

DEPARTMENT OF ENGINEERING
NEWS

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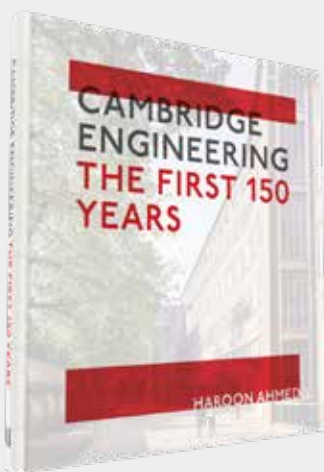
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Cambridge Engineering The First 150 Years

"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

Cover image: Heartsense monitor. Credit: Cambridge Heartwear.

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Note from the editors

Research collaboration is essential for engineering as solutions so often involve the successful integration of technical, industrial, regulatory and social systems. Team work came to the fore in the summer, when the Department of Engineering, as part of the Quantum Communications Hub, helped launch the UK's first quantum network between three sites in the city, enabling 'unhackable' communications, made secure by the laws of physics. You can read more about this on Page 4.

The University's outstanding performance in research and development has also been officially recognised by Boeing, with an award that pays tribute to a research partnership with the Department of Engineering that stretches back 15 years. Read more about this achievement on Page 7.

Engineering now routinely crosses the traditional boundaries between disciplines. On Page 10, we take a look at brain interfaces, bioelectronics and human disease. From his lab in the Nanoscience Centre, Professor George Malliaras is busy researching how bioelectronics and organic electronics can be used to create novel implantable devices that interface with the brain, and which could treat a range of diseases.

The theme of collaboration and networking continues with news of the Cambridge University Engineers' Association (CUEA). The association is run by alumni for alumni. CUEA President, Brian Phillipson, has led an exciting relaunch of the association and is reaching out to all past students and staff. To get in touch, email: cueaenquiries@eng.cam.ac.uk

Charlotte Hester and Jacqueline Siggers

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New Head of Department Professor Richard Prager



Profile

Richard's research focuses on the development of better non-invasive diagnostic medical imaging systems based on ultrasound.

Significant projects have included new fast and accurate calibration systems for tracked 3D ultrasound, the development of a high definition tracked 3D ultrasound system, innovative work on image-based freehand 3D ultrasound without an external tracking device, real-time 3D ultrasound deconvolution for image enhancement and three-dimensional elastography. He also led a project to develop a hybrid scanner that combines the benefits of both tracked and mechanically-swept 3D ultrasound.

He is currently working on novel algorithms for high-resolution ultrasonic beam-forming.

He was Deputy Head of Department, responsible for undergraduate teaching, from 2006 to 2012.

Most recently, he has been Head of the University School of Technology from 2014 to 2018.

He has an ongoing interest in developing web resources to help applicants prepare for university admissions interviews in engineering (i-want-to-study-engineering.org).

www.eng.cam.ac.uk/profiles/rwp12

When I was at school, a friend gave me a little book called "The Great Crash 1929". In it, J K Galbraith describes the causes and consequences of the great American stock market crash. When summing up the lessons learned from this piece of economic history, he remarks that "very specific and personal misfortune awaits those who presume to believe that the future is revealed to them".

Yet predicting the future appears to be a regular necessity for engineering academics. We must understand which problems will be most important and what innovations will be key to solving them. In the past, Cambridge has been rather good at this. How can this be? People in Cambridge are not imbued with a gift for foretelling the future any more than anyone else.

To some extent, our success in identifying and solving problems is because of

the unusually high degree of individual academic autonomy that we enjoy. Academics can work on what they want, how they want and for as long as they want. This leads to a great benefit. Instead of just one engineering vision for the future, we have hundreds. The chances of achieving breakthroughs are greatly multiplied.

Academic freedom is a key strength of the Cambridge culture, but it is under threat from external pressures. My priority as Head of Department is to celebrate this strength and demonstrate that it is as valuable as ever in meeting the complex challenges posed by a fast-paced, uncertain world.

I look forward to keeping you informed of our progress in future newsletters.

**Professor Richard Prager FEng,
FIET, CEng**

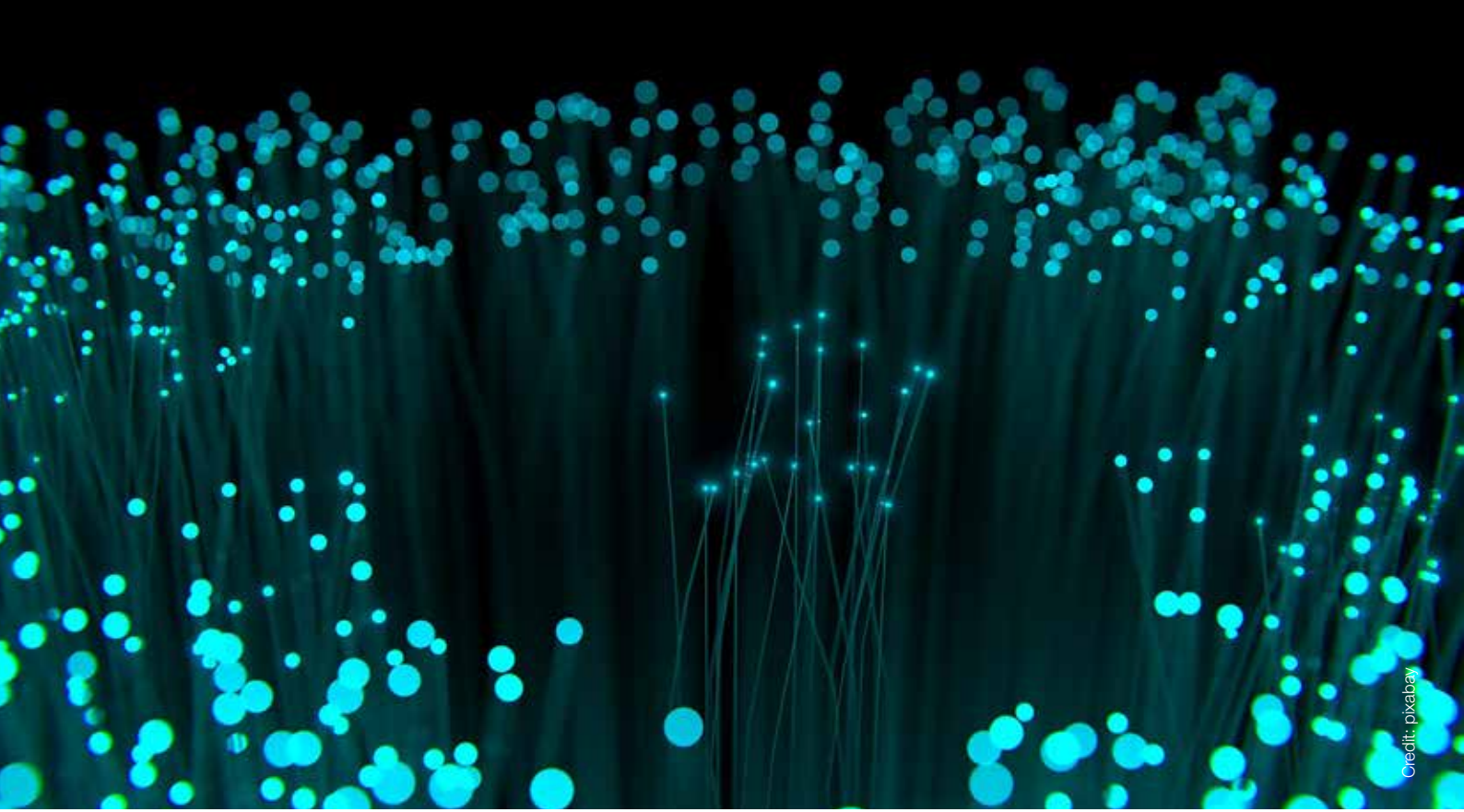
Preparing the next generation of engineers

Richard Prager has an ongoing interest in developing web resources to help applicants prepare for university admissions interviews in engineering.

i-want-to-study-engineering.org, which he developed in partnership with The Underwood Trust, is an online question bank of over 500 maths, physics and engineering puzzles, which have been made available free of charge. Anyone stumped by a problem can click on a hint video and get detailed help from Cambridge Engineering students on how to tackle the problem.

The exercises on the website are designed to inspire and challenge students and hopefully encourage them to consider studying engineering at university.

Some schools are more experienced than others at preparing their pupils for competitive engineering entrance interviews. This website aims to level the playing field by providing a collection of technical interview questions that everyone can use for practice. It also includes games designed to teach ideas that are important in both mathematics and physics.



Credit: pixabay

Cambridge launches UK's first quantum network

The UK's first quantum network has been launched in Cambridge, enabling 'unhackable' communications, made secure by the laws of physics, between three sites around the city.

The 'metro' network provides secure quantum communications between the Electrical Engineering Division at West Cambridge, the Department of Engineering in the city centre and Toshiba Research Europe Ltd (TREL) on the Cambridge Science Park.

Quantum links are so secure because they rely on particles of light, or photons, to transmit encryption keys through the optical fibre. Should an attacker attempt to intercept the communication, the key itself changes through the laws of quantum mechanics, rendering the stolen data useless.

Researchers have been testing the ultra-secure network, providing stable generation of quantum keys at rates between two and three megabits per second. These keys are used to securely encrypt data, both in transit and in storage. Performance has exceeded expectations, with the highest recorded sustained generation of keys in field trials that include encryption of data in multiple 100 gigabit channels.

The Cambridge network is a project of the Quantum Communications Hub, a consortium of eight UK universities, as well

as private sector companies and public sector stakeholders. The network was built by Hub partners including the University's Electrical Engineering Division and TREL, which also supplied the Quantum Key Distribution (QKD) systems. Further input came from ADVA Optical Networking, which supplied the optical transmission equipment, and the University's Granta Backbone Network, which provided the optical fibre.

