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DEPARTMENT OF ENGINEERING NEWS

UNIVERSITY OF CAMBRIDGE

In this issue

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The Harding Challenge

You may have already heard about the Harding Challenge from your College, but did you know a gift to your department could also qualify?

If you are a new donor to the Collegiate University, or have not given since July 2019, your gift to support students in your department will be eligible for the Harding Challenge. As such, your gift will unlock, pound for pound, a contribution to a special fund for undergraduate financial support, benefitting both your department and undergraduates in greatest need across Cambridge.

This time-limited challenge is the first time Collegiate Cambridge has come together in a fundraising effort to extend the impact of a donor's gift, which enables us to do more for undergraduates than ever before.

For more information, please contact our Senior Associate Director for Engineering: Victoria.Thompson@admin.cam.ac.uk

Cover image: Alumnus Fotis Fotiadis, CEO and co-founder of Better Origin. Credit: Patrick Williamson Photography.

Note from the editors

This autumn, all eyes have been on the COP26 climate summit.

The Department's Whittle Laboratory and the Cambridge Institute for Sustainability Leadership (CISL) chose COP26 as the setting from which to launch officially the Aviation Impact Accelerator (AIA) – an international group of experts who are developing a simulator that explores scenarios for achieving net zero flight (p4).

As part of efforts to meet the UK Government's 2050 net zero goal, our engineers are bringing their expertise to the table across many areas, from developing next-generation batteries to power up electric vehicles (p14), to contributing to a Cambridge-led report highlighting net zero solutions which could be implemented now, such as the electrification of road freight (p16).

Meanwhile, researchers at the Centre for the Study of Existential Risk (CSER) and our Department, have identified maggots as a 'future food' that must be mass-farmed to combat malnutrition in the face of climate change and other threats (p5).

Also on the insect trail is alumnus Fotis Fotiadis, whose company is tackling the future of food security, by using cutting-edge technology powered by Artificial Intelligence (AI) and automation to re-introduce insects as the missing link in our modern food chain (p7).

Now that's food for thought!

Charlotte Hester and Jacqueline Saggers

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Credit: Graham CopeKoga

Head's welcome

Welcome to the *Department of Engineering News*.

The Department exists to deliver education and research and, so far, we have continued to do this through all the phases of the pandemic. However, we have had to make compromises. Some research has been delayed and we have had to find ways to do our teaching with appropriate safety arrangements. Someone captured the feelings of many when they said that the reduction in personal interaction had "taken the sparkle out" of our work.

COVID is far from over and we still need to have safety measures, but this term is all about putting the sparkle back in our work. Most staff are back using our buildings, at least part of the time. The students are doing laboratories and practicals in person. The Dyson Centre for Engineering Design is in action. We ran the Lego laboratory for all the new first-year students in October. Supervisions and teaching that we can fit into the available rooms are mostly taking place in person. The research never stopped, but more flexible rules are now enabling it to regain its normal momentum.

Some of the changes forced on the Department by the pandemic have proved beneficial. We are continuing to make recordings of lectures. Some students find the ability to review the recordings makes it easier for them to understand the material. We are also continuing to generate other online educational content and to give students electronics kits to experiment with at home. Experience with videoconferencing software has transformed research seminars, because it is now easier to arrange talks from all over the world without anyone having to travel.

This issue of the Newsletter captures the gradual return of "sparkle" to our work. Engineering has acquitted itself well throughout COVID by delivering valuable research results to help address the challenges of the pandemic. We have maintained teaching and research momentum. We are already making significant contributions to the national priorities of sustainability, prosperity and resilience that will accelerate us all out of the crisis. We are looking forward to a productive and exciting year ahead.

Professor Richard Prager FREng, FIET, CEng

> Some of the changes forced on the Department by the pandemic have proved beneficial.

Developing a simulator to accelerate the path to net zero flight

Aviation Impact Accelerator

"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 academic and industry experts to take on this challenge."

Prof. Rob Miller
Director, Whittle Laboratory,
Co-lead of the project

The University of Cambridge has announced the launch of the Aviation Impact Accelerator (AIA) – an international group of experts in aerospace, economics, policy and climate science, who are developing an interactive evidence-based simulator that explores scenarios for achieving net zero flight.

Led by the Department's Whittle Laboratory and the Cambridge Institute for Sustainability Leadership (CISL), the AIA includes a team of multidisciplinary experts from across the University, including Engineering Department academics from Hopkinson Laboratory and the Engineering Design Centre, together with the Air Transportation Systems Lab at University College London and the Melbourne Energy Institute at the University of Melbourne.

