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DEPARTMENT OF ENGINEERING

# NEWS

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invent world's first zero  
emissions cement**

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## Help shape the future of the Newsletter

Please complete the Department Newsletter survey.

➔ [www.eng.cam.ac.uk/survey](http://www.eng.cam.ac.uk/survey)

The survey will remain open until **31 January 2023**

Thank you for your help.



Cover image: Silver nanoparticles on a silicon MEMS (micro-electro-mechanical systems) device. Credit: Malar Chellasivalingam. 2020-21 ZEISS Photography Competition, Department of Engineering, University of Cambridge. © 2022 University of Cambridge and Contributors as identified. The content of Department of Engineering News, with the exception of images and illustrations, is made available for non-commercial re-use in another work under the terms of the Creative Commons Attribution-Non-Commercial-ShareAlike Licence <https://creativecommons.org/licenses/by-nc-sa/4.0/>, subject to acknowledgement of the original author/s, title of individual work and the University of Cambridge. This Licence requires any new work with an adaptation of content to be distributed and re-licensed under the same licence terms.

## Note from the editors

We would like to invite you to complete our Department Newsletter survey at the link below.

We hope to collect as much feedback as possible from our alumni community to help shape the future of the Newsletter.

Please note the survey may take up to 5 minutes to complete.

The survey will remain open until **31 January 2023**, as we are aware that postal services can be slow and some of our overseas alumni may not receive their Newsletter as quickly as others.

[www.eng.cam.ac.uk/survey](http://www.eng.cam.ac.uk/survey)

If you have any questions about the survey, please do get in touch by emailing [marketing@eng.cam.ac.uk](mailto:marketing@eng.cam.ac.uk)

Thank you for your help.

**Charlotte Hester and Jacqueline Siggers**

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## Head's welcome

It is wonderful to anticipate a new academic year with the return of face-to-face interaction and working together once again. We can start to think about the scope for future achievements in our research, rather than having to focus on just keeping things going through difficult times. Part of the joy of a large multidisciplinary department is the way we can cover so many areas and create collaborative links between them. Our research strengths sometimes centre around skills and techniques such as machine learning or the manipulation of graphene. Sometimes they are grouped around applications such as support for the energy transition or the maintenance of bridges and underground metro tunnels. All the main traditional disciplines of engineering are covered in one way or another.

But there is one area that is not a traditional engineering focus where this department seems to have quietly built up an interesting focus, where about 7% of all our group leaders work. This area is the engineering principles of biological neural systems, or engineering neuroscience. It is an interesting and important field because ultimately, it holds the key to ways of improving mental health, curing mental illness and dealing with other diseases of the brain and nervous system such as Parkinson's disease. At a deeper level, the more we understand how our brains work, the better we will understand ourselves, and the more accurate our self-image as human beings will be. Furthermore, we are learning new ways of creating artificial intelligence by mimicking techniques and computational structures found in the brain.



Credit: Graham Copekoga

In neuroscience, as in many other fields, we can innovate by copying nature.

Two articles in this issue feature research linked to this area. **Page 16** features the work of Dr Timothy O'Leary and Dr Michael E. Rule on the adaptable nature of neural coding. **Page 15** features details of a miniature brain sensor invented by Elise Jenkins and Ben Woodington, developed in Professor George Malliaras' group, where many techniques are studied for interfacing biological neural systems to electrical circuits and sensors. That is just two groups and there are many more. In areas related to the work of Dr O'Leary, we have Professor Rodolphe Sepulchre working on spiking control systems; Professor Glenn Vinnicombe analysing the mechanisms of early invertebrate vision; and Dr Fulvio Forni studying the way oscillators, switches and regulators are created in neural systems. Related to Professor Malliaras, there are other group leaders with an applied focus such as Dr Stefan Goetz, who develops techniques for neuromodulation and the detection of neural activity, and Dr Flavia Mancini, who studies the neural basis of pain. In addition, we have the more theoretical group of Computational Biological Learning (CBL) including Dr Yashar Ahmadian Tehrani, who studies how large networks of neurons give rise to perception and higher level cognitive functions; Professor Máté Lengyel, who works on computational learning and memory; and Dr Guillaume Hennequin, who studies neural dynamics and control. CBL was originally created by Professor Daniel Wolpert, who is now primarily based at Columbia University,

but keeps a strong link with colleagues in Cambridge. Overall, we have a richer ecosystem in the engineering neuroscience than in many of our more conventional disciplines.

This leads to the question: why is it good to do neuroscience in a department of engineering? The essence of the challenge is to work out how a system works, given some information about its structure and some examples of what it achieves. The information is often vague and general, which makes this difficult. But knowledge of control theory, information theory, parallel computational architectures, coding algorithms, probability and inference, provide a key context and often limit the nature of the solution that can be considered. The mathematical toolboxes that are standard for engineers are conveniently complementary to the more experimental approaches pursued in biological neuroscience laboratories. For these reasons, engineering neuroscience is an entirely appropriate field for the department to develop and I am optimistic that our colleagues will make a significant contribution.

This is perhaps an extreme example, but I see the boundaries of engineering being stretched across the whole department. As we appoint new staff, they understand the challenges of the future and see which problems are going to be most important for us to solve. Engineering is much more an attitude of mind than a fixed list of topics to study.

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

→ The Electric Arc Furnace steel recycling process. For the Cambridge Electric Cement process, this material will be cooled to make Portland cement clinker



Credit: UKFIREs

## Cambridge engineers invent world's first zero emissions cement

Three Cambridge engineers, Dr Cyrille Dunant, Dr Pippa Horton and Professor Julian Allwood, have filed a patent and been awarded new research funding for their invention of the world's first emissions-free route to recycle Portland cement.

Replacing today's cement is one of the hardest challenges on the journey to a safe climate with zero emissions. There are many options to make cement with reduced emissions, mainly based on mixing new reactive cement (clinker) with other supplementary materials. However, until now, it has not been possible to make the reactive component of cement without emissions. The new invention achieves this for the first time within the parameters of established industrial processes.

The inspiration for Cambridge Electric Cement struck inventor Cyrille Dunant when he noticed that the chemistry of used cement is virtually identical to that of the lime-flux used in conventional steel recycling processes. The new cement is therefore made in a virtuous recycling loop, that not only eliminates the emissions of cement production, but also saves raw materials, and even reduces the emissions required in making lime-flux.

The new process begins with concrete waste from demolition of old buildings. This is crushed, to separate the stones and sand that form concrete from the mixture of cement powder and water that binds them together. The old cement powder is then used instead of lime-flux in steel recycling. As the steel melts, the flux forms a slag that

floats on the liquid steel, to protect it from oxygen in the air. After the recycled steel is tapped off, the liquid slag is cooled rapidly in air and ground up into a powder that is virtually identical to the clinker that is the basis of new Portland cement. In pilot-scale trials of the new process the Cambridge team have demonstrated this combined recycling process, and the results show that it has the chemical composition of a clinker made with today's process.

The new cement was invented as part of the large multi-university UK FIREs programme led by Professor Allwood, which aims to enable a rapid transition to zero emissions based on using today's technologies differently, rather than waiting for the new energy technologies of hydrogen and carbon storage. Invention of the cement has been rewarded with a new research grant of £1.7m from EPSRC, to allow the inventors to collaborate with Dr Zushu Li at Warwick University and Dr Rupert Myers at Imperial College, to reveal the underlying science behind the new process. The new grant will fund an additional team of researchers, to probe the range of concrete wastes that can be processed into Cambridge Electric Cement, evaluate how the process interacts with steel making, and confirm the performance of the resulting material.

Professor Allwood said: "If Cambridge Electric Cement lives up to the promise it has shown in early laboratory trials, it could be a turning point in the journey to a safe future climate. Combining steel and cement recycling in a single process powered by renewable electricity could secure the supply of the basic materials of construction to support the infrastructure of a zero emissions world and enable economic development where it is most needed."

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Combining steel and cement recycling in a single process powered by renewable electricity could secure the supply of the basic materials of construction to support the infrastructure of a zero emissions world and enable economic development where it is most needed.

Professor Julian Allwood



ukfires.org

→ Graduate student Tobias Naegele is seen fabricating an implantable device for chemotherapy delivery. The microfluidic *in vitro* model is shown (bottom, right)

Credit: Keith Heppell (images left and centre); Yuanyuan Bei (image bottom, right)



## How targeted drug delivery technologies can help in the fight against cancer

Researchers from the Department of Engineering are working with scientists and clinicians on the development of targeted drug delivery technologies for three hard-to-treat cancers – mesothelioma, pancreatic cancer and glioblastoma (an aggressive form of brain tumour). These cancers are hard to treat because they come with their own defence mechanisms.

The researchers' goal is to develop and validate novel drug delivery technologies to support the work of clinicians and improve survival rates for patients. The technologies can all be classed as platform technologies and are applicable to multiple cancers as well as other conditions.

The EPSRC Interdisciplinary Research Collaboration (IRC) in Targeted Delivery for Hard-to-Treat Cancers comprises five founding universities: Cambridge, Imperial College London, UCL, Glasgow and Birmingham, and more recently Nottingham, alongside several partner organisations. Survival rates for hard-to-treat cancers remain below 14%. Nine out of 10 people diagnosed with one of these specific tumours in the chest lining, pancreas and brain will succumb to the disease. This is why the IRC is developing high capacity nanoscale molecular vehicles and injectable gels, as well as implantable devices, to better target hard-to-treat cancers.

**Nanoscale molecular vehicles** have the aim of delivering drugs exactly where they are needed and nowhere else. They are adaptable and offer high drug carrying capacity and controlled release.

**Gels that can be injected** onto the cavity surface of the brain after a tumour has been removed, gradually release anti-cancer drugs to eliminate any residual tumour cells.

Combining gels and molecular vehicles enables opportunities to enhance therapies and control delivery timescales.

**Implantable devices** deliver high concentrations of drugs directly to tumours that are difficult to operate on.

"Having a specific clinical focus is necessary to best progress the technologies from the lab to the bedside in a timely fashion," said Professor George Malliaras, Director of the IRC and Prince Philip Professor of Technology. "We develop materials and devices and explore their structure and properties before transitioning to models and validating processes, always driving development towards human trials.

"To this end, we engage with clinicians from the very start to map the real-life needs for technology development, what has to happen when, where the path leads, and what and where the bottlenecks and obstacles might be. In this truly interdisciplinary process, our scientists, engineers and clinicians are all adept at communicating across traditional discipline boundaries."

Ronan Daly, Professor of Advanced Manufacturing, and his team (Research Associates Dr Niamh Fox, Dr Etienne Rognin and Dr Qingxin Zhang) from the Institute for Manufacturing (IfM), part of the Department of Engineering, are supporting all of the drug delivery technology areas through the

development of simulation tools. One of these enables IRC researchers to accurately explore how a drug would diffuse in the brain and carry out experiments with great precision to consider different modes of operation for an implantable deliverable device.