The UK Quantum Network is funded by the Engineering and Physical Sciences Research Council (EPSRC) through the UK's National Quantum Technologies Programme. It brings together concentrations of research excellence and innovation, facilitating greater collaboration between the two in development of applications that exploit the unique formal guarantee of security provided by quantum physics.

"The development of the UK Quantum Network has already led to a much greater understanding of the potential of this technology in secure applications in a range of fields, in addition to bringing new insights into the operation of the systems in

practice," said Professor Ian White from the Department of Engineering. "I have no doubt that the network will bring much benefit in the future to researchers, developers and users."



The development of the UK Quantum Network has already led to a much greater understanding of the potential of this technology in secure applications in a range of fields, in addition to bringing new insights into the operation of the systems in practice.

Professor Ian White



www.quantumcommshub.net
uknqt.epsrc.ac.uk



PhD student's electronic engineering achievements celebrated with award

Postdoctoral Research Associate Nicole Weckman has been recognised as one of the brightest and most talented young electronic engineers in the UK today.

Nicole was selected by Electronics Weekly as part of its 2018 BrightSparks Design Engineers of Tomorrow programme, in partnership with RS Components. It celebrates the achievements of young engineers who are already making a difference in the first years of their working life, or who are studying, but showing the promise to become the people behind big future innovations in electronics.

Nicole's PhD research in The Nanoscience Centre has focused on the initial stages of the development of point-of-care (POC) biosensors, based on micro fabricated silicon micro-electro-mechanical systems (MEMS). According to Nicole, MEMS are the ideal platform for POC sensing systems as they are small, low cost when mass produced, can provide real-time results, and can be easily integrated with electronics to create small, portable systems to analyse human fluid samples such as sweat and saliva.

She has published two journal papers and four international conference papers based on her work, with two further journal papers published on related work. A common challenge with MEMS is that they are typically highly damped when in contact with a fluid, reducing their sensitivity or even rendering them unusable. Her MEMS devices perform better in a water droplet than in air by taking advantage of the acoustic properties of the air-water interface. Nicole overcame another common challenge by designing a biochemical system to specifically detect one type of protein from a mixture without interference from very similar proteins.

She is currently researching nanopore biosensors and helped to develop a working, human-sized model of a nanopore biosensor which was shown earlier this year at the Royal Society Summer Science Exhibition 2018.

"I'm trying to develop biosensors to help diagnose people at early stages of different diseases," said Nicole. "It's quite an interdisciplinary project in that it combines electronics but also mechanical engineering, biochemistry and biology."

"I'm very proud and honoured to be named a BrightSparks award winner. I wasn't expecting it and it was a wonderful surprise," she added.

Nicole has also taken the lead in creating opportunities for biomedical researchers of different backgrounds to discuss research ideas and share knowledge. Outside of work, Nicole has focused on outreach events encouraging girls to consider careers in science, technology, engineering, and maths (STEM).

“

I'm trying to develop biosensors to help diagnose people at early stages of different diseases. It's quite an interdisciplinary project in that it combines electronics but also mechanical engineering, biochemistry and biology.

PhD student Nicole Weckman



www.nanoscience.cam.ac.uk
www.electronicweekly.com/brightsparks

Low-cost AI heart monitor developed by Cambridge start-up



Credit: Cambridge Heartwear

A Cambridge start-up has developed a low-cost next-generation wearable heart and cardiovascular function monitor which uses Artificial Intelligence (AI) to diagnose heart rhythm and respiratory problems in real time.

The company, Cambridge Heartwear, hopes to use its wireless monitor to improve the detection of irregular and dangerous heart rhythms and reduce the impact of stroke and stroke-related mortality and morbidity, which affects 120,000 people in the UK each year.

Professor Roberto Cipolla, a world leader in computer vision and real-world applications, met cardiologist and clinical academic Dr Rameen Shakur in 2015, a year after Roberto's father had died of a stroke. Their ongoing research collaboration has now led to the formation of Cambridge Heartwear, a company based on the Cambridge Science Park.

The company's device, called Heartsense, includes a multiple lead ECG, oxygen sensing, temperature and tracking device that can be comfortably worn by patients for early screening. Sensors are enclosed in a robust waterproof casing, and the data produced is far more sensitive than that from current single lead wearable devices, as the development team has used its knowledge of clinical anatomy and electrophysiology to place leads for maximal signal output.

This data is wirelessly streamed in real time to the cloud where adaptive AI algorithms are able to identify clinically relevant irregular and dangerous rhythms just as a physician would. The device incorporates multiple independent sensors,

in order to produce more specific and sensitive data than current heart monitors can provide.

The research challenge was to produce algorithms that can learn from a limited amount of supervision from the cardiologist. "Our aim was not to replace the cardiologist, but to give them diagnostic support in real time," said Professor Cipolla.

To encourage the adoption by clinicians, the team ensured that the output of the AI algorithms also included the information commonly used by a cardiologist. "This was not necessary for the final diagnosis but made the system a little more understandable and explainable than typical Deep Learning systems, which are still thought of as black boxes," said Professor Cipolla.

NHS figures suggest atrial fibrillation (AF), the most common heart rhythm disturbance encountered by doctors, affects in excess of one million people across the UK. According to national and international data, more than 80% of people who either die or are left with severe neurological deficits following a stroke had an irregular heartbeat as the underlying cause. However, irregular heartbeat is often diagnosed only after a person has had a stroke.

"It makes sense to pick up AF before someone has a stroke and put preventative treatment in place," said Dr Shakur, who was formerly a Wellcome Trust Clinical Fellow at Cambridge and is now based at

MIT. "Unfortunately, the technology and clinical care systems we currently have in place aren't really doing this."

"If you're wearing an ECG over a long period of time, you're collecting a huge amount of data," he added. "Finding an irregularity among all the normal rhythms can be like looking for a needle in a haystack. I wanted to automate this process, helping the patient to get a diagnosis and start on treatment."

To solve this problem, Dr Shakur began collaborating with Professor Cipolla and students from the Department of Engineering. The collaboration led to the founding of Cambridge Heartwear in 2017 and the development of the unique device and some powerful algorithms that can automatically interpret ECG data, which have an accuracy level in excess of 95%.

In 2017, the company secured funding to build and test 100 prototypes of the new heart monitor and to extend its AI capability. The Royal College of Art has also helped in the ergonomic design of the device. Heartsense will cost substantially less than the current ECG Holter monitor.

Clinical trials in Lancashire, UK, have begun with patients enrolled from the primary care setting.



www.cambridgeheartwear.com

INNOVATION AWARD

University of Cambridge



Credit: The Boeing Company 2018

University of Cambridge wins Boeing Innovation Award

The University of Cambridge's outstanding performance in research and development has been recognised by Boeing in its 2017 Supplier of the Year Awards.

Accepting the Award on behalf of the University of Cambridge were Philip Guildford, Director of Strategy and Operations at the Department of Engineering, Professor of Laser Engineering, Bill O'Neill, and Dr John Durrell, Reader in Superconductor Engineering.

Mr Guildford said: "We thought working with Boeing engineers on such exciting research for the last 15 years was already prize enough, but now Boeing has topped this wonderful experience with its most prestigious award – we are thrilled."

Professor David Cardwell, Pro-Vice-Chancellor for Strategy and Planning, co-ordinated the Boeing partnership for Cambridge for many years, a role that was taken over in 2017 by Professor Duncan McFarlane.

Researchers from the Distributed Information and Automation Laboratory

(DIAL) at the Department's Institute for Manufacturing (IfM) have been working with Boeing since 2005, finding intelligent solutions to some challenging industrial problems. DIAL, headed up by Professor McFarlane, has worked with Boeing on seven major projects to date, addressing three key challenges: how to manage supply chains more effectively, how to improve production resilience and how to make airports and airlines more efficient and robust. The lab is currently implementing a production quality tracking system in one of Boeing's US facilities.

Researchers in the Bulk Superconductivity Group, supported by Boeing, set a new Guinness World Record in 2014 for the strongest magnetic field trapped in a superconductor (17.6 tesla – corresponding to an energy density that is roughly 350 times greater than that generated by a typical fridge magnet), beating a record that stood for more than a decade. They have since demonstrated a portable superconducting magnetic system that can act as a high-performance substitute for a conventional permanent magnet and can attain a 3-tesla level for the magnetic field.

The team, led by Dr John Durrell, is planning further testing for more magnetic

↑ Collecting the Boeing Innovation Award were Professor Bill O'Neill (holding the Award), Dr John Durrell (centre), and Philip Guildford (centre, right)

power and overall efficiency. The Group aims to enhance both the fundamental performance of superconducting bulks and to tailor them for specific applications.

And Bill O'Neill, Professor of Laser Engineering, is working with Boeing on a new generation of laser-based manufacturing technologies aimed at improving quality and productivity.

Boeing Chairman, President and CEO Dennis Muilenburg said: "Our continued success in an increasingly challenging business environment is driven in large part by having the aerospace industry's best team and talent – and that includes the world's best supply chain.

"The 2017 Supplier of the Year Award recipients all share a passion for innovation, collaboration and sustained exceptional performance – qualities we look for in all of our industry partners."

What causes the sound of a dripping tap – and how do you stop it?



Credit: pixabay

Scientists have solved the riddle behind one of the most recognisable, and annoying, household sounds: the dripping tap. And crucially, they have also identified a simple solution to stop it, which most of us already have in our kitchens.

Using ultra-high-speed cameras and modern audio capture techniques, the researchers found that the ‘plink, plink’ sound produced by a water droplet hitting a liquid surface is caused not by the droplet itself, but by the oscillation of a small bubble of air trapped beneath the water’s surface. The bubble forces the water surface itself to vibrate, acting like a piston to drive the airborne sound.

In addition, the researchers found that changing the surface tension of the surface, for example by adding washing-up liquid, can stop the sound. The results are published in the journal *Scientific Reports*.

Despite the fact that humans have been kept awake by the sound of dripping water from a leaky tap or roof for generations, the exact source of the sound has not been known until now.

“A lot of work has been done on the physical mechanics of a dripping tap, but not very much has been done on the sound,” said Dr Anurag Agarwal, Reader in Acoustics and Biomedical Technology, who led the research. “But thanks to modern video and audio technology, we can finally find out exactly where the sound is coming from, which may help us to stop it.”