The AIA is in partnership with HRH The Prince of Wales' Sustainable Markets Initiative, The World Economic Forum, Cambridge Zero (the University's climate initiative), MathWorks and SATAVIA, and is supported by industry advisors Rolls-Royce, Boeing, BP, Heathrow and Siemens Energy. It was launched officially at the 26th UN Climate Change Conference of the Parties (COP26) in November 2021.

The simulator will capture the whole aviation sector: from the sources of renewable electricity and raw materials, to the production and transport of fuel, to the introduction of new aircraft technologies and operations. Leaders in industry and government will gain an understanding of the potential for change and the trade-offs between decisions. The hope is that the simulator will guide innovation, investment and policy action, as well as providing wider educational benefits to the public.

Professor Rob Miller, Director of the Whittle Laboratory and co-lead of the project, 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."

The simulator was conceived in early 2020 at a roundtable hosted by HRH The Prince of Wales and attended by senior industry leaders, government and academia. Through an intuitive interface, the user will be able to simulate future scenarios to 2050 and calculate the resource requirements such as renewable electricity and land use, the climate impact, both CO_2 and non-CO_2, and the cost of flying.

Brian Yutko, Chief Engineer for Sustainability and Future Mobility at Boeing, said: "The Boeing team is excited to engage collaboratively in the AIA to evaluate potential pathways to a net zero aviation sector. By working across academia and industry, we can take a truly systems-level approach to assessing the life-cycle impacts of aviation from energy source all the way to passenger journeys. This work will inform how we can take further actions to contribute to the UK government 2050 net zero goal and ensure aerospace remains safe and sustainable."

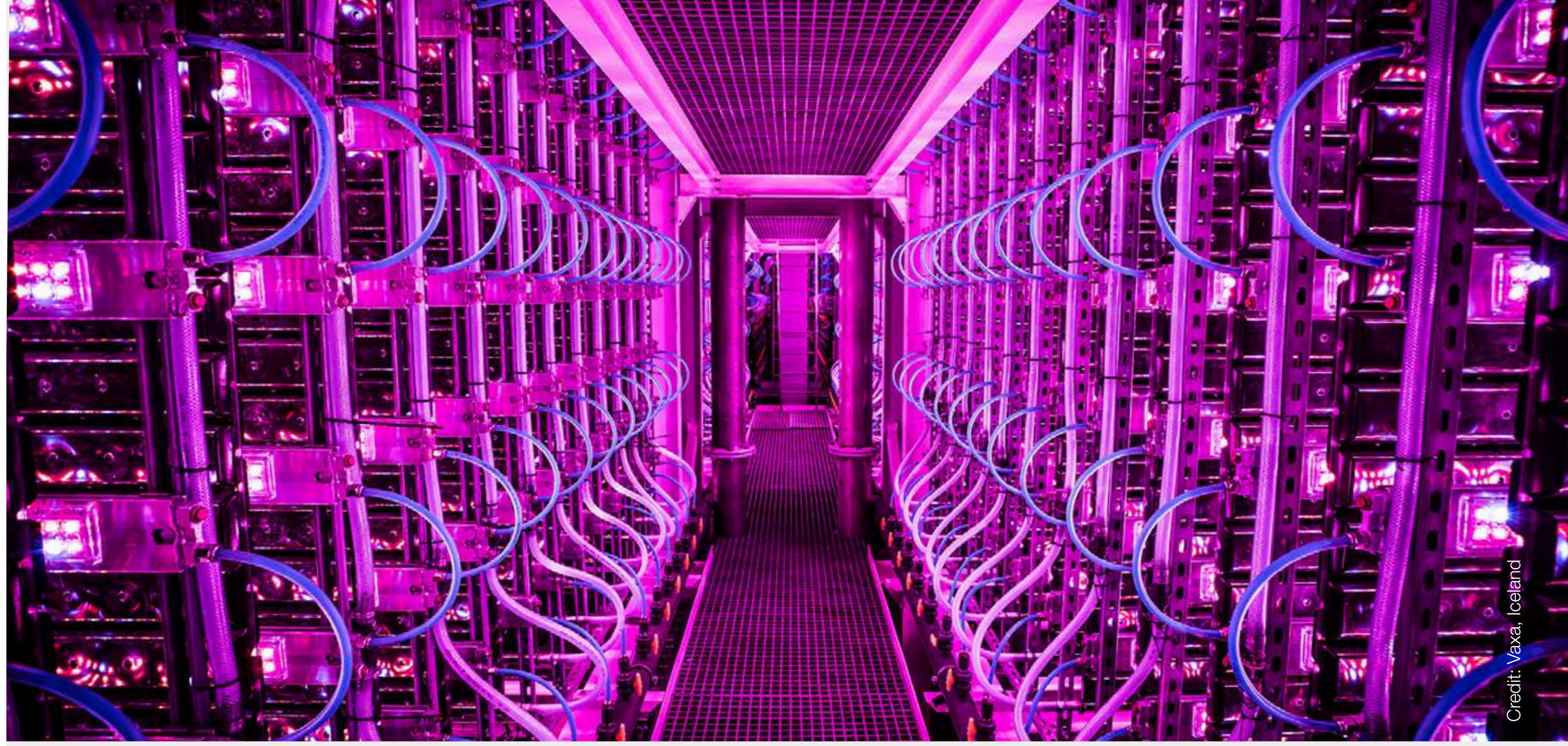
Options in the simulator include the type of energy used (such as hydrogen, batteries and a range of sustainable aviation fuels); the type of aircraft and aircraft technologies; the way in which aircraft are operated; and the value judgments made by the public and government.