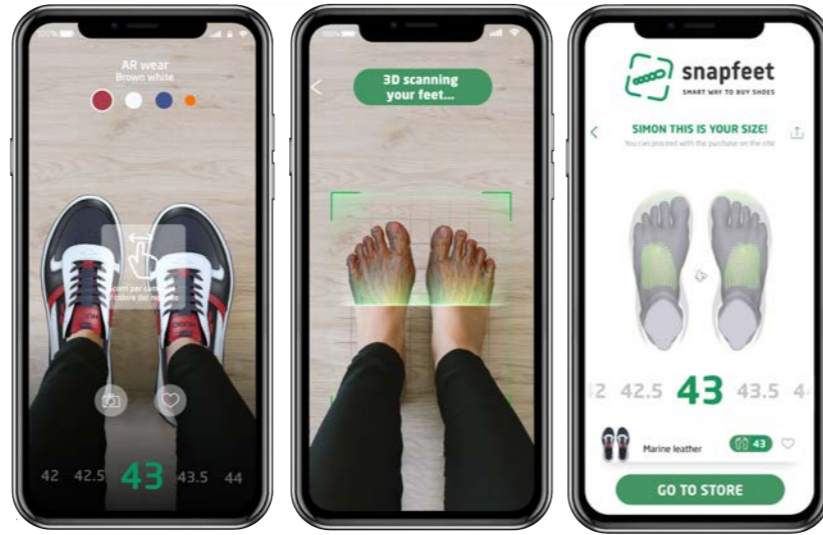
Professor Daly said: "As new platform technologies are created to solve the world's biggest challenges, we also need new infratechnologies to support their development. These are the underpinning tools that help with translation. They are purpose-built to enable rapid understanding and feedback to the researchers to help with design iterations. We support the technology leaders by developing these tools so they can better predict how best to help a patient."

Shery Huang, Professor of Bioengineering, has been working with colleagues from the Department of Clinical Neuroscience and the Department of Paediatrics on the development of a microfluidic device to perform comparative studies to understand the behaviour of patient-derived glioblastoma stem-like cells and their interactions with the blood-brain barrier.



Watch the IRC's animation explainer: [youtu.be/pZaRkMx00ok](https://youtu.be/pZaRkMx00ok)  
[teddy.eng.cam.ac.uk](http://teddy.eng.cam.ac.uk)

## Computer vision for virtual footwear fitting and shoe size suggestion



Snapfeet is a new mobile phone app that shows how well shoes will fit based on the 3D shape of the user's foot. It also offers a simple augmented reality (AR) visualisation of what the shoes will look like on the feet.

The app technology is designed for online shoe retailers to offer to their customers, to provide accurate fitting of different styles of shoe and the opportunity to see how the shoes will look on the shopper's feet. This should lead to less footwear being returned. There is a huge cost in returns, both monetary and environmental. Many shoe retailers make very little revenue from online sales due to the high rate of returns, so this app aims to change this.

Professor Roberto Cipolla and his team Dr James Charles and PhD student Ollie Boyne from the Machine Intelligence group have created the app working in collaboration with Giorgio Raccanelli and the team at Snapfeet.

The Snapfeet app allows the customer to wear the shoes virtually via their phone thanks to AR and find their perfect shoe fit in a few moments.

Snapfeet creates, in realtime, an accurate 3D copy of the user's feet. In a few seconds it is possible to make a 3D model of both feet, simply by taking a few mobile phone photographs from different viewpoints.

Taking the user's foot shape and comparing it to the shoe geometry, Snapfeet is then able to recommend the correct size for each type of shoe, communicating to the user the degree of comfort that can be achieved in the different parts of the foot: toe, instep, heel and sole.

Giorgio Raccanelli says: "You download the Snapfeet app, register, take a few pictures all the way around the foot, and a 3D model of the foot will appear, allowing you to immediately start shopping. The

application automatically compares the three dimensional image of the foot with the chosen shoe style, showing you how it will fit, or will directly suggest a style that is most suited to your foot shape."

Snapfeet have their first big customers in Hugo Boss and Golden Goose.

Initially, when the user opens the app, there is a calibration phase where the user begins tracking the camera using the latest AR features on mobile phones.

The app builds upon AR technology to track the camera and calculate how far it is moving; it also detects the foot and the floor, providing a good idea of world space.

As the phone moves around, certain key points of interest on the foot are detected to help determine the foot length and width, then a 3D mesh is created from these measurements and the model is laid over the user's foot in AR so the user can visually validate if it is correct.

Snapfeet allows you to adjust the model in realtime and then immediately obtain the 3D model of your foot on the phone.

There are three machine learning foot algorithms in play. One is building the parameterised foot model; the second is the machine learning that recovers the parameters of the model from multi-view images as you move the mobile phone around. The third machine learning algorithm within the app compares the 3D foot model against all the shoe shapes, or "lasts", that the customer is interested in and will then return a size of those shoes that will best fit the user's foot. This is the virtual try on.

The algorithm will take the foot model and digitally place it inside all the shoes

chosen and give you a comfort score.

You are then able to render a virtual shoe onto your feet using the AR. The app also detects where the legs/trousers are so it can get the correct occlusion effect, using machine learning to capture the tracking of the foot.

The app also uses AR once it has recovered the foot shape so the user can get the "feel" of actually trying on the shoe. The AR element of the app then allows the user to see what the shoes will look like on their feet and whether they go well with a particular outfit.

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A parametrised foot model and novel deep learning algorithms for recognising curves and surfaces allowed us to run the 3D reconstruction algorithm in real-time on the device.

Professor Roberto Cipolla



**Download the app:**  
[snapfeet.io/en/snapfeet-en](https://snapfeet.io/en/snapfeet-en)

## ALUMNI UPDATE

### Meet Jabulani Nyathi – a champion of sustainable development



Alumnus Jabulani Nyathi is an engineer on a mission. Born and raised in South Africa, his commitment to sustainable development is strong. Having recently achieved a Master of Philosophy in the field, he is now involved in the ongoing energy transition in South Africa, focusing on zero and low carbon fuels – a calling close to his heart.

Motivated by a desire to make a difference and to build on his prior chemical engineering knowledge, Jabulani came to Cambridge to study for an MPhil in Engineering for Sustainable Development as part of the 2020/21 cohort. His reasons for this were threefold.

"Firstly, it has become evident that in order to ensure sustainable growth within South Africa, where I am from, leaders are required to understand the multifaceted nature of solving issues caused by the country's reliance on a predominantly coal-based grid and economy," he said.

"Secondly, individuals are needed globally who can innovate in engineering industries whilst accounting for the reality of climate change – the ticking time bomb.

"Lastly, a personal acknowledgment of mine is the need to foster a community of like-minded individuals who can collaborate in a cross-functional manner to sustainably bring about benefit to society."

For his MPhil dissertation research, Jabulani focused on South Africa's Just Transition – a qualitative look at the various interventions that could be implemented in order to achieve sustainable production and tackle the country's reliance on coal. Jabulani identified transition management, socio-economic development, and support mechanisms for coal workers, communities and the environment, as interventions that could help.

"I love the problem-solving side of engineering and the opportunity to use science in this process," he said. "For me,

this is my profession and passion and these skills are crucial in addressing climate change and its effects.

"I am currently an analyst consultant focusing on zero and low carbon fuels. I work in the Power Planning and Solutions unit of an engineering consultancy and I am involved in an array of projects there, from shipping decarbonisation studies to cost of service studies for utilities in sub-Saharan Africa.

"My current work involves South Africa and the ongoing energy transition, with my aim being to make a return to South Africa to aid in the implementation of this transition and further my research in the area.

"In the near future, I will gain valuable industry experience in the field of sustainability consultancy, focusing on sustainable infrastructure and operations. My goal is to continue working in the field of sustainable development, contributing my engineering expertise towards figuring out how net zero and the global decarbonisation agenda can be best implemented for the benefit of future generations."

#### Making your goals a reality

Jabulani's message to others looking to follow a similar route into engineering is clear: believe to achieve.

"To other African youth considering engineering as a field to pursue, I would say it is important to believe it is possible to achieve the goals that you set out. There are people out there and opportunities that can aid in making these goals a reality.

"A lack of resources can often seem like a massive hindrance, but I am testament that somehow things can work out (I achieved scholarships to support my undergraduate and graduate studies); it just takes a bit of courage and perseverance."

#### Joining the Cambridge community

Despite studying during the COVID-19 pandemic, which presented its own challenges, Jabulani says he enjoyed his time at Cambridge.

"I look back on my time at Cambridge with gratitude for a unique experience, one that sits at the centre of knowledge creation and academia.

"My time at Cambridge was incredible for many reasons. Some of these include the opportunity to sing as part of the Magdalene College Choir, having the opportunity to live in one of the most beautiful places in the world, and interacting with some of the most amazing and interesting people I have ever met.

"The year was, of course, challenging due to the pandemic, but the Engineering and Sustainable Development cohort of 2020/21, along with the teaching staff, were particularly inspiring. Their knowledge and individual approaches to trying to solve the world's most pressing challenges have had a positive impact on me."



[www-esdmphil.eng.cam.ac.uk](https://www-esdmphil.eng.cam.ac.uk)



## Royal visit to world-leading Cambridge sustainability projects

↑ His Majesty The King visited the University's Whittle Laboratory

During a visit to groundbreaking sustainability projects at the University of Cambridge earlier this year, King Charles III, then known as HRH The Prince of Wales, met with experts and practitioners from all sectors and disciplines working together to solve the world's biggest problems.

His Majesty visited the Whittle Laboratory to see groundbreaking work hosted there on how to accelerate the transition to sustainable aviation.

He was joined by the former Secretary of State for Business, Energy and Industrial Strategy, Kwasi Kwarteng, and key figures from the aviation sector, including business and government representatives, to see both cutting-edge, zero-emission technology under development and a new global whole-system model of the aviation sector developed by the Aviation Impact Accelerator (AIA). The AIA is an industry-academia initiative started more than two years ago by a challenge from His Majesty for Cambridge to accelerate the transition towards sustainable flight. The AIA is led by the Whittle Laboratory and the Cambridge Institute for Sustainability Leadership (CISL).

Speaking at the time, former Business Secretary Kwasi Kwarteng said: "We are determined to seize the economic opportunities of the global shift to greener aviation technologies, which will help to secure growth and thousands of jobs across the country. That is why just this

week we have announced record levels of government funding for our Aerospace Technology Institute R&D programme.

"It has been fantastic to accompany HRH The Prince of Wales on a visit to one of our country's great seats of learning to discover more about some of the incredible new zero-emission technologies that are currently under development at the world-class Whittle Laboratory."

During the event, His Majesty was introduced to the latest developments on a planned new Whittle Laboratory building, currently under development. This new site would provide facilities for rapid technology development, cutting the time to develop technologies from years to months, and act as a hub for the AIA, a global network of experts working to provide evidence-based insights to unlock system-wide change. By bringing together multidisciplinary global expertise from industry and academia, this new hub will accelerate the aviation sector towards a climate-neutral future and help sustain the UK as a leader in aviation innovation.

