racing (CUER), the UK's leading solar car racing team, has attracted support from around the globe for their campaign to climb the global solar racing rankings.**

Set to compete at the Bridgestone World Solar Challenge in October 2017, this is the team's strongest bid for a top spot at the World Solar Challenge and as a result they have increased their support-raising targets and efforts.

The team has been developing a unique vehicle concept since 2012 and in 2015, became the most successful UK entrant in the Bridgestone World Solar Challenge, the foremost solar racing competition in the world, since 2007.

Latest to get on board with CUER are international companies Qoros and Mazak, both of which are leaders in the automotive and manufacturing industries.

Qoros, an automotive original equipment manufacturer (OEM) in China, develops vehicles that are differentiated in their design, safety and connected services and that exhibit international standards of quality. In the growing Chinese automobile market, Qoros has an exceptional position, with a brand identity and product positioning that is clearly distinguishable from domestic car manufacturers and international joint ventures.

"Qoros is glad to support the CUER team through their journey to the World Solar Challenge," said Dr Leon Liu, Chief Operation Officer of Qoros Auto.

"As a new and innovative force in the auto industry, Qoros is dedicated to becoming a transformational company that embraces the future mobile life. With this vision, we've been working vigorously to speed-up the development of alternative energy technologies as well as support endeavors made by partners and institutions to raise awareness and spark discussions."

Yamazaki Mazak was established in 1919 and has been contributing to the development of the machine tool industry as a leading global company. Yamazaki Mazak manufactures not only advanced machine tools such as multi-tasking centres, CNC turning centres, machining centres and laser processing machines, but also automation systems with the concept of DONE IN ONE to support global manufacturing by providing exceptional productivity and versatility.

Marcus Burton, European Managing Director for Mazak, said: "Mazak Europe is proud to be a supporter of CUER. Encouraging innovation in sustainable vehicle technologies is to be applauded and CUER shares Mazak's aim to provide the inspiration for more young people to seek their future in engineering."

> "Mazak Europe is proud to be a supporter of Cambridge University Eco Racing (CUER). Encouraging innovation in sustainable vehicle technologies is to be applauded and CUER shares Mazak's aim to provide the inspiration for more young people to seek their future in engineering.
>
> Marcus Burton, European Managing Director for Mazak

As the team finalise their latest car design work and turn their attentions to manufacturing, they are looking for further partners to join them on their journey. If you are interested in getting involved in the adventure, visit www.cuer.co.uk

# Inventor Dr John C Taylor OBE donates £2.5m for Cambridge Professorship of Innovation

**Dr John C Taylor OBE is donating £2.5 million to the University of Cambridge to set up the Professorship of Innovation, a prestigious new chair at the world-leading Department of Engineering.**

"I wish to celebrate British ingenuity and inventiveness," he said. "It's essential to develop inventions into production for the benefit of the creator, while generating local employment through manufacturing growth.

"Too little is discussed these days about business financial freedom and job creation, while too much attention is paid to venture capitalist business models, which can leave an inventor with little ownership. One of my proudest achievements in business is that I never borrowed a penny from anyone. This is because I always focussed on cash flow and used the revenue from manufacturing to fund innovation.

"I very much look forward to being invited to talk on this subject and spread the message of practical manufacturing throughout the engineering community."

In 2008, Dr John C Taylor (Corpus 1956) created and donated to his former college the popular Corpus Chronophage Clock, positioned outside the Taylor Library at Corpus, which has now become one of the city's most popular tourist attractions.

The new professorship, which has been endowed in perpetuity, will combine teaching and research to ensure young engineers unite innovation with practicality when approaching design.

Professor David Cardwell, Head of the Department of Engineering, said: "We are extremely grateful for this generous benefaction from Dr John C Taylor and honoured that this professorship will not only bear the name of such a distinguished inventor and engineer, but will help future generations to follow in his footsteps."

↑ Dr John C Taylor in front of the popular Corpus Chronophage Clock, that he created and donated to his former college

Cambridge launched its £2 billion Dear World… Yours, Cambridge philanthropic campaign for the University and Colleges in October 2015. It has just celebrated its most successful fundraising year ever, raising more than £210 million including Dr John C Taylor's gift.

www.philanthropy.cam.ac.uk

> We are extremely grateful for this generous benefaction from Dr John C Taylor and honoured that this professorship will not only bear the name of such a distinguished inventor and engineer, but will help future generations to follow in his footsteps.
>
> Professor David Cardwell

# Robin Jackson Design Fund

After graduating from Trinity Hall, Robin Jackson completed his National Service before working for a period in industry. In 1965, he was appointed Lecturer in Electrical Engineering and elected a Fellow of Selwyn College.