The simulator will take a whole system approach, from the source of the electricity, to the methods of fuel production and transport, to the passenger journey.

Clare Shine, Director of CISL, said: "International travel helps people and societies connect. To retain this opportunity for future generations, we must urgently address aviation's environmental impact as part of systemic decarbonisation of the economy. This calls for imaginative and inclusive innovation, which is why the AIA brings together insight from industry, policy and civil society."

Dr Emily Shuckburgh OBE, Director of Cambridge Zero, said: "The transition to a zero-carbon future requires a bold response to climate change. The AIA is such a bold response, bringing together multidisciplinary expertise to inform decision making and enable meaningful change."

cisl.cam.ac.uk/centres/centre-for-policy-and-industrial-transformation/aviation-impact-accelerator
whittle.eng.cam.ac.uk
zero.cam.ac.uk



↑ Example future food farming system: Enclosed, modular photobioreactor cultivating Chlorella, a rich source of essential nutrients including amino acids, iron, zinc and B-vitamins.

Maggots among future foods that must be mass-farmed to combat malnutrition

Radical changes to the food system are needed to safeguard our food supply and combat malnutrition in the face of climate change, environmental degradation and epidemics, says new report.

Cambridge researchers say our future global food supply cannot be safeguarded by traditional approaches to improving food production. They suggest that state-of-the-art, controlled-environment systems, producing novel foods, should be integrated into the food system to reduce vulnerability to environmental changes, pests and diseases. Their report is published in the journal *Nature Food*.

The researchers say that global malnutrition could be eradicated by farming foods including spirulina, chlorella, larvae of insects such as the house fly, mycoprotein (protein derived from fungi) and macro-algae such as sugar kelp. These foods have already attracted interest as nutritious and more sustainable alternatives to traditional plant and animal-based foods.

The production of these 'future foods' could change the way food systems operate. They can be grown at scale in modular, compact systems suitable for urban settings as well as isolated communities such as those on remote islands. In an approach the researchers call 'polycentric food networks', food could be produced locally and consistently by communities – reducing reliance on global supply chains.

To reach their conclusions, the researchers analysed around 500 published scientific papers on different future food production systems. The most promising, including microalgae photo-bioreactors (devices that use a light source to grow microorganisms) and insect breeding greenhouses, reduce exposure to the hazards of the natural environment by farming in closed, controlled environments.

"Foods like sugar kelp, flies, mealworm and single-celled algae such as chlorella, have the potential to provide healthy, risk-resilient diets that can address malnutrition around the world," said Dr Asaf Tzachor, a researcher at the Centre for the Study of Existential Risk (CSER) at Cambridge and first author of the report.

He added: "Our current food system is vulnerable. It's exposed to a litany of risks – floods and frosts, droughts and dry spells, pathogens and parasites – which marginal improvements in productivity won't change. To future-proof our food supply we need to integrate completely new ways of farming into the current system."

The report argues that it is dangerous to rely on food produced through conventional farming and supply systems, which are at risk of serious disruption from a variety of factors beyond human control. The COVID-19 pandemic highlighted this vulnerability: government-imposed restrictions on travel disrupted food production and supply chains across the world.

In parallel, recent environmental challenges to food systems include wildfires and droughts in North America, outbreaks of African swine fever affecting pigs in Asia and Europe, and swarms of desert locust in East Africa. Climate change is anticipated to worsen these threats.

"Advances in technology open up many possibilities for alternative food supply systems that are more risk-resilient, and can efficiently supply sustainable nutrition to billions of people," said Catherine Richards, a doctoral researcher at CSER and the Department of Engineering.

She added: "The coronavirus pandemic is just one example of increasing threats to our globalised food system. Diversifying our diet with these future foods will be important in achieving food security for all."