Dr Agarwal, who leads the Acoustics Lab, first decided to investigate this problem while visiting a friend who had a small leak in the roof of his house. Dr Agarwal’s research investigates acoustics and aerodynamics of aerospace, domestic appliances and biomedical applications. “While I was being kept awake by the sound of water falling into a bucket placed underneath the leak, I started

thinking about this problem,” he said. “The next day I discussed it with my friend and another visiting academic, and we were all surprised that no one had actually answered the question of what causes the sound.”

Working with Dr Peter Jordan from the University of Poitiers, who spent a term in Cambridge through a Fellowship from Emmanuel College, and final-year undergraduate Sam Phillips, Dr Agarwal set up an experiment to investigate the problem. Their setup used an ultra-high-speed camera, a microphone and a hydrophone to record droplets falling into a tank of water.

Water droplets have been a source of scientific curiosity for more than a century: the earliest photographs of drop impacts were published in 1908, and scientists have been trying to figure out the source of the sound ever since.

The fluid mechanics of a water droplet hitting a liquid surface are well-known: when the droplet hits the surface, it causes the formation of a cavity, which quickly recoils due to the surface tension of the liquid, resulting in a rising column of liquid. Since the cavity recoils so fast after the droplet’s impact, it causes a small air bubble to get trapped underwater.

Previous studies have posited that the ‘plink’ sound is caused by the impact itself, the resonance of the cavity, or the underwater sound field propagating through the water surface, but have not been able to confirm this experimentally.

In their experiment, the Cambridge researchers found that somewhat counter-intuitively, the initial splash, the formation

of the cavity, and the jet of liquid are all effectively silent. The source of the sound is the trapped air bubble.

“Using high-speed cameras and high-sensitivity microphones, we were able to directly observe the oscillation of the air bubble for the first time, showing that the air bubble is the key driver for both the underwater sound, and the distinctive airborne ‘plink’ sound,” said Sam Phillips, who is now a PhD student in the Department of Engineering. “However, the airborne sound is not simply the underwater sound field spreading to the surface, as had been previously thought.”

In order for the ‘plink’ to be significant, the trapped air bubble needs to be close to the bottom of the cavity caused by the drop impact. The bubble then drives oscillations of the water surface at the bottom of the cavity, acting like a piston driving sound waves into the air. This is a more efficient mechanism by which the underwater bubble drives the airborne sound field than had previously been suggested.

According to the researchers, while the study was purely curiosity-driven, the results could be used to develop more efficient ways to measure rainfall or to develop a convincing synthesised sound for water droplets in gaming or movies, which has not yet been achieved.



Watch the video:
youtu.be/-iP3Dwy0RSQ
acoustics.eng.cam.ac.uk



Medicine: how research into supply chains will help you take care of yourself

↑ Keep taking the tablets

Researchers are working with pharmaceutical companies to make improvements across the whole supply chain, from how a pill is made to the moment it is swallowed by the patient.

Dr Jag Srαι, Head of the Institute for Manufacturing (IfM)'s Centre for International Manufacturing, explains that upwards of 30% of prescribed drugs are not taken by patients and, in the case of respiratory drugs, where application is more intricate, 70% are not taken as directed. The numbers vary depending on the type of condition being treated but they are alarmingly high across the board. This has consequences, and not only for the patient. The cost to the taxpayer of drugs that are not being used is considerable and reduces the pot of money available for patient care.

“In a world of scarce resources this in itself seems incredibly wasteful. But there are other reasons to be concerned,” adds Dr Srαι. “Around 50% of patients taking antibiotics don't complete the course. The consequences of this are potentially catastrophic as infections become increasingly resistant to drug treatment. And drugs contain active ingredients which, when disposed of inappropriately, end up as contaminants in our water supply.”

Tackling the thorny problem of patient compliance is just one aspect of the pharmaceutical industry that Dr Srαι and his team at the IfM are looking to revolutionise. They are working with other universities and major UK pharmaceutical companies AstraZeneca and GSK to make improvements across the whole supply chain.

Most pharmaceutical manufacturing still takes place in huge factory complexes,

where large volumes of chemicals are processed in a series of ‘batch-processing’ steps, and often a dozen or more are required to produce the final oral dose tablet. Developing new drugs is an expensive business and so big pharma companies hope for a ‘blockbuster’ drug – a medicine that could be used to treat a very common condition, such as asthma or high blood pressure, and that can be manufactured in large quantities.

But, says Dr Srαι, the manufacture of these blockbuster drugs is becoming a thing of the past. The batch process is costly, inefficient and makes less sense when producing medicines in small volumes.

New ‘continuous’ manufacturing processes mean that drugs can be made in a more flow-through model, requiring fewer steps in the manufacturing process, and in volumes better aligned with market demand. In the case of small volume manufacture, this technology breakthrough can support the move towards more personalised medicine.

“Combine this with the way in which digital technologies are transforming supply chains – through flexible production and automation, using sensors to track location, quality and authenticity, and big data analytics on consumption patterns – and it's clear that the pharmaceutical industry is on the cusp of a huge change,” adds Dr Srαι.

Recognising this, and to make sure they harness the value these advances in science

and technology can deliver, pharmaceutical companies are working together in a number of ‘pre-competitive forums’.

The IfM team is playing a key part in two major related UK initiatives: the Continuous Manufacturing and Crystallisation (CMAC) Future Manufacturing Research Hub based at Strathclyde University, funded by £10m from the Engineering and Physical Sciences Research Council and a further £31m from industry; and REMEDIES, a £23m UK pharmaceutical supply-chain sector project, jointly funded by government and industry.

CMAC is focused on the move to continuous manufacturing and REMEDIES on developing new clinical and commercial supply chains.

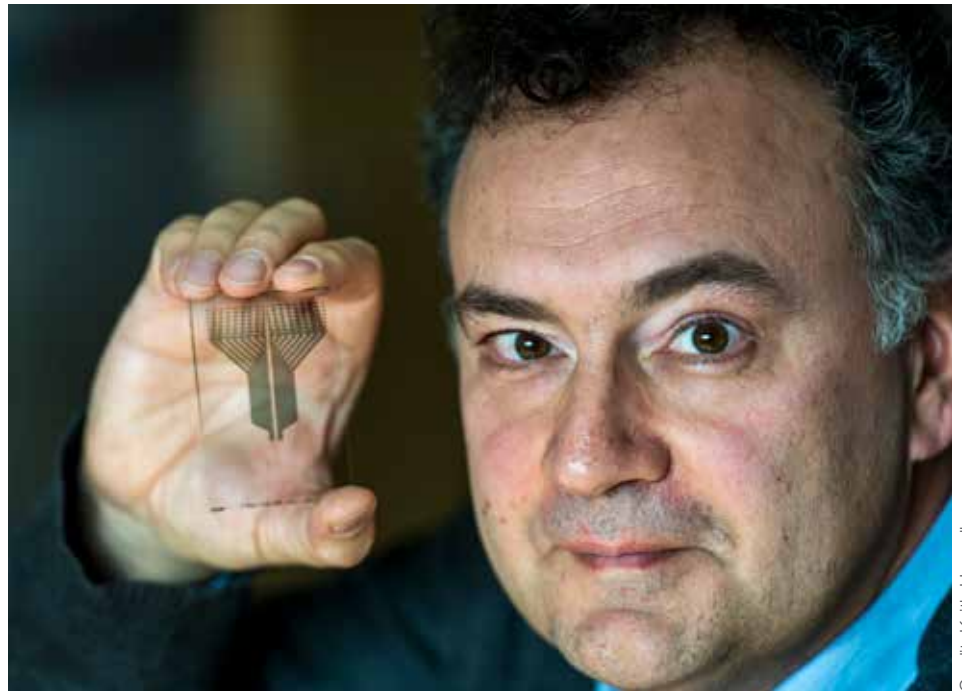
“We can envisage a future in which for some medicines, production is no longer a highly centralised large-scale batch operation but one where manufacturing is more about continuous processing, more distributed in nature, smaller scale and closer to the point of consumption,” said Dr Srαι.

He adds: “In some instances we are already able to ‘print’ tablet medicines on demand, and we are now exploring whether this might take place at more local sites, or at the local pharmacy or even in our own homes.”



www.ifm.eng.cam.ac.uk/research/cim/

Brain interfaces, bioelectronics and human disease



Credit: Keith Heppell

Could brain interfaces enable us to treat a wide range of diseases?

Professor George Malliaras, who has been appointed the Prince Philip Professor of Technology at the Department of Engineering, is busy setting up his lab at the Nanoscience Centre to continue his work on using bioelectronics and organic electronics to create novel implantable devices that interface with the brain. Among those who could benefit are patients with epilepsy, for whom standard treatments are not successful or suitable.

An organic electronic ion micropump for implanting in the brain has been developed by Professor Malliaras and fellow researchers in France and Sweden. If successful, it could enable doctors to use a wider gamut of drugs that would, if delivered by conventional methods into the body, be toxic to other organs.

The micropump would also enable the use of drugs that would not normally get past the blood-brain barrier to be delivered directly into the brain – and to the specific area required.

“Also, lower doses can be administered – and only when needed by using a closed-loop system that monitors the brain,” adds Professor Malliaras. “There are a lot of advantages.”

The battery-powered micropump – 20 times thinner than a human hair – has no moving parts. Instead, the pumping is achieved by applying an electric field. It has proved successful in the lab, but the pump has yet to be tested in humans.

“There is quite a lot of work that needs to be done and I believe it’s beyond the

scope of a single academic group to take it to the clinic,” says Professor Malliaras.

And he reveals: “We will need a bigger consortium and I’m in the process of doing that here in the context of brain tumours.

“Since I arrived in Cambridge, I’ve found a great opportunity for using this device for cases of brain tumours that are inoperable, such as glioblastomas that lie in an area of the brain with high functionality. It would offer localised chemotherapy.