In 1995, Robin fell ill and, very sadly, died aged 57.

Robin made a large number of significant contributions to the Department. He was an extremely conscientious and very popular teacher. When the Engineering Tripos was reformed into the current 4-year MEng course in the early 1990s, he was a key member of the team that set up the 2nd year Integrated Design Project (IDP), which ran for the first time in October 1993.

Many of his research efforts were directed at improving the lives of disabled people and he became a pioneer and world leader in Rehabilitation Robotics.

He was extremely self-effacing and his obituary in the Selwyn Calendar ended: 'He will be remembered … as a man who did much good quietly.'

To recognise Robin's significant contributions to Design Education and Rehabilitation Robotics, a permanent Robin Jackson Design Fund has been created in the Department's Dyson Centre for Engineering Design.

www.dysoncentre.eng.cam.ac.uk/robin-jackson-design-fund

# Waterworld

## Can we learn to live with flooding?


Credit: Edward Barsley

**Flash floods, burst riverbanks, overflowing drains, contaminants leaching into waterways: some of the disruptive, damaging and hazardous consequences of having too much rain. But can cities be designed and adapted to live more flexibly with water – to treat it as friend rather than foe?**

This is the question being considered by the Department's engineers following the disruption caused by flooding brought about by Storm Desmond, for example, which hit the north of the UK in December 2015.

In its wake came floods, the misery of muddy, polluted water surging through homes and the disruption of closed businesses, schools and roads.

With rapid urban growth and progressively unpredictable weather, the resilience of cities worldwide will become increasingly tested in this way – and not just to extreme events but even to heavier-than-normal rainstorms. How can flood risk be managed?

There is of course no 'one-size-fits-all' strategy. For some communities, defence is a possibility. For others, retreat is the only option.

"But for those unable to do either, we need to fundamentally rewrite the rule book on how we perceive water as a hazard to towns and cities," says Ed Barsley, PhD student working with Dr Emily So in the Cambridge University Centre for Risk in the Built Environment (CURBE).

Barsley believes that adaptation and planning for resilience can provide a unique opportunity for increasing the quality of towns and cities.

Dr Dick Fenner, Reader in Engineering Sustainability, agrees that resilience to water should be regarded positively. He is currently part of the UK-wide Urban Flood Resilience project, which is developing strategies to manage urban flood risk in ways that also pay dividends in many other areas, through 'greening' the city and capturing storm water as a resource.

"We want to turn rainfall into a win-win event," he says.

When it comes to dealing with floods, one of the major difficulties that many cities face is the impermeability of the built environment. In a city that is paved, concreted and asphalted, surface water can't soak away quickly and naturally into the earth.

Newcastle city centre, for instance, is around 92% impermeable, and has suffered major flooding in the past. "The 'flood footprint' of the 2012 'Toon Monsoon' caused around £129 million in direct damages and £102 million in indirect damages, rippling to economic sectors far beyond the physical location of the event," says Dr Fenner.

"Traditionally, cities have been built to capture water run-off in gutters and drains, to be piped away. But where is away? And how big would we have to build these pipes if the city can't cope now?" he adds.

Cities worldwide are already taking up the concept of 'greening', using permeable paving, bioswales (shallow ditches filled with vegetation), street planting, roof gardens and pocket parks. Green infrastructure benefits health and biodiversity and can help combat rising $CO_2$ levels, heat island effects, air pollution and noise.