Written by Jacqueline Garget

cser.ac.uk

IfM plugs into new Made Smarter investments in smart manufacturing

The Institute for Manufacturing (IfM) is partnering on multiple strands of a new £53 million investment in smart manufacturing and connected supply chains from UK Research and Innovation (UKRI) and Made Smarter.

Leading the IfM contributions will be partnerships in two new Made Smarter Innovation research centres:

The Digital Medicines Manufacturing Research Centre, led by the University of Strathclyde with partnership from Loughborough University and the University of Cambridge, will accelerate the adoption of industry digital technologies (IDTs) across the pharma sector to transform medicines development and manufacturing productivity and drive patient-centric supply.

The Research Centre for Connected Factories, led by the University of Nottingham with partnership from the University of Sheffield and the University of Cambridge, plans to develop new digital manufacturing infrastructure that can autonomously adapt into different configurations to meet specific product and volume requirements, supply chain variations and disruptions.

The research will provide a blueprint for a unique connected network of future smart factories able to cost-effectively manufacture complex products on demand, while exhibiting new levels of resilience and responsiveness to rapid and unpredictable change.

As part of the funding awarded from Made Smarter, the IfM will also undertake collaborative research as part of the SmartPSC project, where digital technologies will be applied to integrate the pharmaceutical manufacturing supply chain and enhance efficiency, productivity, flexibility, resilience and sustainability.

In addition, the IfM will lead on one of several flagship projects of the new Made Smarter Innovation Digital Supply Chain Innovation Hub, focusing on just-in-time medicines supply.

Professor Duncan McFarlane, Head of the IfM's Distributed Information & Automation Laboratory and Cambridge lead on the Research Centre for Connected Factories, said: "This new centre will allow us to explore the ways in which different developments such as IoT, additive manufacturing and human-centred technologies can be combined to produce greater adaptability both within a factory and between factories. The whole notion of a digital systems architecture for manufacturing will be reassessed as part of this work."

Dr Jag Srai, Head of the IfM's Centre for International Manufacturing and Cambridge lead on the three healthcare-related projects, said: "We are delighted to be playing a key role in these initiatives supported by Made Smarter and UKRI. With partners across the pharmaceutical industry, academia and technology providers, these digital supply chain projects in healthcare will enable more responsive production and supply, important to further boost digital healthcare innovation."

About Made Smarter Innovation

Made Smarter Innovation is a national programme to help businesses who make things capitalise on new digital technologies. The programme will support the transformation of the UK's manufacturing capabilities through the development and innovation of IDTs. It gives UK manufacturers access to a digital innovation ecosystem that helps prove their idea, quickly develop it with experts and then scale it. The £300 million partnership between government and industry will provide match-funding, specialist advice and result in radical manufacturing solutions, delivered by UKRI.

ifm.eng.cam.ac.uk

ALUMNI UPDATE

Meet Fotis Fotiadis – CEO and co-founder of Better Origin

Alumnus Fotis Fotiadis is CEO and co-founder of Better Origin, a company pioneering the transformation of organic waste into high quality functional animal feed.

Fotis completed an MPhil in Engineering for Sustainable Development and went on to co-found the Cambridge-based food tech start-up Better Origin, tackling the future of food security. They are pioneering work with the missing link in the food chain: insects. Their aim is to reduce waste and increase food production at the same time.

Fotis tells us about his career and the inspiration behind Better Origin:

Why did you decide to join the MPhil in Engineering for Sustainable Development?

After my undergraduate studies, I worked in the oil and gas industry and realised that when humans set their minds on something, they can make it happen. On the other hand, I was deeply concerned and somewhat saddened by the negative impact of the industry on our planet and ultimately our health and wellbeing. Channelling all this energy and brilliance in a way that is slowly destroying our planet had me up at night thinking about the future.

My love for nature and the outdoors made me rethink where I wanted to devote my life, energy, skills and brain power. This is what propelled me to explore a different career path, as I looked for something that I was passionate about and that would motivate me sufficiently to devote my life to. I was looking for something that would have a meaningfully positive impact in the world and that I could eventually look back on and feel proud.

What inspired you into your field?

The power of technology has always fascinated me. Looking back over the last 100 years, it is truly amazing what massive improvements in our daily lives we have brought about through technology and engineering. What is most inspiring to me is that everything around us, all these incredible technological innovations, from flying rockets into space to the creation of the Internet, have been developed by just humans. I am a big believer in the power of technology when used in the right way. The question is how can we put all this brilliance and energy towards a sustainable future, where technology and nature work in synergy and harmony?