Professor Rob Miller, Director of the Whittle Laboratory, said: "Achieving an

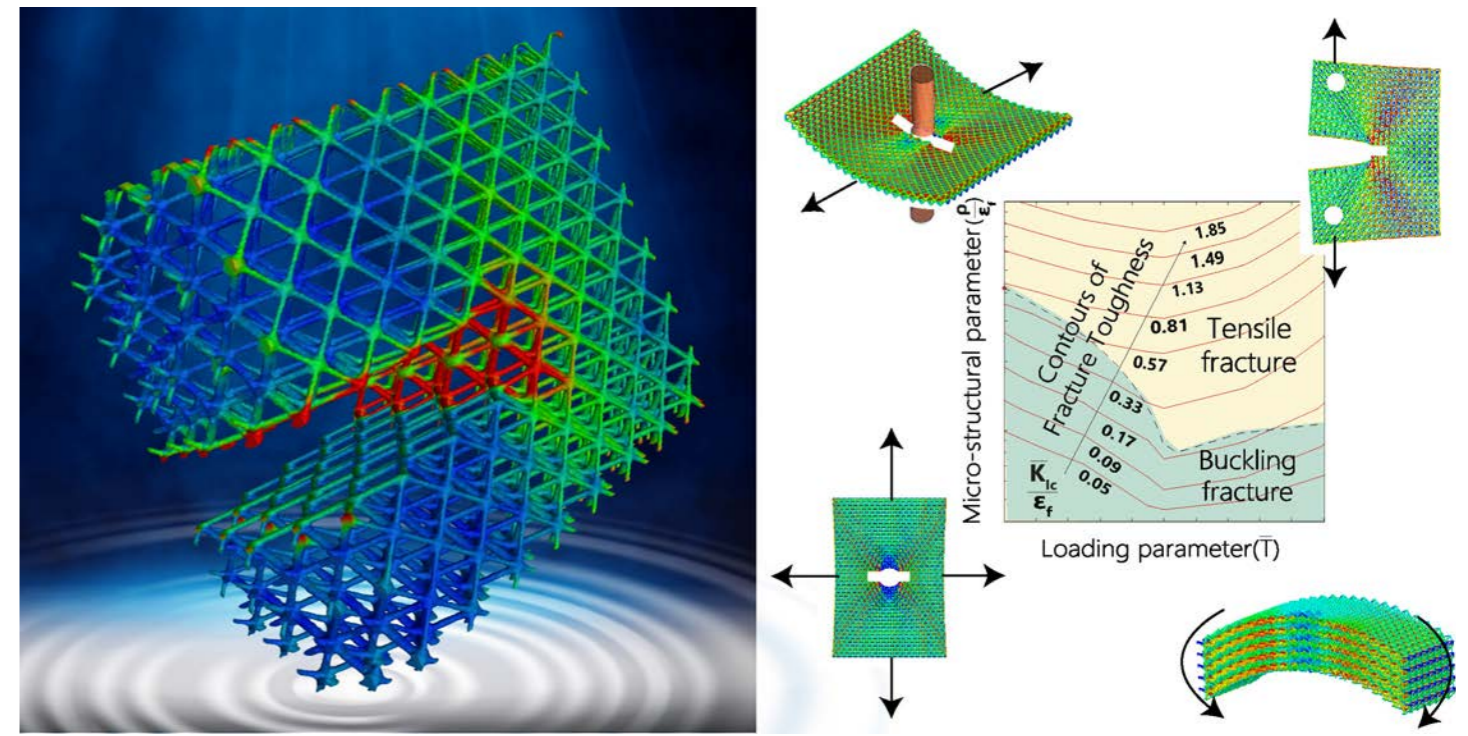
aviation sector with no climate impact is one of society's biggest challenges. Solving it will require a complex combination of technology, business, human behaviour and policy. We have assembled a world-class team of academics and industry experts to take on this challenge."

**Achieving an aviation sector with no climate impact is one of society's biggest challenges. Solving it will require a complex combination of technology, business, human behaviour and policy. We have assembled a world-class team of academics and industry experts to take on this challenge.**

Professor Rob Miller



whittle.eng.cam.ac.uk



## Unlocking the toughness of metamaterials could transform future mechanical design

↑ Emergence of 'fracture mechanism maps' for the design of mechanical metamaterials

Researchers have identified the criteria needed to develop tough and damage-tolerant mechanical metamaterials. Using experiments and numerical analysis, the team investigated the continuum theories of elastic fracture mechanics in three-dimensional architected solids.

Mechanical metamaterials are an emerging class of ultralight materials with extreme functional properties, made possible thanks to recent advances in additive manufacturing. Their potential for use in a plethora of engineering applications, particularly as structural components, owing to their simultaneous high strength at low densities, for example, has been limited due to difficulties in evaluating failure and understanding 3D metamaterials' tolerance to damage and defects.

But now, research led by the University of Cambridge takes a new look at the fundamental concepts of fracture mechanics in truss-based architected solids and provides a framework that has the potential to be applied to any 3D metamaterial, regardless of its topology and its constituent material properties. The aim here is to aid designers with a tool to not only invent new failure resilient 3D metamaterials, but also provide an engineering methodology to design with these materials. The results are reported in the journal *Nature Materials*, accompanied by a news and views report also in *Nature Materials*.

Using cutting-edge experimental techniques, the researchers were able to generate 'fracture mechanism maps' that can be used by metamaterial designers to evaluate failure in different applications and assess the toughness of the metamaterial – something that has, until now, been the limiting factor in mechanical design. These 'maps' enable the optimised metamaterial topology to be selected, based on the desired design parameters: for example, parent material property and lattice relative density.

Dr Angkur Shaikeea, the Ashby Research Fellow in the Department of Engineering and lead author of the study, said: "The design protocol we have developed can be used to identify topologies that maximise the damage tolerance and/or fracture toughness of metamaterials. This will enable the selection of optimal structural metamaterials for applications ranging from battery electrodes to thermal insulation."

The research, supervised by Professor Vikram Deshpande in the Cambridge Centre for Micromechanics, included collaboration

with Professor Xiaoyu (Rayne) Zheng's group at the University of California, Los Angeles, U.S.A.



**The design protocol we have developed will enable the selection of optimal structural metamaterials for applications ranging from battery electrodes to thermal insulation.**

Dr Angkur Shaikeea

→ Dr Francesco Amoruso during a live demo of the DfT-funded project



## New steering tech to reduce carbon emissions of HGVs

A new low-cost and lightweight steering technology, which began life in the Transport Research Group at the Department of Engineering, will be developed into a full-scale prototype on a Heavy Goods Vehicle (HGV) tractor-trailer, after being awarded a £30,000 grant by the Department for Transport (DfT).

The project aims to develop and test an innovative brake-actuated steering technology to improve the manoeuvrability of a wide range of larger vehicles on the road, reducing carbon emissions and tyre wear.

The active rear-steering system, which sits within one of the DfT's three key challenge areas – the 'Future of Freight' – will be validated through controlled track testing for a variety of road surfaces, loads and number of steered axles. The project, titled *Brake-Actuated Steering to reduce the carbon emissions of HGVs*, has been funded under the DfT's 2021 Transport Research and Innovation Grants programme.

The brake-actuated steering concept, developed by Research Associate Dr Francesco Amoruso during his PhD, controls the brakes on a trailer during cornering, allowing articulated vehicles to safely navigate in urban and rural areas. A single-axle proof-of-concept on an HGV trailer was built and successfully tested during Dr Amoruso's PhD.

"In addition to significant improvements in manoeuvrability, the benefits of brake-actuated steering include unlocking the use of higher capacity vehicles in many urban and rural areas, improving efficiency, and reducing emissions and operating costs," said Dr Amoruso, co-principal investigator of the project. "The system eliminates tyre wear during cornering, enabling the use of fuel-efficient tyres."

HGVs in the UK must prove their manoeuvrability performance by successfully completing the roundabout test. As a vehicle's length increases, it becomes more productive and uses less energy per freight task. However, it is difficult for longer vehicles to pass the roundabout test and their lack of manoeuvrability poses a safety problem, particularly the increased tail swing (displacement of the vehicle's rear edge compared to the front outer wheel). Large tail swings reach further than the front of the vehicle and can lead to collisions with parked vehicles and street furniture and can block adjacent lanes.

Dr Daniel Ainalis, Senior Research Associate and principal investigator of the project, said: "As global urbanisation continues, it will become increasingly important to reduce the number of vehicles on our roads. Improving the energy consumption of each vehicle by using longer vehicles is one of the only ways of achieving this. Vehicle manoeuvrability constraints are also important in rural areas, for example where the capacity of vehicles can be limited by narrow entrances to farms, requiring many more vehicle journeys (e.g. to collect milk). Another issue with reduced manoeuvrability of longer HGVs is the severe tyre scrubbing during cornering that rapidly wears the tyres and produces non-exhaust emissions. This is

why the development and testing of our innovative low-cost and lightweight steering technology can help pave the way to more environmentally-friendly freight vehicles."

Professor David Cebon, Director of the Centre for Sustainable Road Freight, added: "We are delighted to have received this grant from the DfT to continue our work with industrial partners improving the productivity and environmental performance of HGVs. Trailer steering is an enabling technology that can dramatically improve HGV performance in a wide variety of application areas."

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In addition to significant improvements in manoeuvrability, the benefits of brake-actuated steering include unlocking the use of higher capacity vehicles in many urban and rural areas, improving efficiency, and reducing emissions and operating costs.

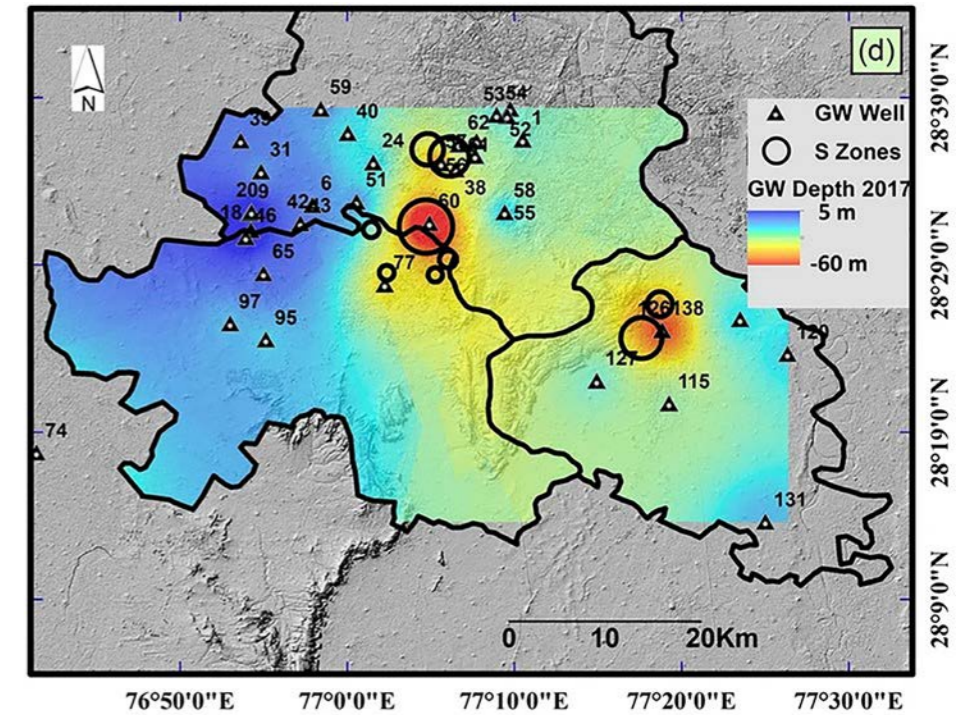
Dr Francesco Amoruso



csrf.ac.uk

→ Land subsidence and groundwater extraction in National Capital Region (NCR), Delhi, India. The black circles (S-zones) represent the regions undergoing subsidence, identified using a satellite-based technique known as 'interferometry'. The red-green-blue map in the background depicts the groundwater levels in the region, with red representing deeper levels and blue representing groundwater at a shallower depth. In-situ groundwater levels well data (white triangles) are collected by Central Groundwater Board (CGWB), India

Credit: Garg, S., et al. *Tracking hidden crisis in India's capital from space: implications of unsustainable groundwater use*. *Sci Rep* 12, 651 (2022)



## Hidden crisis in India's capital unveiled using satellite data

Using satellite data, researchers have found that around 100 sq km in and around Delhi have high risk of land subsidence. Groundwater extraction is causing parts of the city to sink, with the largest area experiencing subsidence just 800m away from Delhi's international airport.

Land subsidence is a severe and often overlooked geological hazard and a widespread global problem. It can be attributed to underground extraction of minerals, oil, gas and water, as well as natural events such as soil compaction, earthquake, and loess deposits. According to U.S. Geological Survey, more than 80% of land subsidence across the world is due to excessive groundwater extraction. When water is extracted from aquifers, the clay between pockets of water collapse gradually, leading to land subsidence.