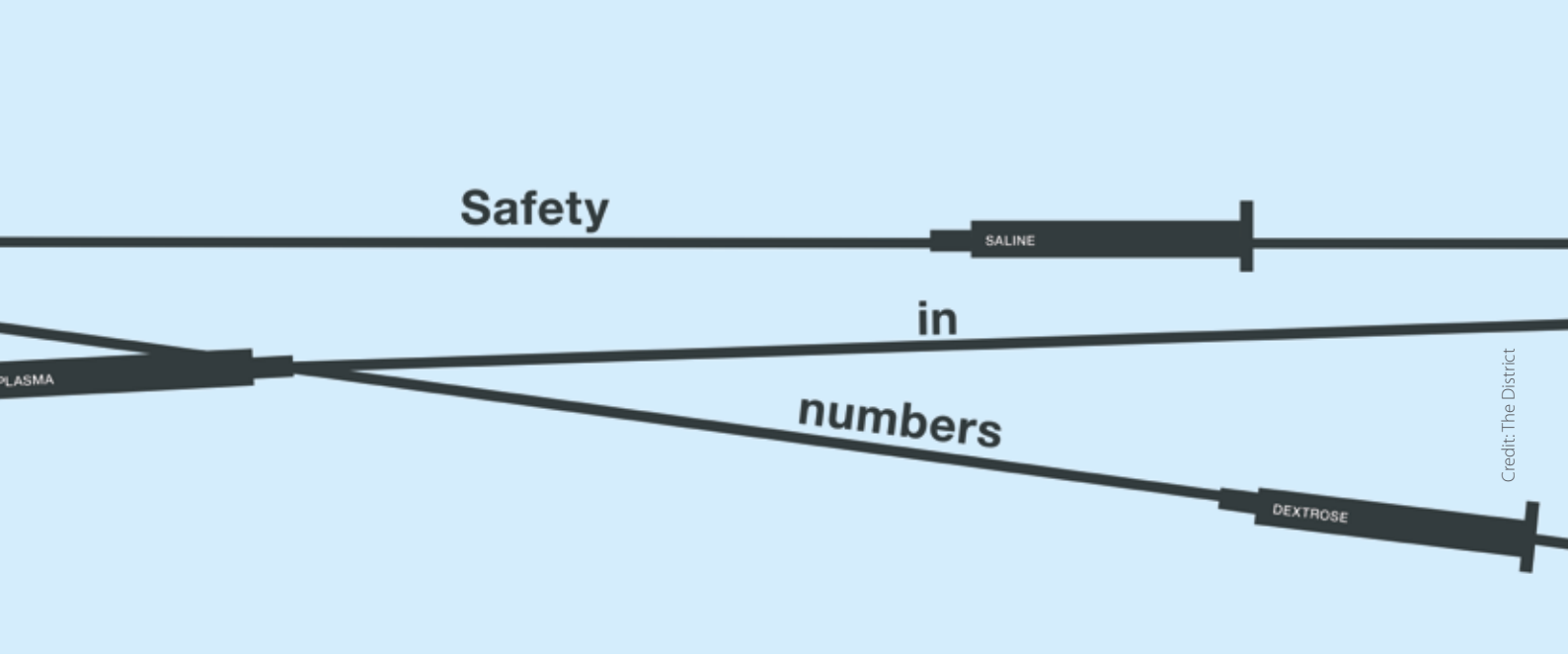
One of the major outputs from the Blue-Green Cities project, (completed by Fenner and his colleagues in 2016) is a 'toolbox' for authorities, planners, businesses and communities to decide on the best options. The tools were developed by evaluating the performance benefits of green infrastructure gathered from sites in both the UK and USA.

The principle behind a 'Blue–Green City' is to create a more natural water cycle – one in which the city's water management and its green infrastructure can be brought together.

As part of an ongoing demonstration study in Newcastle, a Learning Action Alliance network was set up with local stakeholders that has, says Fenner, led to opportunities for Newcastle that reflect the priorities and preferences of communities and local residents. The work is currently being extended in a new study area of Ebbsfleet and is developing similar partnerships with local stakeholders.

Now, Newcastle City Council, the Environment Agency, Northumbrian Water, Newcastle University, Arup and Royal Haskoning DHV, have combined to be the first organisations in the country to explicitly commit to a blue-green approach, as recommended by the research. The hope is that other local and national organisations will follow suit.

www.bluegreencities.ac.uk
www.urbanfloodresilience.ac.uk
www.eng.cam.ac.uk/profiles/raf37




# Keeping patients safe in hospital

**Healthcare is a complex beast and too often problems arise that can put patients' health – and in some cases, lives – at risk. A new collaboration involving the Department's engineers hopes to get to the bottom of what's going wrong – and to offer new ways of solving the problems.**

In November 2004, Mary McClinton was admitted to Virginia Mason Medical Center in Seattle, USA, to receive treatment for a brain aneurysm, a potentially serious swelling in a blood vessel. What followed was a tragedy, made worse by the fact that it was entirely preventable.