This challenge is what inspired me to enter the field of sustainable engineering and it was during the MPhil programme at Cambridge, that I had the opportunity to participate in several entrepreneurial competitions that acted as the spark to eventually starting Better Origin. Dealing with food waste is a classic example where nature does such a perfect job, while humans are terrible at it. Therefore my thought was; if with the power of technology we can mimic nature, then we can virtually eliminate waste and make our modern food chain sustainable.

Please tell the story of Better Origin and explain how Better Origin X1 works.

It was during my master's year, whilst taking part in a University of Cambridge entrepreneurship competition, that I met Miha Pipan and together we co-founded Better Origin. The problem we set out to solve was how to reduce food waste and so we started looking into natural mechanisms that work. That is how insects came about.

Insect larvae are nature's mechanism to convert waste nutrients back into essential nutrients in the food chain. They act as the missing link between waste and food. Just think about it for a moment: what happens when an apple drops off a tree and biodegrades? Either it is absorbed by the soil as fertiliser or insect larvae consume the waste and convert it into fats and proteins in their bodies – essential nutrients for the growth of animals and humans.

At Better Origin, we use cutting-edge technology powered by artificial intelligence (AI) and automation to re-introduce insects as the missing link in our modern food chain.

The Better Origin X1 is the world's first fully autonomous insect mini-farm. We have managed to squeeze a factory in a standard shipping container that can be deployed on any farm in the world to convert local food waste to animal feed through insects. Our decentralised solution localises the food supply chain and ensures food security for the future.

At the moment we are focusing on the poultry sector; however, we have got ambitious plans for the future, looking to introduce insects as feed and food throughout the whole food supply chain. It is simply a much more sustainable and efficient way of producing animal protein while reducing waste, more than any other method available.

Our solution can produce the same amount of food currently produced on 1500sqm in just 1sqm. This means that it is 1500x more efficient than current farming practices!

We closed our latest round of $3M in December 2020 and will be fundraising again soon. The support will drive our technology forward and help us scale up in the UK and worldwide.

betterorigin.co.uk

Credit: Euan Cameron on Unsplash

↑ A long-exposure shot of traffic on the motorway

New business-led Prosperity Partnerships announced

Three new research projects involving Cambridge engineers have been announced in support of the Government's UK Innovation Strategy. The Prosperity Partnerships, as they are known, are among eight being supported with an investment of almost £60 million by the Engineering and Physical Sciences Research Council (EPSRC), part of UK Research and Innovation (UKRI), businesses and universities.

Digital roads technology

In an £8.6 million project led by Dr Ioannis Brilakis, Laing O'Rourke Reader in Construction Engineering, researchers will explore how Digital Twins, smart materials, data science and robotic monitoring can work together to develop a connected physical and digital road infrastructure system.

The project, titled *Digital Roads,* aims to improve the cost, time, quality, safety, sustainability and resilience performance of expressways. The co-investigators are Dr Fumiya Iida, Professor Abir Al-Tabbaa and Professor Mark Girolami. They will work in partnership with Highways England and construction and engineering company Costain.

The vision is to deliver roads made out of smart materials that can measure and monitor their own performance over time. The researchers will use graphene-infused concrete coatings to enable self-sensing on both the road surface and the median barrier, informing the road's Digital Twin through robotic monitoring. These self-sensing and self-healing materials, along with a wide range of measured data, will inform the data science-enabled digital processes, resulting in making better design, construction, maintenance and operation predictions. This will make roads considerably less expensive, more reliable and safer, allowing highways agencies and councils to identify when repair work is needed.

Dr Brilakis said: "*Digital Roads* is the beacon of our broader £15 million Digital Roads of the Future initiative, which also includes the £5.9 million EU MSCA COFUND FUTUREROADS Fellowships Programme and other programmes aimed at jump-starting the digital transformation of our roads sector. Combined, these programmes will build a critical mass of over 50 researchers at Cambridge over the next five years, working collaboratively with Highways England, Costain and many other industry partners to rethink roads delivery and management, deliver impact directly to all partners involved, and set the foundations for a long-term Institute on the Future of Roads."

Professor Girolami, Sir Kirby Laing Professor of Civil Engineering, Royal Academy of Engineering Research Chair at the University of Cambridge, Academic Director for CSIC and Programme Director for Data-Centric Engineering at The Alan Turing Institute, said: "We can consider *Digital Roads* as providing one of the components of the cyber-physical fabric essential for more resilient and robust UK infrastructure. *Digital Roads* is an excellent example of the need for multi-disciplinary teams adopting a data-centric engineering approach to address some of the grand challenges we face."