“That is a new area, but we are being opportunistic. We are a group that develops medical technologies and a large part of the group tries to remain agnostic of the final application. We explore those with different collaborations.”

With any such interface, precision measurements of the brain’s electrical activity are crucial – but embedding electrodes into the brain is a challenging task, which carries the risk of striking a blood vessel.

Professor Malliaras and colleagues have developed a sensor of electric potential that can sit over the brain and measure the activity of a single neuron without disturbing its environment.

“Before this device came along, the only way you could measure single neurons was to penetrate the brain and sit very close to them,” he says.

“We developed a device where we optimised both the mechanical and electrical contact with the brain, which means we can now sit at the surface of the brain and have very small electrodes that form very good contact. They have enough

spatial resolution to pick up single neuronal signals. This would be used for more accurate mapping. Before you perform any surgery on brain tumours or epileptogenic zones, you need to map the brain to see what functionality lies there.

“With these electrodes, the mapping can be done much more accurately.

“It’s a bit like clingfilm – it’s four microns thick. If you put it between your finger, you can’t feel it.”

In a paper published in August 2016, Professor Malliaras and colleagues unveiled the ‘bioelectronic neural pixel’ – technology combining this clingfilm-like sensor with the organic electronic micropump.

The system was used to measure epileptic activity in a brain slice model, and delivered neurotransmitter drugs to the same sites to control it.

“We were able to detect activity that was abnormal and then turn on the pump and silence it,” explains Professor Malliaras.

“Both the sensor and the actuator, which is the pump, utilise a conducting polymer which is a material capable of transporting both electronic and ionic carriers. As a result, you can have the same material sensing the electric field and pumping the drug.”

Such a system could be used to treat a range of neurological conditions.

Written by Paul Brackley for The Cambridge Independent

↑ Demo team, from left, Cambridge resident John Aldridge, engineering student Nathaniel Trueman, engineering student David Morris, natural sciences student Abigail Rees, and Dr Hugh Hunt

Dambusters expert brings ‘bouncing bomb’ engineering to life



Credit: Graham CopeKoga

Dambusters expert Dr Hugh Hunt demonstrated the engineering and science behind the ‘bouncing bomb’ live at the Royal Albert Hall as part of a commemorative event.

The demonstration was carried out on 17 May to mark the 75th anniversary of the legendary Dambusters raid of the Second World War, with support from Trinity College engineering students Nathaniel Trueman and David Morris, Corpus Christi natural sciences student Abigail Rees, and Cambridge resident John Aldridge. It was simulcast at 400 cinemas nationwide as part of *The Dam Busters with Dan Snow*.

Historian Dan Snow reflected on the work of the mastermind behind the operation, Sir Barnes Wallis, whose ‘bouncing bomb’ was carried by 19 Lancasters for the attack on the dams of Germany’s Ruhr Valley.

And Dr Hunt, Reader in Engineering Dynamics and Vibration, explained the science and demonstrated the challenge of dropping a spinning bomb at the right moment to avoid German defences in the reservoir, sink beside the dam wall and then explode.

Operation Chastise breached two dams in Germany’s industrial heartland and damaged a third, unleashing torrents of water that destroyed mines, factories and houses, wrecked transport systems and ruined farmland.

While Germany scrambled to repair the damage and resume the power supplies that fed their war effort, Britain celebrated a propaganda coup. Images of the breached dams – thought to be impregnable – were splashed across newspapers and the aircrew of RAF 617 Squadron, led by Wing Commander Guy Gibson, became famous.

Barnes Wallis’ daughters also took part in the 17 May event, bringing with them the marbles their father used to develop his idea of a bomb that skipped across water; an idea he initially thought up in the family bathtub.

Dr Hunt knows all about Barnes Wallis’ invention. He played a vital role in recreating the iconic raid for the 2011 Channel 4 documentary, *Dambusters: Building the Bouncing Bomb*. Made by Windfall Films, the two-hour documentary won the Royal Television Society Award for best history programme and Dr Hunt went on to win the Royal Academy of Engineering’s 2015 Rooke Award for Public Engagement.

Dr Hunt said: “We understood the theory behind the bouncing bomb, but because Wallis’ original calculations and designs had been lost, no-one knew how the bomb was actually built nor whether it was possible to repeat the mission.”

The Channel 4 team of dam engineers, explosive experts, mechanics, pilots and Dr Hunt managed to do just that, constructing simulated bouncing ‘bombs’ from scratch and dropping them from a Second World War aircraft on a specially made one-third scale dam in a remote part of Canada.

The documentary was a challenge to make but millions of people around the world watched it and, says Dr Hunt, hopefully it explained the engineering behind Wallis’ invention.

“It really was touch and go whether we would succeed in recreating the 1943 mission,” he said. “We brought that learning to the Royal Albert Hall – this time using a bowling machine, tennis balls and a paddling pool, to explain the remarkable feat of Wallis and the 617 Squadron pilots.”



Watch the practice run of the Dambusters ‘bouncing bomb’ demo: youtu.be/B13f2J4UmvU

Growing Underground

How smart monitoring is helping an urban farm to flourish

An innovative and award-winning urban farming facility is creating energy-efficient growing conditions in tunnels 120ft below the busy streets of Clapham in London.

Micro greens and salad leaves are thriving with the help of a smart monitoring programme that records temperature, humidity and CO₂ levels.

Growing Underground, which launched in 2015 and is located in former WW2 air-raid shelters, uses hydroponic systems to sustainably produce the pesticide-free crop. The tunnels are leased from Transport for London (TfL), which was happy to see them being put to work having lain dormant for 60 years.

The aim of Growing Underground is to bring edible crop production to the heart of the city while minimising the carbon impact of food transportation. The verdant trays of fennel, garlic chives, pea shoots and coriander, among others, can be picked and on a plate in a restaurant within hours. The forward-thinking company, which sells its greens through Ocado and Marks & Spencer and aims to be carbon neutral, has also been awarded the BBC Future Food Award.

Cambridge Centre for Smart Infrastructure and Construction (CSIC) Co-Investigator Dr Ruchi Choudhary, who leads the Energy Efficient Cities initiative (EECi) at the Department of Engineering, started working with Growing Underground in 2015, following an energy-optimising project



Credit: Growing Underground

completed for the Royal Botanic Gardens, Kew. This retrofit study of the greenhouses at Kew saw the development of a simulation model that incorporated the heat and mass transfer associated with plant transpiration into the dynamic energy simulation of the greenhouse structures.

“The idea was to expand the energy-optimisation project into urban farming, and the collaboration with Growing Underground provided the ideal environment,” says Melanie Jans-Singh, an EECi PhD student investigating the integration of urban farming to cities reusing wasted resources.

A range of instrumentation, including wireless sensors and web cams that monitor temperature, humidity, CO₂, air velocity and light, was installed in a section of the tunnel that is being used for growing crops. “Most sensors need cables. Our sensors are wireless and are designed to cope with the humidity underground,” said Melanie.

There are two tunnels on different levels – in total 65,000 square feet of burrows with the capacity to accommodate up to 8,000 people – and Growing Underground has plans to expand the business.

Data collected from the instrumentation is informing the heat and mass transfer model of this unique ‘tunnel greenhouse’. “Our monitoring is helping Growing Underground to optimise the yield while reducing energy consumption,” said Melanie. “If, for example, there is a doubt about how the plants are growing at a certain spot, I can refer to the measurement of air velocity so that we can identify the precise conditions. When the plants are growing better in one area than another, the

instrumentation helps us to work out why.”

Real-time monitoring means that conditions can be changed according to the analysed data. Ventilation is the chief energy consumer at the Growing Underground project, and monitoring data has enabled adjustments that have cut consumption for ventilation without affecting yield.

The founders of the partially crowd-funded company, Richard Ballard, who discovered the tunnels when he was a film student scouting for locations, and Steven Dring, who has a background in logistics, are able to access the data 24/7. The analysed data itself is of value; it creates a ‘lifetime performance passport’ which provides the asset owners, present and future, with a rich source of information.

“We have been very lucky to partner with the University of Cambridge. Ruchi and her team have really helped us monitor and develop the space which will enable us to eventually get the optimum growing environment,” said Richard. “They have provided us with monthly reports which have allowed us to make adjustments to improve temperature, humidity and air velocity, and now we are working together to improve CO₂ levels through enrichment.”

The collaboration between business and academia benefits all stakeholders. Growing Underground is providing the case study for further research and the academics are delivering data that will help the crops, and the company, to flourish.



www.eeci.cam.ac.uk
growing-underground.com

Institute for Manufacturing Design Show 2018

In the first year of the two-year Manufacturing Engineering Tripos (MET) course at the Institute for Manufacturing (IfM), students develop a new product, with real business potential.

The students put together displays each year to explain the technical ideas and business potential behind their design work. The projects are always diverse and normally include conceptual solutions, technical and experimental designs. Students are encouraged to produce and show working prototypes wherever possible.

Some of the 2018 projects are outlined below, summarised by the students in their own words:

Hexamill

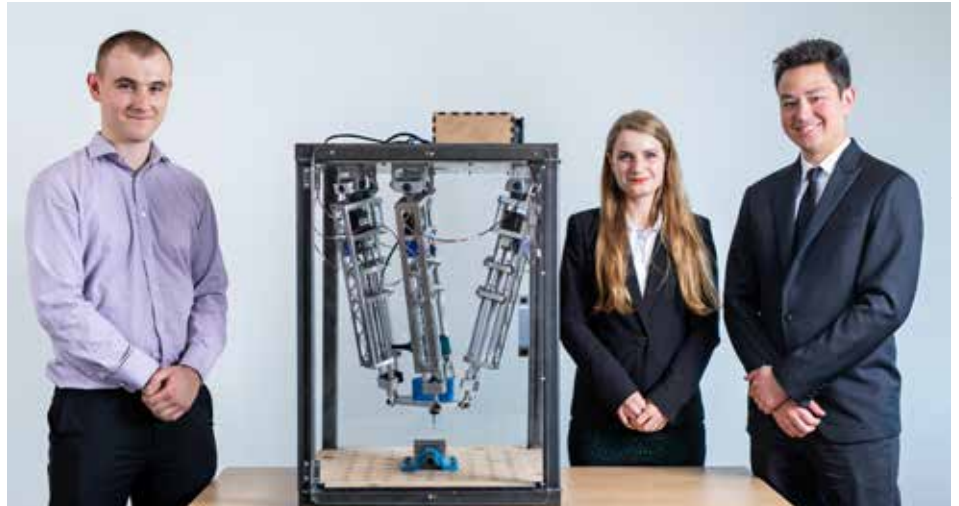
The Hexamill is a six-axis desktop milling machine that combines the versatility of a 3D printer with the manufacturing quality of a CNC mill.