A study titled *Tracking hidden crisis in India's capital from space: implications of unsustainable groundwater use*, published in the journal *Nature*, has found that the rate of land subsidence near Delhi Airport is accelerating rapidly.

During the years 2014–2016, the subsidence was found to be approximately 11cm/year which rose significantly by almost 50% over the next two years to around 17cm/year. The trend remained almost the same during 2018–2019, the study found.

"Of all the areas that are under threat, Kapashera near the airport was the most

vulnerable because the subsidence rate is extremely high," said Shagun Garg, a doctoral researcher in the EPSRC Centre for Doctoral Training in Future Infrastructure and Built Environment: Resilience in a Changing World (FIBE2), who is part of the project team.

"The airport requires stable ground because of the risk of major disruption if there's significant ground movement," Garg said. "Kuala Lumpur Airport is an example to understand the implications of land subsidence where cracks on taxiways and water-logging emerged due to soil settlement. Continuous monitoring of Delhi International Airport and its connecting roads is therefore crucial."

The growing population expansion and urbanisation require an enormous amount of water to satisfy demand. There is a huge gap of 750 million litres a day between the demand and the supply. Millions of residents do not have access to a piped water supply and rely on groundwater for their daily needs. In some places, the water depth is as high as 120m below ground level. The groundwater shortage is further complicated by Delhi's unchecked

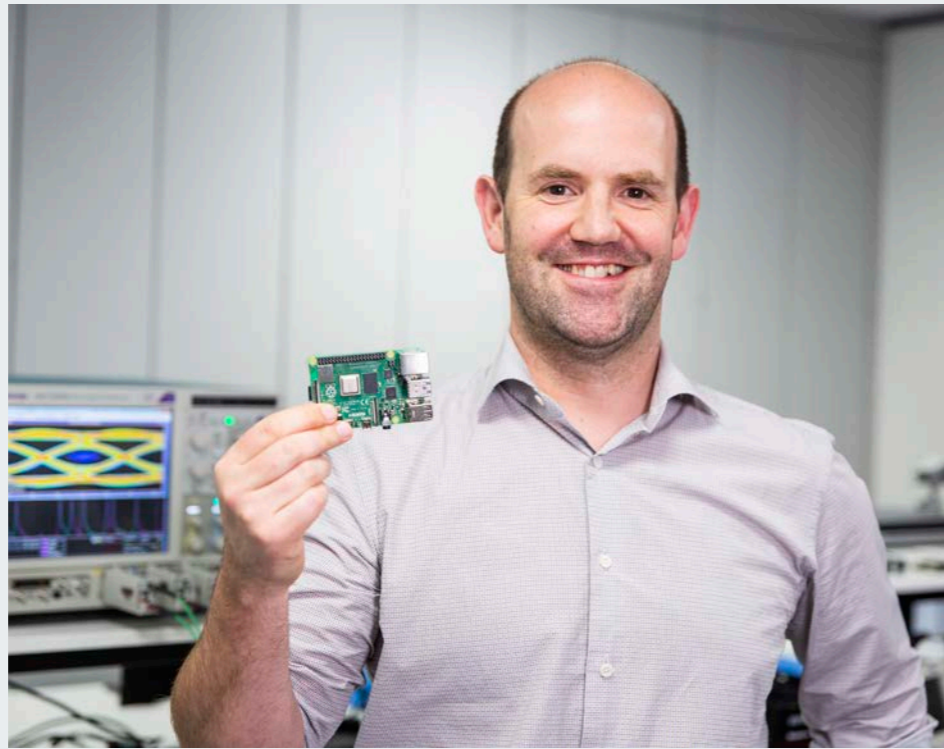
urbanisation, which is disrupting the rejuvenation of the city's aquifers. Concrete and other infrastructure have overtaken the city, blocking rainwater from absorbing into the ground.

Rainwater harvesting is one solution to the problem. Harvesting rainwater will not only bridge the gap between demand and supply, but will also replenish the falling groundwater levels.

"The Central Ground Water Board, the Geological Survey of India, and the Ministry of Urban Affairs need to investigate whether these trends are reversible," Garg said. "We suggest the government and policymakers should have a detailed understanding of the geophysical properties of the areas undergoing subsidence, and incentivise rainwater harvesting while ensuring strict implementation of laws against illegal mining of groundwater. The building conditions in hazard zones should be evaluated and proper measures should be taken."



www.fibe-cdt.eng.cam.ac.uk



Credit: Raspberry Pi

## ALUMNI UPDATE

# The life of Pi: Ten years of Raspberry Pi

The most successful computer ever to come out of the UK celebrates its tenth anniversary this year.

Which is a more brutal environment – a large factory or a child’s bedroom? And what does one have to do with the other?

When alumnus Eben Upton, co-founder of Raspberry Pi, was thinking about what he wanted an ultra-low-cost computer to be, one of the key requirements was that it be durable: able to withstand being tossed into a backpack hundreds of times.

Now, more than a decade later, a computer that was designed in part to withstand the rough and tumble of childhood has also found a home in tens of thousands of industrial applications throughout the world, representing around 40% of its annual sales.

Raspberry Pi has created a whole new class of computing device, transforming the way engineers design control systems in industry, and has become a standard component of intelligent interfacing. Its adaptability, stability and low price make it ideal for applications including electric vehicle charging, Internet of Things (IoT), or retrofitting factory machinery so that it can be monitored digitally to spot faults that can slow down production.

Today, the \$35 credit-card-sized device is the best-selling computer to come out of the UK. Raspberry Pi has also created over 300 jobs, both at the Sony Europe B.V. factory in Pencoed, Wales, where it’s manufactured, and at the Raspberry Pi Foundation, a charity based in Cambridge

that promotes the study of basic computer science in schools.

Ten years after the first Raspberry Pi was shipped in 2012, more than 40 million of the devices have been sold worldwide, creating a market worth in excess of \$1 billion, plus more in peripherals.

Raspberry Pi wasn’t invented to boost shareholder value or turn its founders into billionaires; it was created as a charity to increase the number and calibre of students applying to study computer science at Cambridge, to give young people access to programmable hardware at a low price, and to equip a new generation with the coding skills that are so important in today’s economy. All profits are returned to the Raspberry Pi Foundation to support its educational programmes worldwide.

Raspberry Pi has helped kick-start a renewed interest in coding for young people through the development of online resources, coding clubs, programmes and competitions, which have reached millions of people from more than 100 countries. It runs two large networks of after-school clubs, CoderDojo and Code Club, and produces a range of online resources to support self-directed learning around the world.

The Raspberry Pi Foundation is part of a consortium – together with STEM Learning and BCS, The Chartered Institute for IT – that is running the National Centre for Computing Education in England. This

is a government-funded initiative providing comprehensive support for schools and colleges in England to offer a world-leading computing education, from Key Stage 1 through to A level.

Through the National Centre for Computing Education, Raspberry Pi is supporting teachers by providing an extensive range of professional development and certification, bursaries for training, curriculum and teaching resources, community support and more. To date, the consortium has supported more than 26,000 teachers from over 12,000 primary and secondary schools in England.

“Given how far we’ve come, it’s sort of funny to remember how parochial our ambitions were at the start,” said Upton, who was a Director of Studies at St John’s College after completing his PhD at the Department of Computer Science and Technology in 2006.

“There was a massive decline in the number of people applying to study computer science, which was sort of heart-breaking in a place like Cambridge, with its incredibly rich computing heritage. There was a feeling that if we could get a program or a piece of hardware into the hands of young people at the right point in their lives, we might be able to do something to reverse that decline.”

Upton grew up with a BBC Micro, one of the two great Cambridge-designed

computers of the 1980s (the second being the Sinclair Spectrum) that taught a whole generation of UK computer hobbyists how to code. The BBC Micro not only sparked Upton’s love of programming, but made him into a major enthusiast for low-cost computing that young people could own for themselves.

“There were lots of conversations going around at the time, that we should remake the BBC Micro, that it might be an answer to get young people interested in coding,” said Upton, who is also an Executive MBA graduate of Cambridge Judge Business School. “We thought if anyone was going to do it, it should be Cambridge.”

Designing a low-cost, high-functioning computer required expertise in technology, trends, education and manufacturing. The team – including Professors Robert Mullins and Alan Mycroft from Cambridge’s Department of Computer Science and Technology, Cambridge serial entrepreneur and business angel Jack Lang, as well as other Cambridge computer scientists, engineers, and manufacturing entrepreneurs – came up with four interlocking requirements that the Raspberry Pi had to meet.

The first was that it should be a programmable piece of hardware. The second was that it should be fun: children in the 1980s might have become interested in computers because of games, but the nature of computers at the time meant that many of them got into programming almost by accident. The Raspberry Pi had to have that same degree of fun to it and be able to do all of the things that young people might expect from a PC.

The third requirement was affordability: the team settled on a price point of \$25, partly because that was roughly the cost of a textbook, and it was low enough that most families could afford it, and schools would be able to subsidise the small number of families who couldn’t.

The last requirement was robustness. “We really wanted children to have their own Raspberry Pi, and that meant it had to withstand being put in a school bag and taken out a thousand times,” said Upton.

“People saw that it was stable and capable, which made it ideal for all kinds of applications,” said Roger Thornton, Raspberry Pi’s Director of Applications. “Raspberry Pi is now so much more than a fun way for young people to learn how to code. It’s reliable and robust – if you bought one of the original Raspberry Pis back in 2012, it will still work with the 2022 operating system. That longevity is important for industrial applications.”

From the design of the first prototype in 2006 to 2011, the team worked to satisfy the four requirements. Before the Raspberry Pi, no one had produced a low-cost computer that could run an operating system like Linux. The aims of the project were highly democratic: the team wanted to make ownership of an accessible and low-cost device available to all, which in turn would open up the world of programming to people from different ages and backgrounds.

The team’s design was eventually realised with just three chips. With the addition of a low-cost keyboard and a TV for display, it can act as a fully functional programmable computer. It can also be networked and used in groups for more advanced students or for industrial use.

At first, Raspberry Pi was manufactured in China, but production was moved to Sony Europe B.V.’s UK Technology Centre (Sony UK TEC) at Pencoed in South Wales in 2012. “The intention was always to make it in the UK,” said Thornton. “We can easily visit the factory and understand what’s going on there, which has been especially useful during the pandemic.”

Almost all of the actual manufacturing of Raspberry Pi is automated; the people who work in the factory mostly monitor and look after the machines. “This automated approach means that Wales is the most cost-effective place in the world to make a Raspberry Pi, with improved throughput and quality,” said Thornton. “We’ve brought good-paying jobs to the UK, while still producing the low-cost computer that was our original vision.”

“We knew from the start that keeping the cost of manufacturing as low as possible was imperative,” said Sony UK TEC Managing Director Steve Dalton OBE.

“This is indeed a challenge with no simple or one-off solution.

“Finding ways to make our process more efficient today than it was the day before and exploring every aspect of our processes – from small changes in the day-to-day, to major automation projects – allows us to maintain a low manufacturing cost while continuing to grow our team.”