Professor Al-Tabbaa, Head of the FIBE and FIBE2 CDTs and Director of the Resilient Materials for Life (RM4L) programme grant, said: "*Digital Roads* will enable us to capitalise on our long-standing successful partnership with Highways England and Costain to continue our journey together delivering cutting-edge research and innovations. We have set ourselves exciting and challenging targets to deliver significant advances towards making the UK a global leader in digital roads technology and delivering net zero roads."

Dr Iida, Reader in Robotics, said: "This project will see robotics and AI technologies applied to the high-impact application area of civil engineering, where a considerable growth margin is expected. Academic researchers will be better connected and able to collaborate with industrial partners to achieve real-life impact with their research."

By 2030, the *Digital Roads* team aims to develop outcomes to a commercial stage and to follow the same development journey for other road assets such as bridges and tunnels, followed by the entire strategic road network by 2040. This will ensure that roads become safer, serviceable at a lower cost, and maintained more efficiently and sustainably, thus reducing the emissions generated by roadworks and preventing unnecessary delays to motorists.

P24: Explore more Digital Twin-related research

Credit: SevenStorm JUHASZIMRUS from Pexels

AI system for air traffic control

Professor Mark Girolami and Dr Adrian Weller are co-investigators of the collaborative research project titled *Project Bluebird: An AI system for air traffic control*.

The vision is to deliver the world's first artificial intelligence (AI) system to control airspace in live trials, working with air traffic controllers to help manage the complexities of their role. This system utilises digital twinning and machine learning technologies and includes tools and methods that promote safe and trustworthy use of AI. Such tools will become more important with growing use of uncrewed aircraft and airspace playing a crucial role in delivering aviation's commitment to net zero emissions by 2050.

The project has three main research themes:

Develop a probabilistic Digital Twin of UK airspace. This real-time, physics-based computer model will predict future flight trajectories and their likelihoods – essential information for decision-making. It will be trained on a NATS (National Air Traffic Services) dataset of at least 10 million flight records and will take into account the many uncertainties in ATC (air traffic control), such as weather or aircraft performance.

Build a machine learning system that collaborates with humans to control UK airspace. Unlike current human-centric approaches, this system will simultaneously focus on both the immediate, high-risk detection of potential aircraft conflicts, and the lower risk strategic planning of the entire airspace, thus increasing the efficiency of ATC decision-making. To achieve this, researchers will develop algorithms that use the latest machine learning techniques, such as reinforcement learning, to optimise aircraft paths.

Design methods and tools that promote safe, explainable and trustworthy use of AI in ATC systems. This will involve experiments with air traffic controllers to understand how they make decisions, so that these behaviours can be taught to AI systems. The project will also explore ethical questions such as where the responsibility lies if a human-AI system makes a mistake; how to build a system that is trusted by humans; and how to balance the need for both safety and efficiency.

Professor Girolami will work on the development of the Digital Twin.

"The Data-Centric Engineering programme at The Alan Turing Institute has been working with the National Air Traffic Service since 2018 and *Project Bluebird* is the latest collaboration in this partnership," he said. "It is particularly exciting to see The Turing's world-class foundational research in AI, Machine Learning and Digital Twins coming together and being set to deliver next-generation airspace control in addressing the many challenges we face towards 2050."

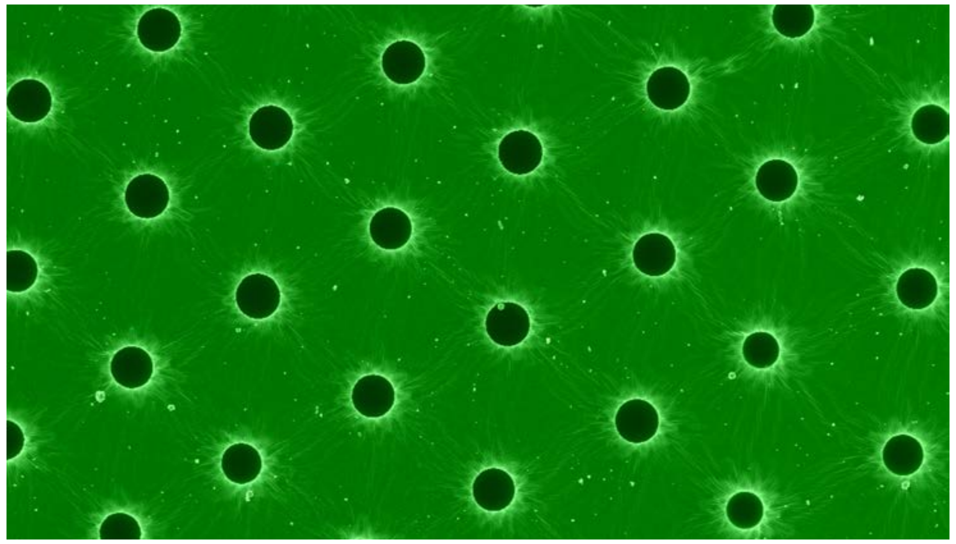
Dr Weller, Principal Research Fellow in Machine Learning at the University of Cambridge, Programme Director for Artificial Intelligence at The Alan Turing Institute and Turing Fellow, will work on the machine learning system and will design methods and tools that promote safe, explainable and trustworthy use of AI in ATC systems.