McClinton was mistakenly injected with the antiseptic chlorhexidine. It happened, the hospital says, because of 'confusion over the three identical stainless steel bowls in the procedure room containing clear liquids — chlorhexidine, contrast dye and saline solution'. Doctors tried amputating one of her legs to save her life, but the damage to her organs was too great: McClinton died 19 days later.

Nine years on, an almost identical accident occurred at Doncaster Royal Infirmary in the UK. Here, the patient, 'Gina', survived, but only after having her leg amputated.

Professor John Clarkson, Director of the Cambridge Engineering Design Centre, is working with Professor Mary Dixon-Woods, RAND Professor of Health Services Research, Department of Public Health and Primary Care, who is on a mission to improve patient safety in the National Health Service and in healthcare worldwide.

Professor Dixon-Woods, who also serves as co-director of the Cambridge Centre for Health Services Research (CCHSR), compares the issue of patient safety to that of climate change, in the sense that it is a 'problem of many hands', with many actors, each making a contribution towards the outcome, and where it is difficult to identify who has responsibility for solving the problem.

"Many patient safety issues arise at the level of the system as a whole, but policies treat patient safety as an issue for each individual organisation," she said.

Nowhere is this more apparent than the issue of 'alarm fatigue'. Each bed in an intensive care unit typically generates 160 alarms per day, caused by machinery that is not integrated.

"You have to assemble all the kit around an intensive care bed manually," she explains. "It doesn't come built as one like an aircraft cockpit. This is not a problem a hospital can solve alone. It needs to be solved at the sector level."

Professor Clarkson has been interested in patient safety for over a decade; in 2004, his team published a report for the Chief Medical Officer entitled 'Design for patient safety – a system-wide design-led approach to tackling patient safety in the NHS'.

"Fundamentally, my work is about asking how can we make it better and what could possibly go wrong," explains Professor Clarkson.

It is not, he says, just about technology, but about the system and the people within the system. When he trains healthcare professionals, he avoids using words like 'risk', which mean different things in medicine and engineering, and instead asks questions to get them thinking about the system.

"We need to look through the eyes of the healthcare providers to see the challenges and to understand where tools and techniques we use in engineering may be of value," he said. "I have no doubt that if you were to put 100 engineers into Addenbrooke's [Hospital], you could help transform its care."

There is a difficulty, he concedes: "There's no formal language of design in healthcare. Do we understand what the need is? Do we understand what the requirements are? Can we think of a range of concepts we might use and then design a solution and test it before we put it in place? We seldom see this in healthcare, and that's partly driven by culture and lack of training, but partly by lack of time."

Professor Dixon-Woods agrees that healthcare can learn much from how engineers approach problems.

"Medical science tends to prioritise trials and particular types of evidence, whereas engineering does rapid tests," she said. "Randomised controlled trials do have a vital role, but on their own they're not the whole solution. There has to be a way of getting our two sides talking."

Only then, she says, will we be able to prevent further tragedies such as the death of Mary McClinton.

www.eng.cam.ac.uk/profiles/pjc10


# New 'green' fertiliser could contribute to food revolution

**A new synthetic fertiliser could help farmers save money, boost food production and reduce planet-warming emissions, say scientists following trials on rice farms in Sri Lanka.**

By slowing down the release of nutrients, the fertiliser will help farmers to increase crop yields using fewer chemicals, the researchers from Britain and Sri Lanka said.

Chemical fertilisers such as the nitrogen-rich urea were key to the agricultural boom of the 1960s and 70s known as the 'Green Revolution', but their cost remains relatively high for farmers in the developing world.

Agricultural production must rise by about 60% to feed a growing global population, expected to reach 9 billion by 2050, according to the United Nation's Food and Agriculture Organisation (FAO).

Urea, commonly used to grow rice, wheat and maize, dissolves quickly when in contact with water and part of its nutrients are washed away before crop roots can absorb them.

As a consequence, more applications are needed, which can prove too expensive for farmers in poor regions, the scientists wrote in the scientific journal *ACS Nano*.

Moreover, unabsorbed urea particles go on to form ammonia that pollutes waterways and eventually causes the release of greenhouse gases into the atmosphere.

The new fertiliser delays the dissolution of urea by binding it with a mineral to slow down the release of nutrients by 12 times.

Gehan Amaratunga, Professor of Engineering and co-author of the report, said: "The plant takes up more of the fertiliser and less is wasted. This goes a long way to reducing the environmental footprint of agriculture."