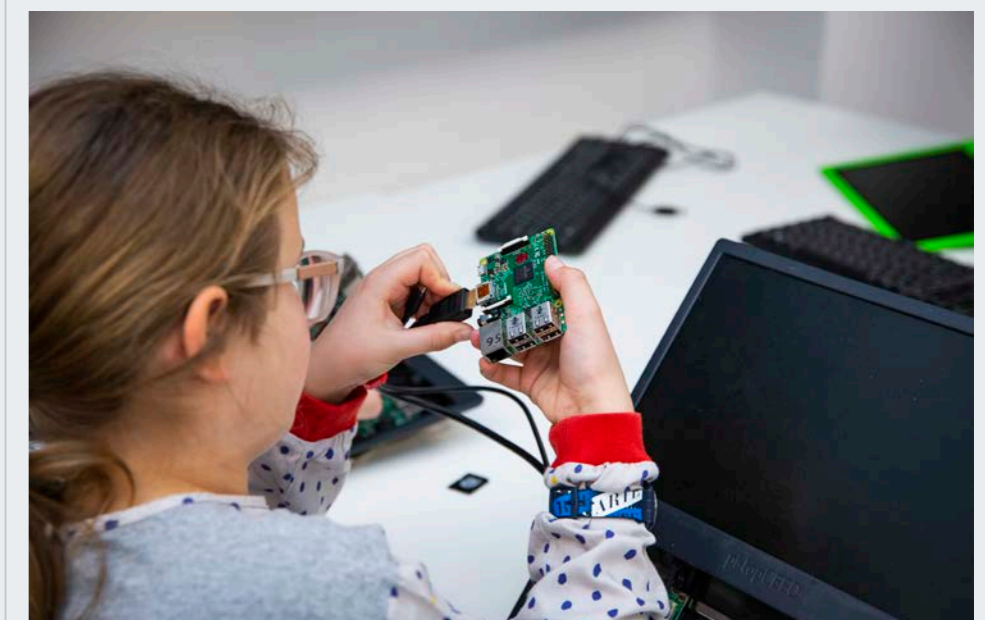
“Raspberry Pi is a British product, created by British engineers, that has found a huge global market,” said Upton. “South Wales has a long tradition of manufacturing, and we are pleased that the success of Raspberry Pi has secured new, skilled jobs in the area. Global success can be transformative within local communities, and we’re proud to be part of that here in Pencoed.”

Another unique aspect of the Raspberry Pi model is that it was set up as a charity: the Raspberry Pi Foundation. “Being set up as a non-profit means we had a different set of drivers than a for-profit company; maybe that’s encouraged us to go harder than we might have done if we’d had a narrow focus on short-term profitability,” said Upton. “But because of the success of the product and the business, the Raspberry Pi Foundation has been able to pursue a range of activities beyond anything we first imagined.”

Written by Sarah Collins



www.raspberrypi.com



Credit: Raspberry Pi



## Powerful post-its

### How Cambridge adapted roadmapping to help organisations make smarter strategic decisions.

Cambridge has made its fair share of inventions but can't lay claim to 'roadmapping', a structured visual method for supporting strategy and innovation. The idea is thought to have emerged about 60 years ago in technology-intensive sectors in the USA, before gradually spreading around the world and between sectors. But what Cambridge's Institute for Manufacturing (IfM) has done is adapt and enhance roadmapping to benefit a rapidly-expanding range of businesses and other organisations.

At the forefront of this work has been Dr Robert Phaal, Director of Research in Strategic Technology and Innovation Management (STIM) in the Department of Engineering. Phaal joined STIM in 1997, arriving from a mechanical engineering background, with a PhD in computational mechanics and industrial experience in technical consulting, contract research and software development.

Phaal hadn't come across roadmapping before, but with a small group of Cambridge colleagues he started to observe how some companies were using it. At the time, very few researchers were thinking about the topic. Today, well over a thousand academic papers have been published.

#### Impact at a glance

- Researchers at the IfM, part of the Department of Engineering, developed roadmapping processes and toolkits to help organisations make better strategic decisions.
- The team has supported businesses and other organisations through more than 500 roadmapping and related projects since 2001.
- Training courses have been delivered to more than 2,000 participants in over 20 countries to enable organisations to develop in-house roadmapping capabilities. Over £15 million in project revenue has been generated.

Phaal recalls: "When we started in around 1998, roadmapping was mostly used in large corporations in very technology-intensive sectors. It wasn't widely known about but there was a perception that it was a heavyweight tool for heavyweight companies. But we could see that lots of companies didn't know how to develop roadmaps, partly because big firms weren't describing how they used them."

Roadmapping can support decision-making in a wide range of scenarios including new product development processes, strategic annual processes or review points where an organisation has to take decisions about resource allocation.

Phaal and his colleagues started conducting experiments with diverse companies to build an understanding of the concepts that could underpin a generic, agile roadmapping tool. They found that the plethora of tools and processes that were already available to support management decisions often failed to interact consistently, robustly or transparently, and set about trying to overcome this.

#### Success

IfM's roadmapping collaborations have facilitated improved business performance and practices, and the adoption of new technologies in an array of primarily UK-based businesses and non-profit organisations. Much of this work is facilitated by the IfM's knowledge transfer unit, IfM Engage, through training and consultancy. Through a combination of self-facilitating templates and training, the team helps organisations to develop in-house roadmapping capabilities.

#### The Future

The team has started to detect growing interest in roadmapping from new sectors, including healthcare, the legal profession, technology ventures and even Higher Education. Phaal says: "It's exciting when you see methods working in one domain cross over into another. You just need

somebody with the imagination to recognise that they have a similar problem and then a clever consultant-facilitator to work roadmapping into that space. Then you can see a real step-change."

He adds: "Healthcare is wide open to benefit from roadmapping, but also Higher Education where the use of formal management methods is less common. We have started to get traction."

Phaal remains frustrated by the seeming lack of interest in roadmapping shown by most business schools. He says: "A lot of managers don't know about roadmapping because of the way their MBAs are orientated. There's a big gap."

Phaal is also impatient for governments to stop working in silos and embrace joined-up thinking to tackle systemic problems and, of course, to recognise that roadmapping is the perfect tool to support this kind of enlightened decision-making.

"Now we're up against the wall with global warming and other problems, we have to start getting smarter. Roadmapping allows the intelligence of people in different positions to be tapped into much more effectively."



Now we're up against the wall with global warming and other problems, we have to start getting smarter. Roadmapping allows the intelligence of people in different positions to be tapped into much more effectively.

Dr Robert Phaal

Written by Tom Almeroth-Williams



Find out more about roadmapping: [www.cambridgeroadmapping.net](http://www.cambridgeroadmapping.net)

## PhD students' bioelectronics start-up wins enterprise competition



Credit: Wolfson College

### Engineering PhD students Elise Jenkins and Ben Woodington, co-founders of Opto Biosystems – a start-up aiming to develop miniaturised implants for the brain to help treat serious medical conditions – have won the 2022 Wolfson Enterprise Competition after they successfully pitched their concept to a panel of judges, entrepreneurs and venture capitalists.

Elise and Ben, who are conducting PhD research in the Department of Engineering's Bioelectronics Laboratory under the supervision of Professor George Malliaras, are looking to revolutionise healthcare by developing miniaturised sensors that can be implanted into the brain to provide an unparalleled stream of data.

"Bioelectronics is the future of medicine," says Elise. "It presents new opportunities for diagnosis and treatment of serious medical conditions such as brain cancer and epilepsy – complicated conditions where the development of new drugs are not necessarily improving our ability to treat these conditions."

Elise's PhD research is focused on electrotherapy for brain tumours. Ben, meanwhile, is using flexible and shape adaptive bioelectronics to sense and stimulate the central nervous system. He takes methods of fabricating devices from the semiconductor industry and applies them to medical devices. The aim is to create small, thin, flexible chips that can be injected into the body via a minimally-invasive procedure. Once these chips connect with the body's central nervous system, they can monitor and relay information that could be used to help design treatments.

"The brain is incredibly powerful and complex, but things go wrong and we need to understand it better," said Elise.

Together, via Opto Biosystems, Elise and Ben are aiming to deliver a therapeutic

device in an outpatient procedure for the first time. The idea is that readings can be taken over an extended period of time, monitoring brain episodes as they happen and tracking brain activity while a person is asleep – with no need for major surgery or an overnight stay in hospital.

The judges of the Wolfson Enterprise Competition were particularly impressed with the way in which the pair had translated their PhD research into a product with practical applications in the real world.

Ben said: "We both work at the cross-section of technology and healthcare. The tools and devices we research in our lab are not intended to be flipped as an academic paper and forgotten about. We are both passionate about moving these exciting technologies from the lab and into the hands of the doctors who can do real good with them."

#### Cancer Tech Accelerator

Outside of the competition, the duo have already successfully pitched their device concept to the Cancer Tech Accelerator – a programme set up to support innovative technologies that can advance the early detection, diagnosis, monitoring or treatment of cancer. Elise and Ben are one of seven teams accepted onto phase two of the programme and they have been awarded £70,000 in funding by Cancer Research UK, Roche and the Medical Research Council, to develop a proof of concept.

#### Elise says:

"Bioelectronics is not buzz or hype; it is turning 'wacky' concepts into real technologies that can change lives.

"I was inspired by the field of bioelectronics early on in my engineering degree, when I began understanding how control systems could be applied to bionic limbs.

"It's a field that is revolutionising the way we understand and treat diseases."

#### Ben says:

"Bioelectronic medicine is one of the most exciting spaces in medicine – if not the most exciting – to be working in right now.

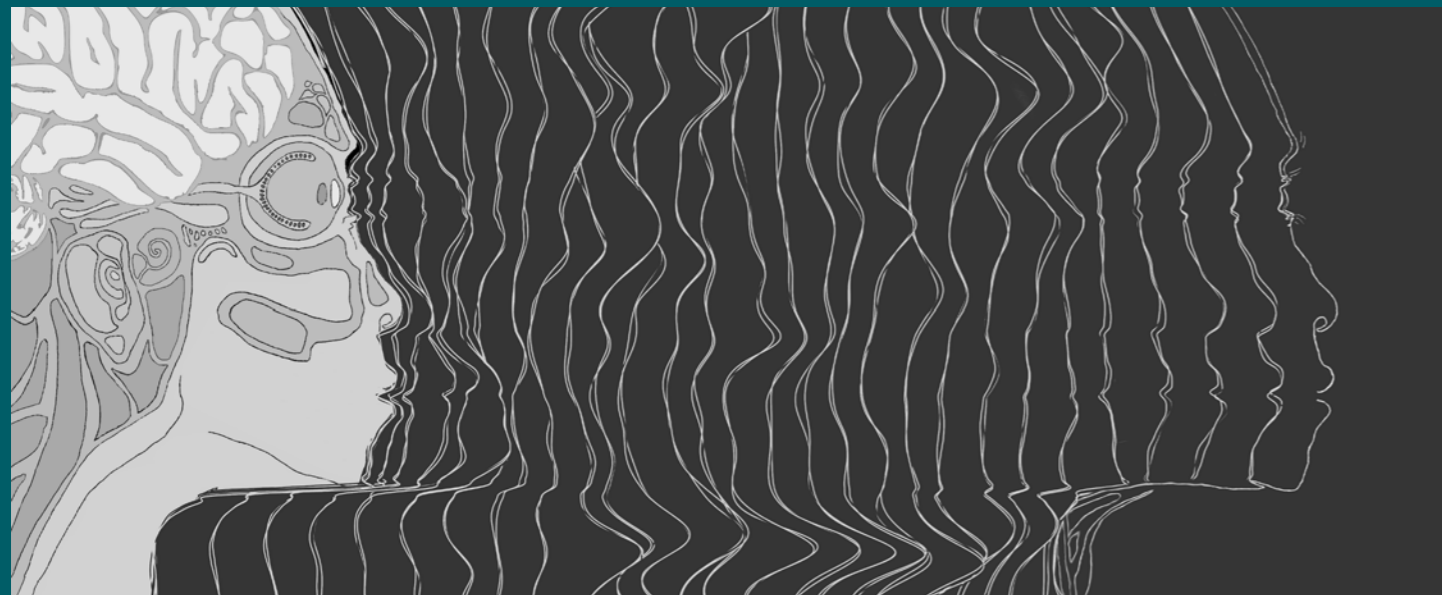
"Advances in material technologies, computing power and electronics have developed to the point that we are now at, where treatments that were once thought of as science fiction (and still are by many non-scientists) are becoming real.