"I am thrilled to be part of a wonderful team of academics and practitioners focused on delivering trustworthy AI for mission-critical air traffic control in practice," he said.

AI in the financial services industry

Dr Weller has also been announced as a co-investigator of another Prosperity Partnership titled *Project FAIR: Framework for responsible adoption of artificial intelligence in the financial services industry*. The project will see The Alan Turing Institute, HSBC and other organisations develop the trustworthy, data-driven AI decision-making approaches that are needed for the wider adoption of these technologies in the financial and professional services sector.

Empty pores visible in a polymer film, where droplets were printed, trapped and released



Accelerating drug discovery and printed personalised drug delivery

Cambridge engineers have demonstrated – for the first time – the digital inkjet printing and self-organisation of microdroplets on fluid surfaces to create structures of functional materials.

These printed drops are naturally trapped at the fluid surface. It is at this point that they are captured as the fluid solidifies around the drops into a solid polymer film. Inspired by the patterns of condensation that form on surfaces, this breakthrough easy-to-manufacture method paves the way for the scaling up of future applications in drug discovery and printed personalised drug delivery.

The Fluids in Advanced Manufacturing research team from the Institute for Manufacturing (IfM), part of the Department of Engineering, are looking at using the drops as microscale test tubes for reactions. They hope that the millions of drops, capable of fitting on a small area, can be used to accelerate drug discovery reactions. The team will investigate this further in work funded by the BBSRC – Biotechnology and Biological Sciences Research Council. Furthermore, the team are exploring the use of capturing and releasing the droplets for tailored treatment of wounds.

Working closely with the BBSRC Impact Acceleration Account and University of Cambridge spin-out LIFNanoRx Limited, which uses quantum biology to capture the healing properties of the stem cell growth factor "LIF", the team envisage printed products with the potential value to transform wound healing.

Polymer films with adjustable pores are essential when it comes to designing for applications such as the controlled release of drugs. An example includes the delivery of a personalised combination dosage via a patch or a dissolvable film placed on the tongue. Now the researchers have combined this advanced printing technique with the principles of a nature-inspired method to provide a manufacturable way of delivering functionality to porous polymer films. The results of the study are published in the journals *Materials Horizons* and the *International Journal of Pharmaceutics*.

Natural water condensation patterns that are seen every day on solid surfaces, and that were studied by Lord Rayleigh in 1911, are often referred to as 'Breath Figures' (BFs). Since the 1990s, it has been known that these BFs could occur as micron-scale water droplets on a fluid surface, with the ability to self-organise and imprint into a permanent microporous polymer structure. Inspired by this, the Cambridge research team have used drop-on-demand (DoD) inkjet printing to control the size of drops, its contents and location on the fluid surface. In comparison to the BF method, this new process delivers improved stability, with excellent control over pore volume and structure, and enables rapid manufacturing of functional, structured polymer films, making applications feasible and scalable.

The inkjet printing process is highly programmable, with the droplet size and the pattern of the droplets delivered to the substrate easily controlled. The content of the drops can be formulated to contain a wide range of functional materials while still printing reliably. This can include pharmaceutical and biological printing. Each drop is mostly submerged and trapped in the fluid, but with a small opening to the outside. In the first application, for drug discovery, this allows subsequent drops to be added and mixed with drops already on the surface, as if they were microscale test tubes. In the second application, this small opening allows material to be released through diffusion. This enabled researchers Dr Qingxin Zhang and Dr Niamh Willis-Fox to examine each step of the process – print, capture and release. Dr Clare Conboy, from Printed Electronics Ltd., also contributed with expertise and measurements of the behaviour of fluids as they begin to solidify and trap the droplets.

In order to improve drop positioning accuracy, self-organisation was explored as a way of bringing the droplets closer together. This is found to be a highly reliable and repeatable way of ensuring near-perfect droplet packing and the team have been showing how to capture the drops in square arrays or as a hexagonal honeycomb-like structure.