Initial trials using the new fertiliser on rice farms in Sri Lanka showed production increased by up to 20% using almost half the amount of fertiliser.

Professor Amaratunga added that he hoped the innovation could help usher in a new, more eco-friendly Green Revolution.

> "The plant takes up more of the fertiliser and less is wasted. This goes a long way to reducing the environmental footprint of agriculture.
>
> Professor Gehan Amaratunga

www.eng.cam.ac.uk/profiles/gaja1

→ Dr Timothy O'Leary

# Do the neurons in our bodies really behave like a sushi conveyor belt?

Credit: Fulvio Forni

**Chris Smith of the Naked Scientists Radio Show interviewed Dr Timothy O'Leary, Lecturer in Information Engineering and Medical Neuroscience, on the Neuronal sushi belt.**

The nerves or neurons that send messages from one end of the body to the other have fascinated anatomists for over a century. An outstanding question is: how do these cells, which can be metres in length, keep all of the remote parts of the cell supplied with energy and raw materials (which are normally made in just one central region of the cell)?

One popular idea is that neurons contain the microscopic equivalent of a conveyor belt system which transports materials to where they need to go inside the cell. Chris Smith met one scientist who has found that anyone waiting for their dinner to be delivered by a system like this would end up very hungry indeed, so something else must be going on…

**Timothy** – We're in a sushi restaurant in Cambridge and it's one of those sushi restaurants that has a snazzy belt mechanism that allows all of the dishes to be delivered to the customers as they sit around the sushi belt.

**Chris** – What has this got to do with cell biology?

**Timothy** – The cells I'm interested in are neurons, and neurons are the cells that essentially make your brain work. A typical person has around 86 billion neurons and one neuron can, potentially, connect thousands of other neurons and it's this connectivity that gives your brain its power.

If we looked at a neuron under a microscope, it would look like a tree, a very bushy tree with lots of branches and some of them very long. If we were to zoom into this neuron and look inside one of the branches, we'd see there are lots of things moving up and down the branch. And this is because neurons are composed of lots of proteins and small components that all need to be manufactured and moved around inside the cell.

Sometimes, material needs to be made in one part of the cell and then shuttled along to another part of the cell. The analogy that we use is the sushi belt because there really is something inside the cell that moves this cargo along in a similar fashion to a sushi belt.

**Chris** – So you can imagine this analogy: the nucleus is the recipe book with the chef standing there cooking stuff, putting it on the plates that then go on the sushi belt. They're then carted around the cell and the customers (the parts of the cell that need them) are going to be lifting dishes off the sushi belt at various points and using them.

**Timothy** – But life isn't really like that. At the molecular level the movements of these particles are stochastic, that means that there's a chance element in it. To explain what that would mean in the sushi restaurant analogy, let's imagine that we're waiting for a tuna roll and it's a few feet away, but then randomly the belt changes direction and starts moving the other way. That would be very frustrating. But what would be even more frustrating is if the person next to us, who doesn't even want the tuna roll, just took the tuna roll, sat it on their table for a while and then maybe decided to put it back on the belt. Those are the kinds of things that can occur at the molecular level by chance and it's for this reason, that we can expect long delays sometimes in this transport mechanism within a neuron.

**Chris** – Are you saying that there must be something else going on because cells would not be able to put up with that?

**Timothy** – That was actually the motivation for this study. What we did was we took experimental data where scientists had measured the movements of these microscopic particles. Then we simply took the measurements and we did the math and we figured out how long it would take, on average, a collection of particles to move across a typical sized neuron and the number turned out to be disappointingly large. It can take many hours or days to distribute cargo throughout a typical neuron. And this came as a surprise because many of us thought that cargo could be distributed on the order of minutes or hours at the very worst.

In recent years, it's been observed that neurons do have the capacity to make things that they need locally. However, the ingredients for the things that they make locally, and the machinery for making them, still need to be delivered to those sites and our claim is that that may take a lot longer than what is currently thought.

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# Honours, awards and prizes

### Honour for pioneers in digital imaging

The 2017 Queen Elizabeth Prize for Engineering was awarded to four pioneers in digital imaging, a group that includes alumnus Michael Tompsett (left).

The £1 million prize celebrates world-changing engineering innovations. Eric Fossum, George Smith, Nobukazu Teranishi and Tompsett – engineers responsible for the creation of digital imaging sensors – were all honoured.