"We are going to see an explosion of treatments enabled by this technology in the near future and to be a part of that is incredible."



[bioelectronics.eng.cam.ac.uk](http://bioelectronics.eng.cam.ac.uk)  
[ee.eng.cam.ac.uk/](http://ee.eng.cam.ac.uk/)





Credit: Michael E. Rule

## Study proposes how changes in the neural code unlock brain's 'inner learning'

Our brains are highly skilled at learning patterns in the world and making sense of them. The brain continually learns and adapts throughout our lives, and even the neurons supporting learned behaviours, such as the daily walk to work, are constantly changing.

This “representational drift” occurs without any obvious change in behaviour or task performance. Everything seems routine and stable, i.e. you follow the same path to work, make the same plan and take the same steps, but all the while, patterns of neural activity in certain parts of the brain are changing. A new study, published in the journal *PNAS*, proposes how the brain stays stable despite changes in the neural code.

Cambridge neuroscientists and study co-authors Dr Michael E. Rule and Professor Timothy O’Leary argue that neurons (the cells that make your brain work) can detect when some of their inputs change, and adjust the strength of influence that one neuron has on another in order to compensate, thus supporting a form of internal learning.

“These changes in the neural code bear similarities to how languages change gradually over time, while faithfully communicating common ideas and concepts,” said Dr Rule, a Leverhulme Early Career Fellow in the Department of Engineering.

While some parts of the brain are plastic and change rapidly, other parts show long-term stability. So how do neural circuits talk to each other without continuously having to re-learn the things

that they have already learned? Even brain-machine interfaces – which are increasingly being used as assisted living devices for people with cognitive or physical impairments – must contend with “drift”.

The researchers argue that homeostatic processes within single cells can help the brain to ‘watch itself’ as it changes, and that internally-generated signals help stable neural populations ‘learn’ how to track the unstable ones. The researchers made this conjecture based on modelling and on data/ observations of living brain activity.

Just like how engineers are currently developing machine learning algorithms to track neural representations as they change – automatically – the researchers propose that something similar to these algorithms could also be at work in the brain, emerging from well-known learning rules and homeostatic processes.

“This might explain how plastic and stable neural populations are able to coexist in the brain,” said Dr Rule. “We already know that ‘representational drift’ happens in the hippocampus – the part of the brain that has a major role in learning and memory – and seems to happen in the parietal cortex – the area responsible for sensory perception and integration.

What we propose are several specific mechanisms that could help make this plasticity compatible with long-term stability through the brain.”

Timothy O’Leary, Professor of Information Engineering and Neuroscience, said the study emphasises the idea that “drift” may arise from continual learning.

“There is a huge unanswered challenge in artificial intelligence, namely the problem of building algorithms that can learn continually without corrupting previously learned information,” he said. “The brain manifestly achieves this, and this work is a step in the direction of finding algorithms that can do the same.”

“These changes in the neural code bear similarities to how languages change gradually over time, while faithfully communicating common ideas and concepts.

Dr Michael E. Rule

## Transformative new research to kick-start the automation of UK infrastructure health monitoring



Credit: Enrique from Pixels

Researchers from the Cambridge Centre for Smart Infrastructure and Construction (CSIC) will join a £7.7 million collaborative project set up to drive new standards for safer, greener, more cost-effective UK infrastructure.

Funded by the Engineering and Physical Sciences Research Council (EPSRC), the ROSEHIPS (Revolutionising Operational Safety and Economy for High-value Infrastructure using Population-based SHM) project will aim to solve the infrastructure asset management problem in the UK for maintaining our buildings and structures, such as bridges and transport networks, via transformative new research to automate health monitoring.

Instead of expensive scheduled inspections, diagnoses can be provided economically by permanently-installed sensors, collecting structural data continuously and interpreting it via computer algorithms. Using Population Based Structural Health Monitoring (PBSHM), the project will develop machine learning, sensing and Digital Twin technology for automated inference of health for structures in operation now, and drive new standards for safer, greener structures in future.

Led by researchers at the University of Sheffield, the project involves the University of Cambridge, Queen’s University Belfast and the University of Exeter, combining sensor development, machine learning and civil engineering expertise. Key industry partners include Northern Ireland Department for Infrastructure, Translink, Arqiva, Cellnex (UK) and Siemens Gamesa. The team at CSIC will contribute expertise in data-centric engineering and foundational statistical machine learning in delivering efficient PBSHM algorithms. Healthy infrastructure is critical to ensuring the continued functionality and growth of UK society and the economy. Unfortunately, monitoring and maintaining our buildings

and transport network is expensive; in the UK, a backlog of maintenance works identified in 2019 will cost £6.7bn<sup>[1]</sup>.

Inspection of bridges is usually carried out visually by human experts. Resources are stretched, so inspections cannot be carried out as often as desired; repairs aren’t made quickly and opportunities are missed to make cost effective decisions on maintenance and improvement. In a few extreme cases structural failure can result in fatalities.

The offshore wind (OW) sector is another area for concern. OW has driven down energy costs and increased power output, pioneering a global change to clean energy. The UK leads globally in OW energy, providing almost one third of the UK’s annual electricity demand and helping meet the UK’s net-zero-by-2050 target. The drive for turbines in deeper water demands new ways of asset management, controlling and limiting operation/maintenance lifetime costs. As turbines increase in numbers, size and capacity, these issues become even more important.

Co-investigator Professor Mark Girolami is an Academic Director for CSIC and the Sir Kirby Laing Professor of Civil Engineering at Cambridge, where he also holds the Royal Academy of Engineering Research Chair in Data-Centric Engineering (DCE).

Professor Girolami said: “This research programme is set to make significant advances in the theory, methodology, application, successful deployment and adoption of PBSHM, in making our critical inter-connected infrastructure safe, resilient and more efficient. This programme will draw on, and build upon, much of the capability and expertise built over the

last decade at CSIC. In particular, the team at CSIC will contribute their unique combination of expertise in data-centric engineering and foundational statistical machine learning in delivering efficient PBSHM algorithms.”

Professor Keith Worden, from the University of Sheffield’s Department of Mechanical Engineering, said: “PBSHM is a game-changing idea, emerging in the UK very recently. It has the potential to overcome current technological barriers and transform our ability to automatically infer the condition of a structure, or a network of structures, from sensor data.

“This programme brings together the perfect team, mixing complementary skills in machine learning and advanced data analysis with expertise in new sensor systems and insight into complex infrastructure systems.”

The work will be underpinned by experiments using facilities such as the Structural Dynamics Laboratory for Verification and Validation (LVV) at the University of Sheffield to monitor the dynamic response and ‘health’ of structures, such as traffic loading, at full scale or near full scale.

[1] Source material: Brown (D.) (Jan. 7, 2019) “Cost of bridge maintenance backlog is £6.7bn”. (Accessed 02/15/2020).



[www-smartinfracture.eng.cam.ac.uk](http://www-smartinfracture.eng.cam.ac.uk)

## Professor to lead the government's Future of Compute Review

World-leading artificial intelligence (AI) researcher Zoubin Ghahramani, Professor of Information Engineering, will lead a review into the UK's advanced computing capabilities, launched as part of the government's new Digital Strategy.

The Future of Compute Review will report to the Chancellor and the Secretary of State for Digital, Culture, Media and Sport. The project will look at the UK's compute needs, develop cost-effective solutions to ensure researchers and industry have what they need to lead the way, and inform a long-term plan for the UK.

Advanced compute – the large-scale processing power, memory and data storage that is used to tackle tasks beyond the capabilities of everyday computers – is an important component of our digital infrastructure and a building block for future capability. It is becoming essential to biology, chemistry, physics and nearly every other area of research, and can also increase business innovation by enhancing R&D and product design processes, driving economic growth and productivity.

During his opening address at London Tech Week earlier this year, the former Chancellor of the Exchequer Rishi Sunak said high-performance computers and cloud capabilities were vital for powering technologies of the future, such as AI,

and this would be critical for the UK's productivity, prosperity and innovation.

"From modelling the effects of climate change, to powering the discovery of new drugs and increasing business innovation, the capabilities of advanced compute are endless," he said. "The UK is a world leader in innovation and this review will help us maintain that position – as we embrace new technologies and the people who create them to drive forward our growth and productivity."

Commenting on his appointment, Professor Ghahramani, who is also Vice President of Research at Google and leads Google Brain, said: "The UK's ability to do the hardest science, and help businesses be even more competitive, depends on more powerful computers. Advanced compute helps us model incredibly complex systems, such as what's happening to the climate and how to stop the spread of pandemics.

"Advanced compute is fundamental to the UK's national interest. This review will deliver a long term plan for UK compute, enabling government, business and academia to remain at the forefront of



innovation and be prepared to fight the biggest challenges of this century.

"I am delighted to lead this review and look forward to bringing my industry and research experience to this important work."

Speaking at the time, former Digital Secretary Nadine Dorries said: "This review will ensure we have the advanced computing abilities to keep the UK at the forefront of the most complex science and cutting edge tech to deliver major benefits for people and businesses."

## Professor Sir Alistair MacFarlane CBE FRS FREng FRSE 1931-2021

Sir Alistair MacFarlane died on 2 November 2021. He was Professor of Engineering at Cambridge from 1974-89 and a Fellow of Selwyn College, then Vice-Master in 1980.

Alistair was elected in 1974 to Chair of Engineering at Cambridge, and became Head of the newly-formed Control and Management Systems Division. Alistair's mission was to extend the frequency domain techniques for the analysis and design of feedback amplifiers and servomechanisms, which had been pioneered principally by Bode and Nyquist in the 1930s, to more general and complex control systems. The particular challenge was multivariable systems, in which several interacting quantities need to be controlled simultaneously. He was convinced that existing graphical methods had to be generalised if such systems were to be tackled routinely by engineers, and he was an early proponent of computer-aided design to support such methods as they were

developed. He also had a deep interest in complex-variable theory and spent much of his career looking for suitable generalisations, convinced that these would lead to graphical methods.

He developed a worldwide reputation for this work and had a large number of research students, many of whom became well-known professors of Control Engineering.