The Hexamill is low cost and designed to allow SMEs to bring CNC milled prototyping in-house. It removes material using a router from a piece of stock material to create the desired shape. Using a Stewart-platform configuration of stepper motor driven lead screw actuators to move the router, the Hexamill can create complex shapes in a range of materials, from foams, to plastics, to aluminium. The Stewart-platform configuration enables the router to tilt, allowing up to six-axis machining, meaning more complex shapes can be created than by a standard three-axis gantry CNC milling machine.

ReadySteadyGyro

ReadySteadyGyro is a wearable device to counteract hand tremors. It is a multi-purpose solution, utilising gyroscopic effects to improve stability and control for the user in a variety of applications.

The device, worn like a glove, utilises gyroscopic forces produced by a motor-driven flywheel to reduce unintended movement of the hand experienced with a tremor. In discussions with the Cambridge branch of Parkinson's UK, ReadySteadyGyro has received positive feedback, and the desire for a final design



↑ Hexamill Team (from left): Matt Escott, Katherine Cook, Bert Dompeling



↑ ReadySteadyGyro Team (from left): Ben Weir, Callum McCarthy, Hugo Gale

that is as unobtrusive and discreet as possible was identified.

LeafLogger

The LeafLogger extrudes solid logs from dry leaves that can then be used in fireplaces or barbecues by the environmentally conscious, making use of natural organic waste.

Using a screw extruder, a mixture of mildly shredded leaves and wax is compressed into a log shape and subsequently heated to fuse it into a solid log.

LeafLogger's competitive advantage lies in the fact that the machine consumes very little power, and makes use of free

access to fallen leaves to provide a source of warmth to those aware of their environmental impact.

From initially targeting landscapers, local authorities and large country estates, the future potential of this machine could lead to processing waste materials such as grass, paper or other combustible waste materials and thus further reduce deforestation.



View all the Design Show photos:
www.eng.cam.ac.uk/Flickr
www.ifm.eng.cam.ac.uk

Tackling global energy savings through efficiency improvements

With society under pressure to meet growing energy needs and lower carbon emissions, Cambridge engineers have collaborated with industry to examine energy use and identify energy savings.

Research on energy efficiency by Dr Jonathan Cullen, Leader of the Resource Efficiency Collective at the Department of Engineering, and his team, has been featured in the BP Technology Outlook (2018) which examines “the potential of technology to change the way we produce and use energy to 2050”.

While looking at efficiency in the global energy system, Dr Cullen and his team examined global energy use across 35 technologies – from cars and power plants to domestic cooking and washing – setting out the current range of efficiencies along with an assessment of the best available technology today and in 2050.

The researchers identified the following areas with the greatest potential for energy saving: cars, heating, cooking, washing and power plants.

They developed a chart, known as a Sankey diagram, which shows how energy is converted and consumed. Natural resources are converted, for example, in industrial operations such as oil refineries or

power stations, and then consumed using devices from engines to light bulbs in order to provide us with energy services such as mobility and lighting. And gas resources, for example, are used to generate power but also piped directly into homes for use in heating or cooking. Although not reflected in the diagram, energy losses and inefficiencies occur at each stage, and can be material.

Dr Cullen said: “The global energy system consists of a diverse range of technologies for transforming and using energy. Yet it is the delivery of energy services – such as heating – rather than energy itself, which drives consumer energy demand. The more efficiently these technologies operate, the less energy is required to deliver energy services.

“In our latest study with BP, we examine global energy use across 35 technologies, provide a technology ranking, and show that total primary energy savings of 217 exajoules (EJ)¹, which is about 40% of current supply, and half the technical efficiency limit, could be achieved.

“If the maximum practical savings were made, demand for coal, oil, natural gas and biomass would be reduced by 31%, 47%, 40%, and 40% respectively, resulting in annual emissions savings of 13.5 gigatonnes of carbon dioxide.

“If proved to be economically viable, energy savings of this order would affect every aspect of the energy supply system.

This is why these findings deserve careful attention as we consider our move towards a future low-carbon economy.”

Cambridge is one of eight partners that have carried out studies over a three-year period with BP focusing on China, Europe and North America. It is hoped the findings will help policymakers consider what additional incentives and measures to introduce based on developments anticipated in technologies known today.

¹ One exajoule is approximately equal to the average annual energy consumption of 26 million homes in North America or 160 million barrels of oil equivalent.

“
It is the delivery of energy services – such as heating – rather than energy itself, which drives consumer energy demand. The more efficiently these technologies operate, the less energy is required to deliver energy services.

Dr Jonathan Cullen



www.bp.com/technologyoutlook
reficiency.eng.cam.ac.uk



Credit: pixabay



Credit: pixabay

Motion capture techniques used to improve treatment of dogs with joint pain

Dogs with diseased elbows may benefit from a new collaborative study between the Departments of Engineering and Veterinary Medicine.

Using technology that is most often seen on a movie set, the researchers are studying dogs with elbow dysplasia – a painful, debilitating and progressive inherited condition that affects a significant percentage of Labrador Retrievers and other popular dog breeds.

Researchers from the two Departments are using three-dimensional motion capture techniques on healthy dogs in order to model the forces on their elbow joints as they move. Once normal patterns of movement have been established, they will be compared against results from dogs affected by elbow dysplasia. The results from the study are expected to provide new insights into the effects of the disease on joint function, potentially allowing for better staging of the disease and earlier intervention. Additionally, understanding how the normal joint functions, will make it possible to develop new surgical implants that will improve joint function and reduce lameness in these dogs.

Elbow dysplasia is an inherited condition that has similarities to hip dysplasia in humans. Labradors and Rottweilers are especially prone to the condition, in which the cartilage surrounding

the elbow joint starts to degrade. Without the cushioning that the cartilage provides, fragments of bone can break off as the bones of the elbow joint grind against each other, causing significant pain for the dog.

“It’s like a ticking time bomb – the first symptoms usually appear when the dogs are young, but they often get worse over time,” said Professor Matthew Allen of the Department of Veterinary Medicine. “The condition can be managed, but there isn’t a really effective treatment for it at the moment.”

Despite the fact that it is an inherited condition, there is currently no genetic test for elbow dysplasia. The condition can only be diagnosed after symptoms have appeared, when dogs have started to limp or otherwise modify their gait to cope with the pain, which can end up causing further damage to the joint.

“Right now, it’s difficult to diagnose the condition until it’s pretty serious,” said Professor Michael Sutcliffe from the Department of Engineering. “If we can develop an engineering model that allows us to calculate the force on the elbow joint, then we can use it to diagnose elbow

dysplasia sooner, and potentially use it in the development of a more effective implant.”

Currently, there are effective implants to replace hip joints in dogs, but replacing an elbow joint with an implant is far more difficult. Although current implants work reasonably well, dogs that have had an elbow joint replaced often struggle to return to full function after surgery.

The researchers, including Professor Sutcliffe’s fourth year students, Luke Johnson, Tom Broughton and Angus Bain, are using motion capture techniques to track the movements of the dogs. This data can then be used to develop mathematical models of the forces passing through normal and diseased joints. The models will be used to predict the success of current and novel surgical procedures, as well as to programme a new robotic joint simulator that has recently been installed in the Surgical Discovery Centre in the Department of Veterinary Medicine.

According to Professor Allen, it’s possible that using the data he and Professor Sutcliffe have collected, a better elbow implant could be available in the clinic in as little as three years.

ALUMNI UPDATE

Colonel Stuart Browse



Colonel Stuart Browse (Late Royal Engineers) has spent much of his engineering career in The British Army designing and building infrastructure to support deployed operations overseas.

Colonel Browse (Jesus College 1988) read engineering after joining the army and after training at the Royal Military Academy, Sandhurst.

As a young Major, Colonel Browse commanded the 62 Cyprus Support Squadron Royal Engineers, an independent support squadron in Dhekelia, Cyprus, from 2003-2005. This was his second tour of duty with the squadron, having served there as a young troop commander immediately after university. In these deployments, he put his newly found engineering skills to the test building a shooting range complex, a small harbour and re-erecting some Doric pillars that had fallen after a 4th century earthquake.

Colonel Browse said: "The Doric pillars were in a Basilica in Pathos, Cyprus, owned and run as a visitor attraction by the Department of Antiquities within the Government of the Republic of Cyprus. The UK Military conducted the task under the banner of 'Military Aid to the Civil Community'. It was also great training for my soldiers. The pillars had never been re-erected because of the difficulty of getting lifting apparatus across the 'priceless' mosaics between the nearest access road and the pillars. I commandeered part of a school playground and built a five-bay Extra Wide Bailey Bridge (a modular steel truss through bridge dating from World War 2) over the mosaics, and drove a 15 tonne military crane onto the site to then erect the pillars. The pillars were lifted using a bespoke friction plate steel harness; 4th century pillars are surprisingly slippery!"

His Professional Engineer Training was completed in 1999 and included 18 months

in Los Angeles, California. He held a number of significant positions of responsibility for the flood protection works in Los Angeles County and the development of the Port of Los Angeles, including hydrographical dredging work. His surfing skills improved enormously in this time.

As a Chartered Civil Engineer, Colonel Browse has completed numerous operational tours delivering operational infrastructure overseas in Bosnia, Kosovo, Iraq and Afghanistan and the broader Middle East, and also airfield assessment work in India.