Their innovations, that revolutionised the visual world, include the charge coupled device (CCD), the pinned photodiode (PPD) and the complementary metal oxide semiconductor (CMOS) image sensor.

Lord Browne of Madingley, Chair of the Queen Elizabeth Prize for Engineering Foundation, said: "The spirit of international collaboration driving the work of George Smith, Michael Tompsett, Nobukazu Teranishi and Eric Fossum encapsulates perfectly the ideals of the QEPrize. In honouring them we hope to inspire the next generation of engineers to continue to push back the frontiers of the possible."

### Engineering postdocs win first prizes and financial investment

Dr Giorgia Longobardi with Cambridge GaN Devices, and Dr Max Bock with Netwookie, have been announced as the winners of the Cambridge Postdoc Enterprise Competition grand finale, and each secured a £20,000 investment.

The pitches for investment were of such a high standard and the judges could not choose between the two winners, so it was decided to award two prizes of £20,000. Among the finalists was Dr Myriam Ouberai (also from Engineering) with Spirea.

The Cambridge Postdoc Enterprise Competition is run jointly by Cambridge Enterprise and the Entrepreneurial Postdocs of Cambridge, and is open to all postdocs at the University of Cambridge.

The competition will open again for entries in May 2017.

### Professor Phil Woodland elected Fellow of Royal Academy of Engineering

Philip Woodland, Professor of Information Engineering, has been elected Fellow of the Royal Academy of Engineering.

Professor Woodland has carried out pioneering work in the development of large vocabulary speech recognition, both in academia and industry. His contributions include the invention of a technique for adapting recognisers automatically to different speakers and the development of a framework for discriminatively training acoustic models to minimise errors. Both are widely used in today's commercial speech recognition systems.

The Royal Academy of Engineering welcomed 50 of the UK's finest engineers as new Fellows following its 40th annual general meeting.

### Alumnus named 'Young Design Engineer of the Year'

Alumnus of the Institute for Manufacturing (IfM) Manufacturing Engineering Tripos (MET) Christopher Bellamy was named 'Young Design Engineer of the Year' at the British Engineering Excellence Awards.

Christopher was recognised for inventing, designing and developing creative and novel solutions for customer problems while working at Jaguar Land Rover. He pioneered a human-centric design process and working closely with the company's consumer insight and human factors teams, he has delivered outstanding results.

Christopher said that the MET course at the IfM played 'a pivotal role in inspiring, educating, and leading [him] in the right direction'.

### Dame Ann Dowling receives the James Watt International Gold Medal

Professor of Mechanical Engineering and Deputy Vice-Chancellor at the University Dame Ann Dowling has been awarded the prestigious medal for excellence in engineering.

The James Watt International Gold Medal is presented every two years to an eminent engineer who has attained worldwide recognition in mechanical engineering.

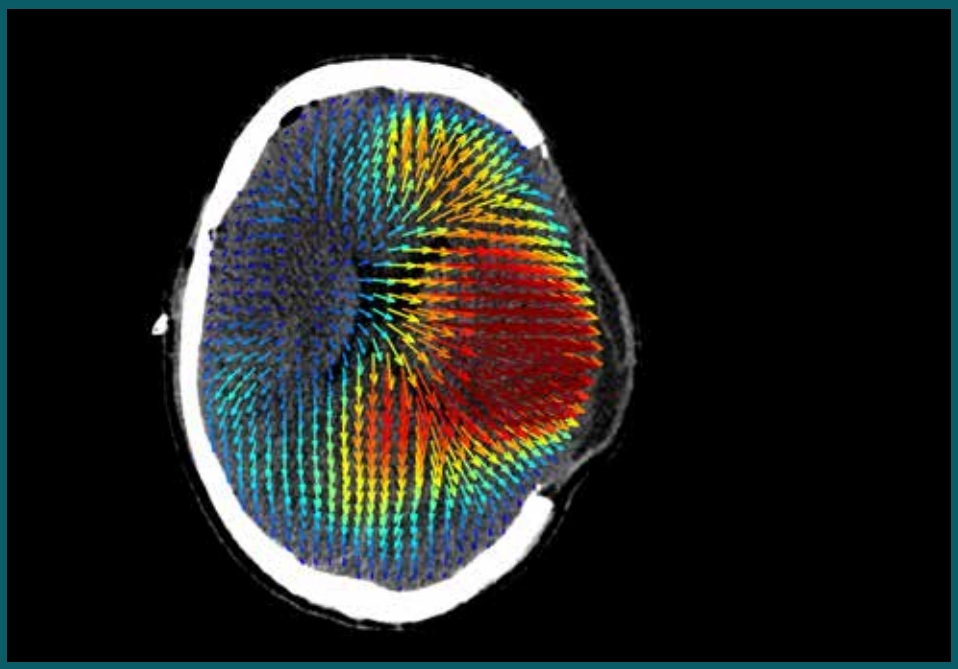
### Public Engagement with Research Awards