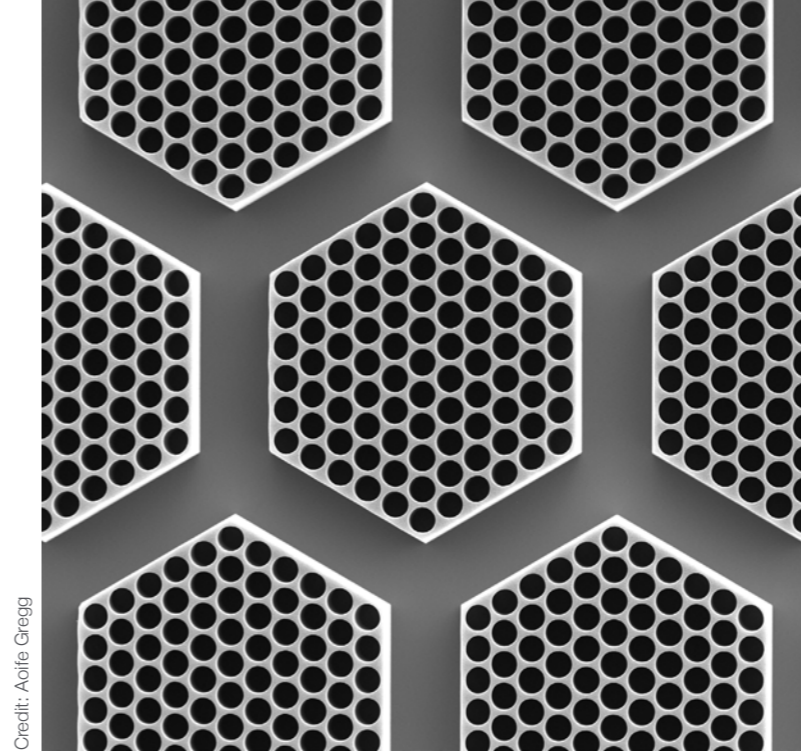
According to Professor Jan Maciejowski and Professor Keith Glover, "Alistair had a life-long fascination with feedback systems. With his research at UMIST and Cambridge he was regarded as a world-leading figure in computer-aided graphical design methods for multivariable feedback systems. He was also a visionary leader, founding the Information Engineering Division and



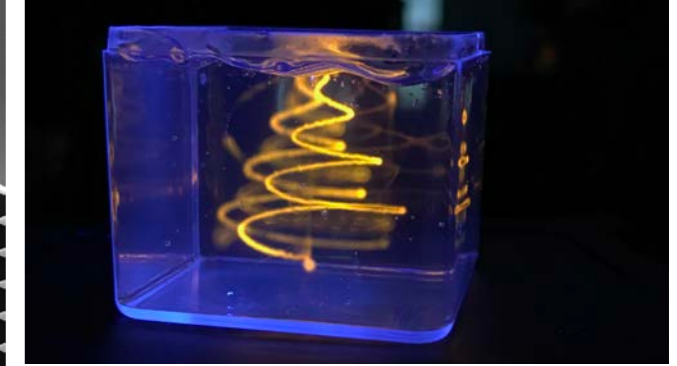
establishing computer-aided teaching facilities in the undergraduate programme. Alistair was also a very supportive and encouraging PhD supervisor, who liked to see students going 'off-piste' in pursuit of their own ideas, although he was rigorous in criticising such ventures without being discouraging."



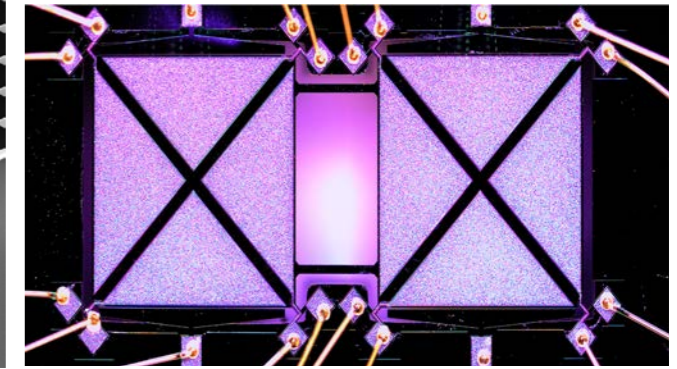
Read the full obituary at: [bit.ly/3BTth7x](https://bit.ly/3BTth7x)



Credit: Aoife Gregg



Credit: Iek Man Lei



Credit: Malar Chellasivalingam

## The winning entries of the Department's 2020-21 ZEISS Photography Competition

Striking imagery and video that encourages you to look at engineering through an artistic lens has won its creators prizes in the Department's 2020-21 Photography Competition, sponsored by ZEISS (Scanning electron microscopy division).

**First Prize** was awarded to PhD student Aoife Gregg, who is part of the EPSRC in Nanoscience and Nanotechnology (NanoDTC) at the University of Cambridge, for her image titled *Honeycombs of carbon nanotubes*.

"My image, taken using a scanning electron microscope, shows forests of vertically-aligned carbon nanotubes which have been grown into the shape of hexagonal pillars with inner pores in a honeycomb pattern," she said.

**Second Prize** was awarded to Iek Man Lei for her image titled *A suspended Christmas tree*. At the time of entering the competition, Iek was a PhD student in the Biointerface Research Group at Cambridge.

Iek said: "My photo shows a suspended 'Christmas tree' printed in a support bath. The experiment was performed with a laboratory-built 3D robotic bioprinter that I developed during my PhD. The setup enables fabrication of soft materials, transforming them into 3D functional structures."

**Third Prize** was awarded to PhD student Eftychia Dichorou, who is part of the Department's Structures Research Group, for her high-speed camera footage titled

*Collapse of a thin mortar scale-model vault under dynamic seismic loads in slow motion*.

Eftychia said: "The video showed the collapse of two thin mortar scale-model vaults, as they were captured, during their harmonic shaking in the centrifuge. The high-speed camera, equipped for the tests, captured a photographic sequence which revealed the entire structural response, starting from the formation and propagation of cracking to the collapse of the structures."

The **Microscopy Prize** was awarded to Research Associate Dr Niamh Fox, who is from the Institute for Manufacturing (IfM), part of the Department of Engineering, for her image titled *Meshing drug delivery with flexible supports*.

Niamh said: "My entry showed a magnified fluorescence image of droplets of fluorescein in polyethylene glycol during development of new methods of drug release. During curing, droplets are printed into a polymer used in a wide range of applications called polydimethylsiloxane (PDMS). The balance of surface tension pins the drop at the surface of a curing PDMS film. The tops of the droplets are left peeking above the PDMS film. This creates

**LEFT: FIRST PRIZE:** Honeycombs of carbon nanotubes

**TOP RIGHT: SECOND PRIZE:** A suspended Christmas tree

**BOTTOM RIGHT: HEAD OF DEPARTMENT PRIZE:** Highly sensitive weakly-coupled MEMS Resonators

an open pore when it cures, which allows drug release."

The **Head of Department Prize** was awarded to Malar Chellasivalingam for her image titled *Highly sensitive weakly-coupled MEMS Resonators*.

Malar said: "My PhD research focused on implementing miniaturised sensors, based on MEMS (micro-electro-mechanical systems) technology, for sensing ultra-fine particles that are emitted from various sources such as exhaust plumes in aircraft engines, diesel engines or automobile exhausts, industrial emissions, dust and smoke. My microscopic image shows a silicon MEMS resonator designed and fabricated as such that it will be highly sensitive to nano-sized particles when used as mass sensors."

The panel of judges included Allan McRobie, Professor of Structural Engineering; Stephen Furzeland from ZEISS; Professor Richard Prager, Head of Department; and Philip Guildford, Chief Operating Officer.



View all of the Competition entries at: [www.eng.cam.ac.uk/Flickr](https://www.eng.cam.ac.uk/Flickr)

→ Professor Eugene Shwageraus (left) with co-PIs from the MaThRad programme, Andreas Kyprianou (University of Bath) and Dr Sarah Osman (NHS University College London Hospital)



## Nuclear industry needs in the 21st century

Cambridge engineers will join mathematicians and medical physics experts in a new five-year research programme looking at radiation transport modelling, bringing together the most modern theories and practical application needs in energy, space and health.

Radiation transport modelling sits at the heart of the design, regulation and operation of some of the most important nuclear technologies for the 21st century. These include the building of new fission and fusion reactors, decommissioning old ones, cancer diagnostics and therapy, and opening up new possibilities in space technologies through, for example, the development of mini reactors as a power source or designing cosmic radiation shielding for space exploration missions.

The £7 million EPSRC-funded programme titled *Mathematical Theory of Radiation Transport: Nuclear Technology Frontiers (MaThRad)*, is being led by the University of Cambridge, University of Bath and the NHS, and involves 26 partners from industry, academia, national labs and international organisations. Postdocs also benefit from six-month internships with industrial partners.

Accurate prediction of how radiation interacts with surrounding matter is based on modelling, with many of the existing methods dating back decades. But now, through the MaThRad programme, a new generation of researchers will work at the interface of mathematics, engineering, healthcare and industry to improve our understanding of how radiation travels through reactor components or human tissues.

The researchers will combine modern mathematical methods from probability theory, advanced computational algorithms based on the Monte Carlo method, and inverse problems, to develop novel approaches to more accurate and computationally efficient radiation transport modelling. Together, they will develop predictive models with quantifiable

accuracy and software prototypes ready for real-world implementation in the energy (nuclear fission, fusion, decommissioning and waste management), healthcare (radiation treatment planning, dose delivery, imaging and diagnostic techniques) and the rapidly developing space nuclear industries.

Central to the programme will be unique software developed by the Department of Engineering, called Stochastic Calculator Of the Neutron transport Equation (SCONE). Designed with a focus on modifiability and ease of learning, the software has been used by undergraduate as well as postgraduate students studying Monte Carlo methods and is suited to the exploration of new ideas.

Eugene Shwageraus, engineering lead for MaThRad and Professor of Nuclear Energy Systems Engineering at Cambridge, said SCONE will allow for fast prototyping and the testing of ideas.

“Many of the existing radiation transport methods were pioneered in the UK in the early days of nuclear power. Unfortunately, these activities have been declining in the last few decades,” he said. “This programme grant offers a unique opportunity to bring together the nuclear engineering and theoretical mathematics communities to revive the much-needed research in the area of radiation transport. The research is particularly timely as the world struggles with issues of climate change and security of energy supply.”

Professor Shwageraus is joined in the programme by Geoff Parks, Professor of Nuclear Engineering and Head of the Computational Design Group in the Cambridge Engineering Design Centre.

“The computational design process depends crucially on the speed and accuracy of the computational models used to evaluate candidate designs,” said Professor Parks. “The developments planned within the MaThRad programme offer exciting opportunities to improve both the design process and the designed product in a wide range of application areas.”

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This programme offers a unique opportunity to bring together the nuclear engineering and theoretical mathematics communities to revive the much-needed research in the area of radiation transport, at a time when the world struggles with issues of climate change and security of energy supply.

Professor Eugene Shwageraus



## £200bn annual opportunity for energy sector to deliver energy savings

The UK’s legal commitment to zero emissions by 2050 requires substantial growth in renewable electricity generation, but rapidly expanding demand is still likely to exceed supply.

The government’s ‘Review of Electricity Market Arrangements’ (REMA), focusing on electricity supply, was published in July 2022.

UK FIRES published a report earlier this year, titled *Energy Sector Innovation within Absolute Zero* detailing the even greater scale of opportunity for energy sector innovation on the demand side.

Where new installation of renewable supply is expected to be worth up to £23bn per year, demand side innovation could be worth nearly ten times more, up to £200bn per year, through a combination of new approaches to delivering energy efficiency, electrification of existing fossil-fueled equipment, innovations that support time-shifting demand and decommissioning old assets.

Professor Julian Allwood said: “The government’s targets to deliver zero emissions are excellent, and essential if we’re to avoid the catastrophic consequences of this summer’s temperature increases becoming normal. Government policy to date has been heavily weighted towards the supply of zero emissions

energy, but we won’t have as much of it as we want. What this report celebrates is the huge and largely unnoticed opportunity for business growth in delivering the products and services of energy saving.”

The UK FIRES report, which builds on the ground-breaking Absolute Zero analysis of realistic pathways to zero emissions in the UK by 2050, demonstrates just how much business growth is possible as we focus national efforts on reducing energy demand to meet anticipated emissions-free supply.

Since 2010 the UK’s non-emitting electricity supply has doubled, and with current commitments the same linear rate of expansion is likely to continue to 2030 and beyond. This growth will be sufficient to replace all today’s gas-powered generation, but will not be enough to meet future demand. As transport, space-heating and industrial processes are electrified, demand for emissions-free electricity will soon outstrip supply, and by 2050 we will have around 60% of what we want.