He said: "I have been incredibly fortunate to have a military engineering career spanning some 34 years, and whilst commanding soldiers on operations will always be for me the most humbling and rewarding experience, being able to do that in the engineering context has been truly fulfilling. Whether it is building indigenous engineering capacity in far flung corners of the developing world, testing the boundaries of physics lifting 4th century pillars, or working at the more strategic level directing infrastructure delivery, policy and programmes, there has never been a dull moment. Even now, I'm still sometimes surprised by the displays of engineering invention, innovation and creativity that some of the soldiers, sailors and airmen I have worked alongside display, when faced with engineering problems in unfamiliar environments."

He has recently set up and led an Infrastructure Optimisation Programme which will look at the optimisation of the existing estate across all estate users and in all environments for the Ministry of

Defence (MOD). It aims to reduce the size of the MOD's built estate by 30% by 2040.

As a Lieutenant Colonel, he commanded the 63 Works Group Royal Engineers (Electrical power generation and distribution), a group of multi-disciplinary design engineers, which included two Operation Herrick tours in Afghanistan. There he delivered airfield infrastructure and stabilisation effect, and economic growth in Southern Helmand through construction. In these jobs, he had both policy responsibilities and a technical remit as the Group's principal Chartered Engineer.

He has worked at The Permanent Joint Headquarters (the headquarters created to command joint and combined military operations), with responsibility for all operational infrastructure and infrastructure policy and strategy overseas. Latterly, he has worked at the heart of the MOD in Whitehall, in Finance and Military Capability, attempting to balance the difficult issue of delivering military capability within increasing financial constraints.

Prior to his time at Jesus College, where he was a 1st XV rugby regular, a member of the University Officers' Training Corps and an occasional rower, Colonel Browse was educated at Welbeck College. He reviews Chartered Engineer and Incorporated Engineer candidates for professional engineering institutions and mentors some aspiring candidates. Colonel Browse is currently responsible for the 50,000 defence portfolio of service family accommodation and is based at RAF Wyton in Huntingdon.

Cambridge joins collaborative project to strengthen the Internet of Things

The Institute for Manufacturing (IfM), part of the Department of Engineering, has been selected to help enhance the Internet of Things (IoT) as part of a new collaborative project.

IoT refers to the internet connection of physical objects, where physical objects are coupled with digital monitoring and analytics capabilities. The *Pitch-In* project (Promoting the Internet of Things via Collaborations between HEIs & Industry) will be led by the University of Sheffield in collaboration with the Universities of Cambridge, Oxford, and Newcastle.

It supports the Government's Industrial Strategy by significantly enhancing the commercialisation and wider exploitation prospects of UK IoT research and technology.

The £4.9 million project, funded under Research England's Connecting Capability Fund (CCF), is one of 14 successful bids awarded across England.

The *Pitch-In* project will investigate the barriers to successful IoT take-up. The project teams will trial solutions, and capture and share good practice learning outcomes. It will focus on four priority sectors which are early adopters of IoT:



Credit: pixabay

health and wellbeing; digital manufacturing; energy systems; and smart cities.

The IfM has been awarded £1 million of the total funding to lead the manufacturing theme, while also supporting the smart cities theme. Dr Alexandra Brintrup will lead the manufacturing theme as Cambridge's principal investigator for the *Pitch-In* project.

Dr Brintrup said: "The project will provide funding for feasibility studies and demonstrators, as well as creating pathways to remove industrial knowledge transfer barriers in this field through the development of best practice guidelines. *Pitch-In* greatly strengthens the IfM's digital manufacturing

research programme, and supports engagement with the Cambridge cluster of high technology companies."

Professor Tim Minshall, Head of IfM, said: "The adoption of digital technologies will be key to the ongoing competitiveness of UK manufacturing firms of all sizes. We are really excited by the opportunity this project offers to accelerate research and its application in this critical technology area."



www.ifm.eng.cam.ac.uk

Cambridge and Nanjing launch strategic collaboration

The new joint centre will support innovative research into smart cities and fully integrated urban environments.

Professor Stephen Toope, the University of Cambridge's Vice-Chancellor, has signed an agreement to formalise a strategic partnership with the Nanjing Municipal Government.

The creation of the Cambridge University-Nanjing Centre of Technology and Innovation will entail the establishment of a joint research centre and the sharing of revenue derived from the commercialisation

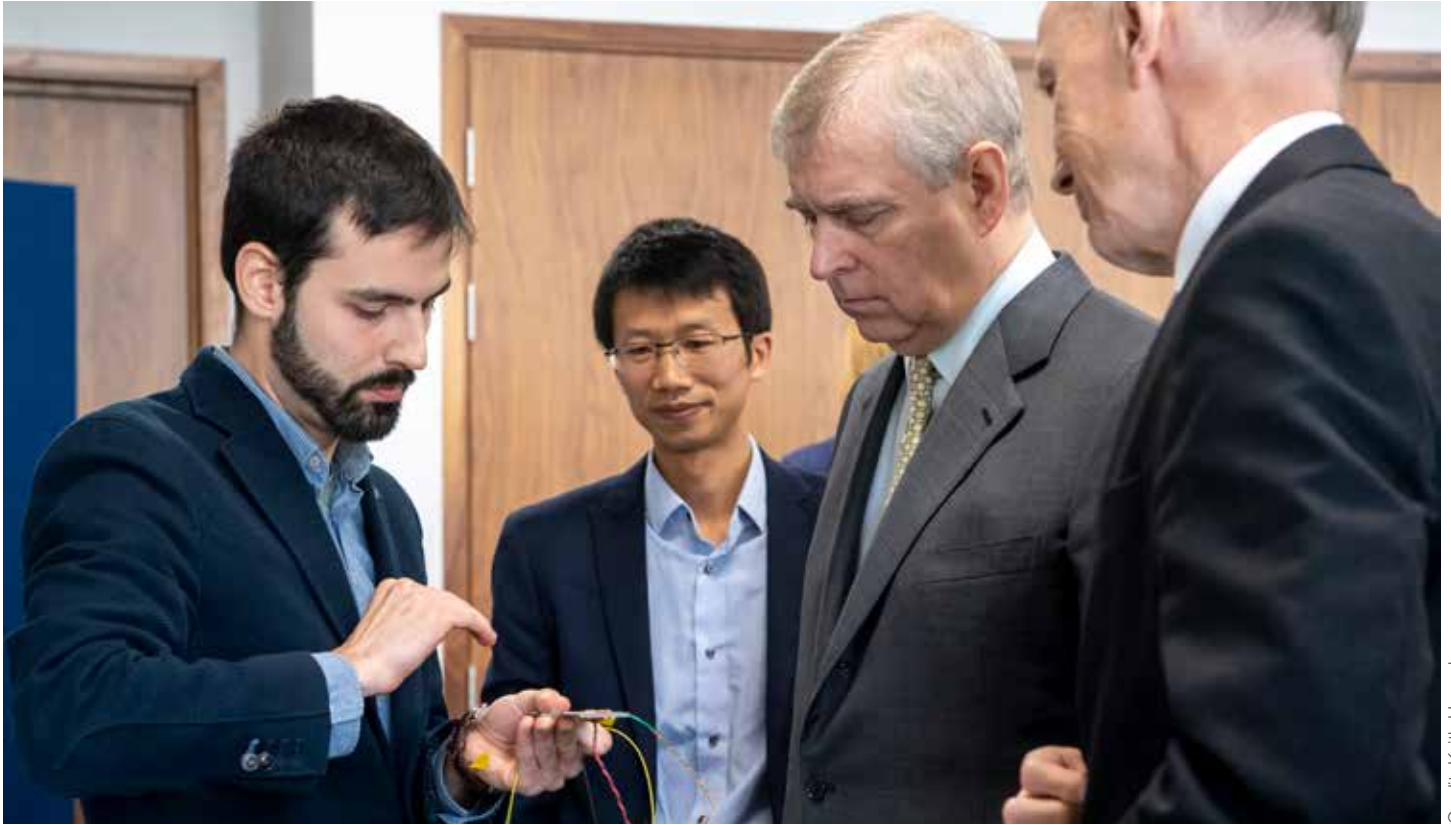
of intellectual property. It is the University's first overseas enterprise at this scale.

The project has been driven by the Department of Engineering. Professor Sir Mark Welland, Head of the University's Electrical Engineering Division, led the negotiations. IP generated by research funded through the Centre will be licensed for commercialisation by the University's innovation branch, Cambridge Enterprise.

At the heart of the new Centre's activities will be research into technologies that support a modern 21st century city with integrated IT, health care and building

management. Innovations emerging from the Centre will enable the development of 'smart' cities in which sensors – applied at the individual level and all the way through to the level of large infrastructure – will enable sustainable lifestyles.

The agreement will fund positions in Nanjing, both academic and management, and will allow Cambridge-based academics to engage with specific, long-term projects in Nanjing. It will also support the establishment of a professorship, based in Cambridge, with responsibility as the Centre's Academic Director.



Credit: Keith Heppel

HRH The Duke of York visits Cambridge

↑ Dr David Rodenas Herráiz and Dr Xioamin Xu demonstrate sensing technology to HRH The Duke of York.

His Royal Highness Prince Andrew, The Duke of York, was welcomed to the Cambridge Centre for Smart Infrastructure and Construction (CSIC) offices in the Department's James Dyson Building.

The Duke of York supports a number of science and technology organisations, including being a Patron of the Institution of Civil Engineers (ICE).

During his visit to CSIC earlier this year, HRH was welcomed by Professor Lord Robert Mair (Head of CSIC and outgoing ICE President), Dr Jennifer Schooling (Director of CSIC and Director of the Research Bridgehead at the Centre for Digital Built Britain), and Professor Simon Guest (Head of Civil Engineering).

A number of CSIC Research Associates presented the latest research projects and deployments in smart infrastructure and construction to The Duke of York. These included:

- A demonstration of fibre optic sensing on CSIC's model of a self-sensing bridge featuring wireless and acoustic sensors
- Monitoring heritage buildings in London during adjacent tunnelling
- Analysis techniques to make sense of vast quantities of data
- Integrating urban farming into derelict spaces and optimising the use of

underground spaces within densely populated cities.