The winners of the 2016 Public Engagement with Research Awards are Mr Bill Nicholl, Lecturer in Design Technology for the Faculty of Education, and Mr Ian Hosking, a Senior Research Associate in the Engineering Design Centre.

They are co-founders of Designing Our Tomorrow (DOT), a platform for transforming design and technology (D&T) education in schools.

Their public engagement initiative began in 2009 and brought together research around inclusive design and creativity in education. Through production of their DOT box set of tools, Bill and Ian have taken active research questions into the classroom and given students control of designing technological solutions.

Engagement with teachers, students and policymakers is integral to the success of their initiative and has resulted in engineering design being included in the National Curriculum and GSCE qualifications. New classroom resources and research partnerships are continually under development.



→ Analysis of shear strain on brain having undergone decompressive craniectomy

# Engineering solutions to traumatic head injuries

**Researchers in the Biomechanics Group, in collaboration with the Department of Clinical Neurosciences, have gained deeper understanding into the mechanics of the skull that can lead to better ways to treat patients with traumatic brain injuries.**

A paper, published recently in *Annals of Biomedical Engineering*, explores some of the clinical issues surrounding decompressive craniectomy. Patients who have suffered traumatic injuries to the head, are victims of stroke or are experiencing a number of other illnesses or infections might undergo severe swelling of the brain. The worry is that, left alone, intracranial pressure can build and permanently damage the brain.

In a decompressive craniectomy, parts of the skull are removed surgically with the goal of allowing the brain to swell without causing damage. This procedure is not without controversy and it is still something of an open question as to how the operation can be optimised to lead to the most positive outcomes for the patient.

To tackle this problem, a cross-disciplinary team of Cambridge researchers wanted to model just how a craniectomy affects the brain. The work was a collaboration between a team led by Dr Michael Sutcliffe, Head of the Biomechanics Group, and a team from the Division of Neurosurgery at Addenbrooke's Hospital that included Professor Peter Hutchinson (Professor of Neurosurgery), Dr Angelos Kolias (Clinical Lecturer in Neurosurgery), and Hadie Adams (Clinical Research Fellow).

The engineering approach to craniectomy included looking at how to balance the trade-off between the size of the hole in the skull and the shear strain in the brain.

"This trade-off means that in theory the bigger you make the hole the better it will relax the pressure and you'll get smaller regions of damage," Dr Sutcliffe said. "But this has side-effects associated with it in the sense that if you have a bigger hole you might get an infection or it might be more difficult to reconstruct the skull."

To find the right balance, Dr Sutcliffe's team considered different sizes of holes to try to discover an optimal point where a further increase in the size of the skull opening no longer gave any benefits in terms of reduced damage.

"Imagine if you took out half the skull – that would be unreasonable clinically," Dr Sutcliffe said. "But our modelling offers some guidelines and helps understand how large a part of the skull should be removed to avoid undesirable side effects."

According to Dr Kolias, bioengineering approaches such as the one described in the paper can help neuroscientists better understand the effects of craniectomy on brain tissue. This work is related to recently published results of a 10-year-long RESCUEicp trial that examined the role of craniectomy as a last-tier therapy for head-injured patients with refractory intracranial hypertension.

"The results confirmed the life-saving nature of the operation," Dr Kolias said. "However, the outcomes of survivors ranged from vegetative state through varying states of disability to good recovery. Hence, there is a real need to understand the factors that could affect the outcome of patients following craniectomy.

"A multidisciplinary approach to the issue of brain deformation following craniectomy will play a central role in the efforts to optimise patient outcomes," he added.

> "Our modelling offers some guidelines and helps understand how large a part of the skull should be removed to avoid undesirable side effects."
>
> Dr Michael Sutcliffe

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