The UK FIRES report reveals four substantial business growth opportunities created by this likely shortage.

UK FIRES is a collaboration between the universities of Cambridge, Oxford, Nottingham, Bath and Imperial College London and is funded by EPSRC.

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Government policy to date has been heavily weighted towards the supply of zero emissions energy, but we won’t have as much of it as we want. What this report celebrates is the huge and largely unnoticed opportunity for business growth in delivering the products and services of energy saving.

Professor Julian Allwood



Read the report at: [ukfires.org/energy-sector-within-absolute-zero/](https://ukfires.org/energy-sector-within-absolute-zero/)

→ Lyndie and her dog Borelli, a spoodle named after Giovanni Alfonso Borelli (considered the father of biomechanics for his research on animal locomotion)



## Women in Engineering

### An interview with PhD student Lyndie Zollinger

For Gates Cambridge Scholar Lyndie Zollinger, studying medical challenges from a mechanical perspective presents the ultimate puzzle. This is why, for her PhD, she is using biomechanical modelling and image analysis techniques to take a closer look at specific knee injuries in dogs and humans (a similar injury shared by both species).

Lyndie will analyse motion patterns and detect abnormalities to help with injury diagnosis, treatment and monitoring. Here, she reveals more about her research, as part of our *Women in Engineering* series.

**I have a family history of knee injuries and this definitely influenced my decision to study knees.** When I was around 13 years old, my brother had knee surgery and I was fascinated by his doctor's explanation for what was causing his problems. I ended up using some PVC pipes, bottle caps and rubber bands to build some models and test what was happening. At the time, I did not know that counted as engineering or even what engineering was, but I had a lot of fun doing it!

**I injured my own knee when a giant hamster wheel fell on top of me.** It happened during a class activity at MIT – Massachusetts Institute of Technology – where I was studying mechanical engineering. This incident fuelled my passion for studying medical challenges from a mechanical perspective. I love being able to use mechanics to break things down and understand what is actually causing a medical issue. For me, it is like solving a mechanics puzzle.

**You can gain valuable information about someone's health just from monitoring the way in which that person moves and walks.** Walking requires the brain, spinal cord, bones, muscles and other tissues to work together in order to move properly. If something is wrong in one or more of these components, then it can affect how we walk

in noticeable ways. Studying the changes in someone's gait can help determine where and why a problem is occurring. Once we know why something is happening, we can then use mechanical modelling to explore how different changes would affect the gait and thus find the ideal treatment for it.

**I have always loved dogs.** When I was discussing project ideas with my supervisor Professor Michael Sutcliffe, he mentioned that he wanted to collaborate more with the Cambridge Veterinary School. So, under the supervision of Professor Matthew Allen from the Department of Veterinary Medicine, I took up the exciting opportunity to work with dogs and research ways to help them. I ultimately chose to focus on studying knees for my PhD research because they are structurally quite similar in both dogs and humans. I am focusing on increasing the availability of gait analysis for injury diagnosis, treatment and monitoring in both species.

**Studying differences between dog breeds can provide insights into some of the natural diversity among humans** – something that is often overlooked in medical research data. My research combines portable low-cost imaging techniques with biomechanical modelling to analyse motion patterns, detect abnormalities and identify specific knee injuries in humans and dogs. This method of gait analysis has the potential to enable GPs, physiotherapists and other medical professionals to assess patient gait without the need for referral to specialised, expensive, and often overwhelmed, gait clinics. This can help speed up assessments, reduce patient backlogs and enable at-home

monitoring of patients as they recover from injuries, ensuring that they stay on track for a normal recovery.

#### Believe to achieve

**The first woman in my neighbourhood who had a STEM career moved there when I was 16.** She was also the first woman I met who had a PhD. Meeting her inspired me to believe I could do what I loved, even if many other people told me it was not possible.

**As I pursue a PhD and academic career in biomechanics, I want to continue mentoring and inspiring more gender minorities to pursue their dreams in STEM fields.** During my undergraduate degree, I worked as a teaching assistant for several courses and as a tutor for a programme that introduced teenage gender minorities to engineering. I loved working with students and seeing them learn and understand new things. I now supervise second-year undergraduates at Cambridge.

**To gender minorities interested in engineering, my advice is: believe you can do it.** Find mentors and role models who inspire you and help you to keep going, even when others seem to be trying to stop you. I do not want anyone to be discouraged from engineering because they do not think they can do it. If you are interested in it and find the right people to help you with it, you can make it happen!



Watch Lyndie's research in action: [youtu.be/tzubJOI-60A](https://youtu.be/tzubJOI-60A)

## Honours, awards and prizes



#### Social Impact Award winner

Undergraduate Nandini Shiralkar has been announced a winner of the Vice-Chancellor's Social Impact Awards 2021/22.

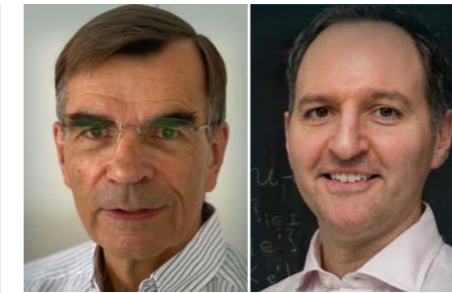
The Awards recognise and celebrate exceptional achievement in social impact amongst University of Cambridge students. Nandini is the founder of the Cambridge Existential Risks Initiative (CERI) – a network of academics and students at Cambridge and beyond, working to mitigate risks that threaten the future of humanity. CERI, which began life in Nandini's bedroom, has now grown to a team of 12 working on various projects.



#### Fellow of the Royal Society

Roberto Cipolla FREng FRS, Professor of Information Engineering, has been elected a Fellow of the Royal Society for his exceptional contributions to science.

Professor Cipolla is distinguished for his research in computer vision and his contributions to the reconstruction, registration and recognition of three-dimensional objects from images. These include novel algorithms for the recovery of accurate 3D shape, visual localisation and semantic segmentation and their translation into commercial products.



#### Queen's Birthday Honours 2022

Professor Stephen Young (pictured left) and Dr Adrian Weller have been recognised in the Queen's Birthday Honours 2022.

Emeritus Professor Stephen Young has been made a Commander of the Order of the British Empire (CBE) for services to software engineering. His research interests lie in the area of spoken language systems, including speech recognition, speech synthesis and dialogue management.

Dr Adrian Weller has been made a Member of the Order of the British Empire (MBE) for services to digital innovation.

"I hope I can encourage more people to get involved as we try together to design, develop and deploy trustworthy technologies that benefit individuals and society," he said.



#### American Physical Society Fellow

Professor Matthew Juniper has been elected a Fellow of the American Physical Society.

His research is in the broad area of fluid dynamics and thermodynamics. Recent applications in his group include magnetic resonance velocimetry, gas turbine engines, cyclonic vacuum cleaners and inkjet printers. He uses physics-based statistical learning to develop quantitatively accurate physics-based models of an application and then uses adjoint-based optimisation to improve their designs. For example, these methods improve the speed and accuracy of magnetic resonance velocimetry by a factor of 100.



#### European Research Council funding

Professors Vikram Deshpande and Rodolphe Sepulchre are among nine Cambridge researchers who have won Advanced Grants awarded by the European Research Council. This is the greatest number of grants won by a UK institution in the 2021 round of funding.

Vikram Deshpande, Professor of Materials Engineering (pictured right), will pursue the research project titled *Graph-based Learning and design of Advanced Mechanical Metamaterials (GLAMM)*.

Rodolphe Sepulchre, Professor of Engineering, Control Group, will pursue the research project titled *Spiking Control Systems: an algorithmic theory for control design of physical event-based systems (SpikyControl)*.



#### IEEE Cledo Brunetti Award

Emeritus Professor John Robertson's outstanding contributions to nanotechnology have been recognised with the 2023 IEEE Cledo Brunetti Award.

He is an expert in electronic materials and has contributed to the production and development of electronic devices. He has undertaken seminal work to develop industrially valuable electronic materials such as HfO<sub>2</sub> (Hafnium dioxide). His prediction of the conduction band offset of HfO<sub>2</sub> allowed it to replace SiO<sub>2</sub> (Silicon dioxide) as the gate oxide in complementary metal oxide semiconductor (CMOS) transistors, and so to continue CMOS scaling. His further work on its defects and interfaces with metals allowed its successful implementation.

→ VividQ's concept of holographic displays for consumer electronics

## ALUMNI UPDATE

# Welcome to Andrzej's world of computer-generated holography



Credit: VividQ

Holographic displays have the power to stop you in your tracks, projecting realistic three-dimensional digital content that floats right in front of your eyes. It is a visual experience that is transforming the way we view, interact and connect with the world around us, says alumnus Andrzej Kaczorowski.

VividQ, the start-up Andrzej co-founded following his PhD, is delivering these types of realistic and immersive visual experiences to next-generation digital displays. Here Andrzej reveals more about the VividQ story.

**I am a technologist and inventor at heart.** Bringing inventions to life is a deeply rewarding experience. I love the whole process, from brainstorming and coming up with an idea to creating the first working prototype that demonstrates functionality not achieved before.

**The operation of complex devices and systems has fascinated me from a young age.** I was fascinated by the inner workings of all the objects surrounding me. That passion was quite unfortunate for my parents, who would often find various household appliances taken to bits. I was successful at taking them apart, but not always at putting them back together. Quite early on, I started showing interest in maths and physics and at the age of 13 began my journey with computer programming. While in high school, my physics teacher encouraged me to explore the topic on my own and I started spending hours in the little school lab. This also motivated my choice of a degree, a BSc in Physics with Computer Science at King's College London. I finished in the top three of the year. Later on, I pursued the Master of

Research (MRes) and a PhD in Photonic Systems Development from the University of Cambridge.

**My PhD laid the groundwork on which VividQ was founded.** While in Cambridge, I specialised in computer-generated holography for displays, a topic that brought together multiple passions of mine: programming, computer graphics, digital cameras, automation and algorithm design. My research explored the ways in which computer-generated holography can be improved and implemented in realistic devices such as pico projectors, optical lithography devices and mixed reality headsets. This included improving the quality of the image itself, speeding up the computation of holograms and correcting optical imperfections in the software. During this time, I demonstrated the first real-time high quality holographic projections on off-the-shelf Graphics Processing Units (GPUs), while under the supervision of Professor Tim Wilkinson. Despite the fact that GPUs were developed specifically for computer graphics, researchers like myself learnt to hijack their power for scientific computation. The method I developed in my research offered hologram generation of up to three orders of magnitude faster than the standard method. Towards the end of my degree, I met my co-founders Dr Darran Milne and Tom Durrant. We were shortly joined by Dr Roman Pechhacker, Aleksandra

Pedraszewska (who I know from the Polish Society) and Dr SJ Senanayake, my PhD colleague who I recommended as a great addition to the team. Together, we gave birth to what would then become VividQ.

**VividQ is a deep-tech company that is on the path to revolutionising display technology.** Our software and IP enables the integration of holographic displays into Augmented Reality (AR), Head-Mounted Displays (HMDs), Head-Up Displays (HUDs) and consumer electronics. Since its inception in 2017, VividQ has grown from six co-founders to 50 full-time employees. In 2021, we closed a new funding round of £11M to showcase holography in consumer applications for the first time.

**This year, VividQ has a line-up of exciting advancements.** In 2022, we launched our VividQ Alpha Program – joint-development projects to productise next-generation gaming HMDs alongside industry partners. We will also continue our prototyping of holographic automotive HUDs and consumer electronic devices. In the future, holography will power all displays and unlock immersive, visual experiences in the Metaverse.



[vivid-q.com](https://vivid-q.com)