Professor Lord Robert Mair said: "We were delighted to welcome The Duke of York to CSIC and have the opportunity to showcase some of the innovations that are transforming infrastructure and construction. The team at CSIC have contributed to a number of pioneering projects, including Crossrail, which demonstrate how technology is creating smart infrastructure and driving industry change.

"As an ambassador for technology and engineering, HRH appreciates the significant opportunities that advancements in digital technologies bring. As we face the challenges of the 21st century, including climate change, population growth and rapid urbanisation, it is the work of civil engineers which will provide solutions to these challenges that will help to change the lives of millions of people for the better."

The Duke of York promotes and raises awareness of British science, technology and engineering expertise. HRH also engages with organisations to support initiatives

that attract increased investment into UK science, technology and engineering.

“

We were delighted to welcome The Duke of York. The team at CSIC have contributed to a number of pioneering projects, including Crossrail, which demonstrate how technology is creating smart infrastructure and driving industry change.

Professor Lord Robert Mair



www-smartinfrasturcture.eng.cam.ac.uk
www.cdbb.cam.ac.uk



A new era for apprenticeships at Cambridge

↑ Daniel Philips, an apprentice in the Department of Engineering

New standards and funding arrangements for apprenticeships offer opportunities to expand training provision for both new and existing staff.

The Department of Engineering started its own programme of apprenticeships some time ago, when it became clear that skills were being lost as an older generation of technicians retired and no-one was coming forward to replace them. Now, thanks to the apprenticeship levy, the Department is expanding its programme: using levy money to pay for the apprentices' training has given the Department more money to spend on salaries.

Alistair Ross, Manager of Design and Technical Services at the Department of Engineering, finds training apprentices fulfilling for several reasons. He did an apprenticeship himself, which he calls “the best thing I ever did” and enjoys passing on his own love of making and machinery. He likes to see the young people he trains developing both as people and as technicians over the course of their apprenticeship.

Alistair said: “Apprenticeships might seem to be an old-fashioned way of training but they’re actually very relevant to the modern world. Not everyone leaves school

wanting to do a degree, or even knowing what their goals are.”

The apprentices he has trained are now competent, confident young people with technical skills and a sense of direction in life – and the Department is now assured that it will have a steady supply of the skilled technicians it needs.

About apprenticeships

Apprenticeships can be offered at many levels, from entry level up to management and degree/postgraduate level.

An apprenticeship is a job accompanied by training that meets an approved national standard (monitored by the Institute for Apprenticeships) and can be offered to existing employees as well as to new starters. All large employers contribute to an apprenticeship levy, and can use this money to train apprentices or provide additional training to existing staff.

The national expansion of apprenticeship standards and funding offers an opportunity to the University to enhance its offering of

off-the-job training for both existing and new staff. This can help departments with succession planning, ensuring that skills gaps are plugged and important skills and knowledge are passed on.

“

Apprenticeships might seem to be an old-fashioned way of training but they’re actually very relevant to the modern world. Not everyone leaves school wanting to do a degree, or even knowing what their goals are.

Alistair Ross



Watch the video: youtu.be/_Yuu18KiksA
www.apprenticeships.admin.cam.ac.uk

→ Elena with the initial prototype of the YoHeart™ – a wearable ECG device to help earlier diagnosis of heart abnormalities at the most accessible cost

Women in Engineering

An interview with Dr Elena Punskeya



As part of our Women in Engineering series, we meet Dr Elena Punskeya, an Affiliated Lecturer and Fellow at Christ's College, entrepreneur, and mother-of-three.

Hi Elena, how did you get into engineering?

A couple of my friends were applying to the Bauman Moscow State Technical University, which is one of the top engineering schools in Russia, and I thought I would give it a go as well. As a girl from a Ukrainian industrial town, no-one really expected me to get in, so I thought at the very least I would get a trip to Moscow out of it.

To everyone's surprise, I did get a place and then started my six years in the field of Applied Mechanics at the Department of Robotics and Automation, graduating as an Engineer-Researcher.

Having realised that designing nuclear reactors or space rockets was not my ideal job for life, I then continued my education with MPhil and PhD degrees in Informational Engineering at the University of Cambridge, followed by a Junior Research Fellowship at Homerton College, and Research Associate and Senior Research Associate positions in the Department of Engineering at Cambridge.

My academic career was focused on Bayesian statistical inference; probabilistic data modelling and simulation-based methods for scientific computing; and applications in the areas of digital communication, signal and image processing, robotics, engineering for life sciences, finances and security.

I embarked on my own technology and product development journey – first by leading the Statistical Research Team in Cambridge-based BlueGnome, and later co-founding my very own first start-

up, Cronto Limited, the pioneer of visual transaction signing for Internet banking (acquired by VASCO Data Security International in 2013 for \$22m).

Following the acquisition, I then undertook the position of the Director of Innovation for VASCO, establishing and leading the VASCO Innovation Labs in Cambridge, creating the vision and research projects for the future products in cyber security.

What are you doing now and what are your plans for the future?

As a Director of Studies in Engineering and a Tutor, I support students at Christ's College. In the Department of Engineering, I'm lecturing the course on Software Engineering and Design (4M21), which also includes a segment on Innovation and Entrepreneurship.

As the Co-Founder and Chief Technology Officer of the medical technology startup Anidium Limited, I'm now back into the active 'product development' mode, using my experience and expertise in the field of consumer electronic devices and machine learning to design and develop YoHeart™ – a wearable ECG device to help earlier diagnosis of heart abnormalities at the most accessible cost.

I'm also lucky to have three lovely daughters (aged 23, eight and three) who make sure I maintain my proficiency in playdough shapes making, programming robotic toys, as well as in my ability to stay on top of the philosophical discussions about children's psychology.

How have you overcome challenges/knockbacks in your career?

My undergraduate years were the times of tanks and barricades on the streets of Moscow, and freedom was the most important word on everyone's lips at the time – freedom of thought, freedom of mind, freedom of choice. As a result, I reached the beginning of my professional career with a strong feeling that anything is possible. When I faced any challenges, all I had to do is remind myself that it is time to prioritise and persevere.

Do you have any advice for women who are considering studying/pursuing a career in engineering?

It has actually never occurred to me that it would be harder for me to achieve something just because I am a woman. I remember that I was told this, of course, but I was told many things that turned out not to be true and/or should not govern your life decisions and aspirations. It is hard for everyone, no matter who you are or what you do, just in a different way. If anything, I have always thought that being a woman gives me a bit of an edge, an advantage. Use your skills and talents, surround yourself with people who give you energy and support, and above all **persevere.**"



www-engineeringdiversity.eng.cam.ac.uk

Increasing student learning with open source Azure service



As the pace of global innovation continues to accelerate, the University of Cambridge is evolving engineering curriculum to teach core concepts faster using higher level, open source tools in the public cloud.

For example, a professor increased learning in an introductory computing class by having students use Microsoft Azure Notebooks Service powered by the Jupyter open source project.

This allows students to spend more time mastering concepts and enhancing problem-solving skills and less time on language syntax. This technology switch also gives students anytime, anywhere access to required tools needed to complete assignments, and it facilitates greater collaboration between professors, students, and the larger community.

To help produce innovative problem solvers, Cambridge is modernising its engineering programme, including introductory computing. Until recently, professors taught required concepts for modelling and simulations using technologies such as MATLAB, and C. students worked individually on exercises. Although this model worked for years, professors wanted to adopt new processes and toolsets.

“We’re developing a style of teaching that reflects the way people work, in industry and in the open source community,” says Garth Wells, Hibbit Professor in Solid Mechanics in the Department of Engineering. “And that’s very much a collaborative approach supported by open source tools and online services. We also want students to be able to work on computation anywhere, anytime, and on any kind of device.”

As a first step in realising his vision, Professor Wells revamped an entry-level computing course, using a web application that allows professors and students to build libraries of shareable notebooks containing text, equations, visualisations, and code.

“We wanted to teach higher-level tools like Python, and Jupyter Notebook is the obvious choice for that,” explains Professor Wells. “With it, we can focus more on concepts and problem solving, and less on languages’ syntax. Plus, Jupyter Notebook is open source, so students can use it, along with their knowledge of computation, for any class and at any organisation, even a start-up.”

Initially, Professor Wells deployed Jupyter Notebook on University servers for a small group of students.

“I could see we were going to have issues because we don’t have the right resources to scale the solution on our servers to support 340 students, particularly when a good fraction of those will use notebooks in all sorts of strange ways that can cause infrastructure problems,” he says. “Around that time, I met with Kenji Takeda, Director of Microsoft Research Cambridge. He put me in touch with engineers in Seattle, who were developing a software-as-a-service version of Jupyter Notebook called Azure Notebooks Service.”

Professor Wells ended up adopting the initial release of Azure Notebook Service for his class instead of managing Jupyter Notebook onsite. “By keeping all

technologies in-house, you inevitably have to rein in your ambitions to fit available resources,” he explains. “With Azure Notebooks, we don’t have to worry about scalability or whether systems will crash if someone does something out of the ordinary.”

The updated computing class was a resounding success. “A lot of my colleagues were concerned that the new course was too difficult. But at the end of the term, those who had taught introductory computing in previous years really marvelled at the level that students reached using Python and Jupyter Notebooks,” adds Professor Wells.

For example, students learned more about plotting data than in previous years by working with public data and open source tools in notebooks. In one lesson, students plotted crime reports in Cambridge by year, month, and category. In another lesson, students created plots with interactive sliders to explore population growth in different regions of the country.

Moving forward, professors at Cambridge see the use of Azure Notebooks Service as a strategic step in evolving engineering curriculum. Students can learn more because they focus on key concepts. They also learn how to use increasingly popular open source technologies and collaborative workflows.



azure.microsoft.com/en-us/education/

Undergraduates put their skills into practice during internship

Engineering undergraduates Tom Vinestock (St John's College) and Stuart Lewis (Magdalene College) completed a 10-week internship at Concrete Canvas. Here they detail their experience.

Hi Tom, what were the highlights of your internship?

In general, I found it rewarding that the work I was doing had tangible outcomes. My research contributed to the development of a new idea and informed the decision on a significant capital expenditure. The more hands-on approach at Concrete Canvas was also a plus; it was brilliant to have relatively ready access to a well-equipped lab and workshop. The company was really welcoming too.

How has this experience helped you with regard to your future career aims?

I learned a lot over the course of my internship about how commercial engineering is practised. I also developed a range of skills, both those taught as part of my course, such as CAD and data analysis, and others which were newer, such as liaising with suppliers, and writing industry-style, as opposed to academic, project and lab reports.

The internship also made me consider the advantages of working for a smaller company, which I hadn't previously considered, and the benefits this brings, such as greater responsibility and faster decision-making, which allowed my project to progress more quickly.

I aim to use my technical skills to work on innovative and worthwhile engineering projects, with some degree of freedom to explore my own ideas. I would also like to do something that has a broadly positive environmental impact.

Stuart, how has the internship benefitted you?

I enjoyed work at Concrete Canvas and would be keen to do more. My work related to the reuse of materials; I was involved in designing and constructing a new machine to try to recycle industry off-cuts.

I enjoyed the freedom that I was given in my project as well as working with lots of different people. It was nice to apply some



Credit: Concrete Canvas

↑ Taking part in the internship, from left, undergraduates Alex Watson, Stuart Lewis, Tom Vinestock, and Joe Holland.

of the skills picked up at University and to develop new and more practical skills.

If you are an employer interested in discussing summer internship opportunities for Cambridge undergraduates, please email placements-coordinator@eng.cam.ac.uk



www.placements.eng.cam.ac.uk

Alumnus makes donation to the Department

Alumnus Rod Cameron (Trinity Hall 1966) made an emotional return to the Department where he once worked and studied, and gifted a generous donation to help fund student projects.

"The privilege of my years here at Cambridge gave me something that is hard to put into words. It has grown more and more important with the passing of the years, so much so, that at the age of 80, I wanted to delay no more in coming back to say 'thank you' to an ancient university that remains at the cutting edge in modern times.

"I had quite an emotional morning when I re-visited the Department of Engineering. Many memories that had started to get cloudy came back crisp and clear as we ventured into older sections of the labs. We visited the

fluid mechanics labs and also the machine shop where I once spent many months. We saw the materials testing of structures labs I knew so well, before finally venturing into the very new and large undergraduate practical hands-on area – the Dyson Centre for Engineering Design. I was so impressed with this new undergraduate training space.

"I was also delighted to make a donation towards a fund for student projects and came away with a renewed bond.

"My PhD, which I began in 1963, looked into an experimental technique; using magnetic reluctance to measure the very thin oil films that lubricate mechanisms in rolling contact under high load. In 1969, I went to work in Mexico to equip a new university engineering lab, before later returning to Canada, where I designed some new machines to process, shred and compact solid waste.

"Clarity of mind allowed me to see that



Credit: Rod Cameron

my first instinct – to work with my hands – especially with precision mechanisms, was, in fact, my true calling. I started studying the making of musical instruments, specifically the baroque flute of the 17th and 18th centuries, as used in the repertoire of composers of that era. My first flute was sold to Stanford University music department in 1975 and I have not been without an order since."



www.philanthropy.cam.ac.uk

Honours, awards and prizes

MacRobert Award winner



Owlstone Medical, creators of a Breath Biopsy platform that could save the global healthcare system more than \$1.5 billion, has won the Royal Academy of Engineering's 2018 MacRobert Award.

The Award recognises outstanding innovation, tangible societal benefit and proven commercial success. Among the winning team members were alumni Billy Boyle, Co-founder and CEO, and David Ruiz-Alonso, Co-founder and COO.

Fellowship for early career researcher



Dr Marina Antoniou has been appointed as a Royal Society Dorothy Hodgkin Fellow for the next five years.

The Fellowship, designed to help scientists and engineers at an early stage of their careers progress to permanent academic positions across the UK, will allow Dr Antoniou to pursue research into 'silicon carbide power devices for smart grid systems'.

Posthumous award

Dr Norman de Bruyne, inventor and pioneer, has been honoured with a posthumous award.

Dr de Bruyne (1904-1997), who lectured and conducted research at the Department from 1937, revolutionised aircraft structural design and manufacture with advanced adhesives.

In tribute, a bronze Aeronautical Heritage Award plaque was presented by the Royal Aeronautical Society to the Department. It is sited at the Trumpington Street entrance.

PhD student joins new advisory panel



Alumna, Chartered Civil Engineer and current PhD student Sakthy Selvakumaran has been selected to the National Infrastructure Commission's new Young Professionals Panel (YPP).

Architects, engineers, designers and energy specialists from across the country are among the 16 founding members of the group chosen to help shape the UK's infrastructure. The YPP has been set up to inform the Commission's work and give a strong voice to the infrastructure sector's future leaders.

Academic achievement honoured



Alumnus Felix Newman has won a British Education Award for outstanding sporting and academic excellence achieved during his Cambridge Master of Engineering degree (MEng).

Felix achieved a First in every year of his studies and a Distinction in his final year. He balanced academic commitments with sporting demands as a member of Cambridge University Boat Club – a role that included rowing for the winning team

in the 162nd Cambridge-Oxford Boat Race in 2016.

Outstanding student research



PhD candidate Ruodan Lu has won a celebratory award in the category of 'Outstanding Student Research Project'.

Ruodan accepted the CETI: Celebration of Engineering & Technology Innovation Award for her PhD project – Automated Bridge Information Model Generation System – which provides a step change in the way existing highway bridges are inspected, by automating the process of virtual bridge model generation. This makes it possible to bring the on-site inspection work into the office.

Interdisciplinary research award

A Rosetrees Trust Award for Interdisciplinary Research between the Departments of Engineering and Medicine has been announced.

The research, which involves Dr Athina Markaki and Dr Alexander Justin from the Department of Engineering, aims to generate the first fully-functional bioengineered bile duct to replace the native bile duct in small and large animal models.

Cambridge MPhil gains accreditation

The MPhil in Nuclear Energy has been accredited by the Energy Institute.

The one-year taught masters degree course, designed to train the nuclear leaders of tomorrow, covers nuclear technology, business and policy, and industry practice. The course is supported by an Industry Club drawn from leading companies that are active in the UK nuclear market.

→ Artist's impression of a nanobot

How to train your drugs: nanotherapeutics



Credit: Yu-Ji

Nanotechnology is creating new opportunities for fighting disease.

Chemotherapy benefits a great many patients but the side effects can be brutal.

When a patient is injected with an anti-cancer drug, the idea is that the molecules will seek out and destroy rogue tumour cells. However, relatively large amounts need to be administered to reach the target in high enough concentrations to be effective. As a result of this high drug concentration, healthy cells may be killed as well as cancer cells, leaving many patients weak, nauseated and vulnerable to infection.

One way that researchers are attempting to improve the safety and efficacy of drugs is to use a relatively new area of research known as nanotherapeutics to target drug delivery just to the cells that need it.

Professor Sir Mark Welland is Head of the Electrical Engineering Division at Cambridge. In recent years, his research has focused on nanotherapeutics, working in collaboration with clinicians and industry to develop better, safer drugs. He and his colleagues don't design new drugs; instead, they design and build smart packaging for existing drugs.

Nanotherapeutics come in many different configurations, but the easiest way to think about them is as small, benign particles filled with a drug. They can be injected in the same way as a normal drug, and are carried through the bloodstream to the target organ, tissue or cell. At this point, a change in the local environment, such as pH, or the use of light or ultrasound, causes the nanoparticles to release their cargo.

Nano-sized tools are increasingly being looked at for diagnosis, drug delivery and therapy.

"There are a huge number of possibilities right now, and probably more to come, which is why there's been so much interest," says Professor Welland.

Using clever chemistry and engineering at the nanoscale, drugs can be 'taught' to behave like a Trojan horse, or to hold their fire until just the right moment, or to recognise the target they're looking for.

"We always try to use techniques that can be scaled up – we avoid using expensive chemistries or expensive equipment, and we've been reasonably successful in that," he adds. "By keeping costs down and using scalable techniques, we've got a far better chance of making a successful treatment for patients."

In 2014, he and collaborators demonstrated that gold nanoparticles could be used to 'smuggle' chemotherapy drugs into cancer cells in glioblastoma multiforme, the most common and aggressive type of brain cancer in adults, which is notoriously difficult to treat. The team engineered nanostructures containing gold and cisplatin, a conventional chemotherapy drug. A coating on the particles made them attracted to tumour cells from glioblastoma patients, so that the nanostructures bound and were absorbed into the cancer cells.

Once inside, these nanostructures were exposed to radiotherapy. This caused the gold to release electrons that damaged the cancer cell's DNA and its overall structure,

enhancing the impact of the chemotherapy drug. The process was so effective that 20 days later, the cell culture showed no evidence of any revival, suggesting that the tumour cells had been destroyed.

While the technique is still several years away from use in humans, tests have begun in mice. Professor Welland's group is working with MedImmune, the biologics R&D arm of pharmaceutical company AstraZeneca, to study the stability of drugs and to design ways to deliver them more effectively using nanotechnology.

The researchers are also targeting diseases like tuberculosis (TB). With funding from the Rosetrees Trust, Professor Welland and postdoctoral researcher Dr Íris da Luz Batalha are working with Professor Andres Floto in the Department of Medicine to improve the efficacy of TB drugs.

Their solution has been to design and develop nontoxic, biodegradable polymers that can be 'fused' with TB drug molecules. As polymer molecules have a long, chain-like shape, drugs can be attached along the length of the polymer backbone, meaning that very large amounts of the drug can be loaded onto each polymer molecule. The polymers are stable in the bloodstream and release the drugs they carry when they reach the target cell. Inside the cell, the pH drops, which causes the polymer to release the drug.



Watch the video 'The Future of Medicine': youtu.be/ZGGDKC3Grl