Dr Ronan Daly, Senior Lecturer in the Science and Technology of Manufacturing, said: "This level of control and order has never been achieved with the alternative Breath Figure droplet self-organisation techniques. We have also enabled a shift towards safer, more environmentally responsible manufacturing of these structures. The result is a low cost and customisable technique that has become dramatically more repeatable and tuneable, and one which paves the way for rapid translation to applications in combination drug delivery and drug discovery techniques."

Dr Su Metcalfe, CEO of LIFNanoRx, said: "The combined powers of printed personalised delivery together with quantum biology of biomimetics, bring a new era of sustainable and universal therapeutics at low cost and high value."

ifm.eng.cam.ac.uk/research/fiam/

Dr Sabesan Sithamparanathan

Department spin-out company wins a Queen's Award for Enterprise

Department spin-out company PervasID develops battery-free Radio Frequency IDentification (RFID) reader systems for automating inventory and asset tracking.

Founded by alumnus Dr Sabesan Sithamparanathan, PervasID is a fast-growing Cambridge-based technology company that designs and supplies world-leading, passive (battery-free) RFID fixed reader systems for automating inventory tracking, stock taking and asset management processes. The patented products are enabling organisations across a wide range of markets to streamline processes by providing visibility into goods, assets and people.

The Queen's Award for Enterprise recognises PervasID's pioneering work in battery-free tag tracking technology to allow enterprises to improve how they manage inventory and to optimise their asset management. Now in their 55th year, the Awards are the most prestigious business accolades in the country, with winning businesses able to use the esteemed Queen's Awards emblem for the next five years. PervasID now joins just over 7,000 UK enterprises to receive this royal recognition since the Awards were established in 1965.

PervasID's technology for passive RAIN (RAdio frequency IdentificatioN) RFID fixed reader systems for automating inventory tracking, stock-taking and asset management processes was developed in Cambridge and is sold around the world. The company's patented products allow organisations across a range of markets to streamline processes by providing unparalleled visibility into goods, assets and people. PervasID's unique technology solution delivers unparalleled accuracy, speed and cost effectiveness.

A single PervasID RFID reader can cover up to 400m2 with 99% plus accuracy in real time, and is capable of readily scaling to much larger areas such as industrial warehouses, multi-storey buildings or sprawling healthcare campuses. The company's RFID readers have significantly greater accuracy, range and speed than any other RFID readers on the market. Its fixed reader products have been deployed in Europe, Asia and the US and clients include high-profile department stores, industrial companies, healthcare establishments, systems integrators and large-scale enterprises. PervasID is headquartered in Cambridge UK, with employees in France and the US.

"There are few things more critical to an enterprise than having clear oversight of where assets are and making sure that they are being used in the most efficient way possible. Our Cambridge-developed battery-free technology allows enterprises of all types to keep track of their inventory and asset cost effectively with unparalleled accuracy and speed," said Sabesan Sithamparanathan, alumnus, founder and CEO of PervasID. "Our company has grown rapidly, with deployments around the globe, and we are delighted to have been recognised with this Queen's Award for our innovation."

The background research that led to PervasID was done by the Department's Centre for Photonic Systems within the EPSRC TINA project.

In July 2021, Dr Sithamparanathan received an RAEng Silver Medal for his pioneering developments that have enabled world-beating commercial products.

> There are few things more critical to an enterprise than having clear oversight of where assets are and making sure that they are being used in the most efficient way possible. Our Cambridge-developed battery-free technology allows enterprises of all types to keep track of their inventory and asset cost effectively with unparalleled accuracy and speed.
>
> Sabesan Sithamparanathan

Spotlight on brain-related research

Disruptive technologies to boost understanding of brain health and disorders

Researchers from the Department's Bioelectronics Laboratory have won investment from the European Commission to gain a more complete understanding of brain health and disorders – and train the next generation of brain scientists.

The collaborative project titled ASTROTECH, funded under Horizon 2020, the EU research and innovation programme, involves industrial partners and nine other universities, as well as the contribution of the private sector in a research and training programme for 15 Early Stage Researchers. The 'training through research' will be on state-of-the-art biomaterials interfaces, electronic and photonic devices, combined with a wide spectrum of complementary expertise, to help create and develop the field of Glial Engineering.

The project will provide innovative tools to record, study and manipulate astrocytes – glial cells that play an important role in brain function – in the healthy and diseased brain. Studies over the past four decades have revealed that astrocytes, which outnumber neurons in the human brain, play a crucial role in numerous functions within the central nervous system. Further, there are a number of neurological disorders that are invariably associated with astrocyte dysregulation, raising the possibility of causal links in brain ischemia (a condition that occurs when there is an insufficient amount of blood flow to the brain), glioma (brain tumours that start in glial cells), epilepsy or depression.

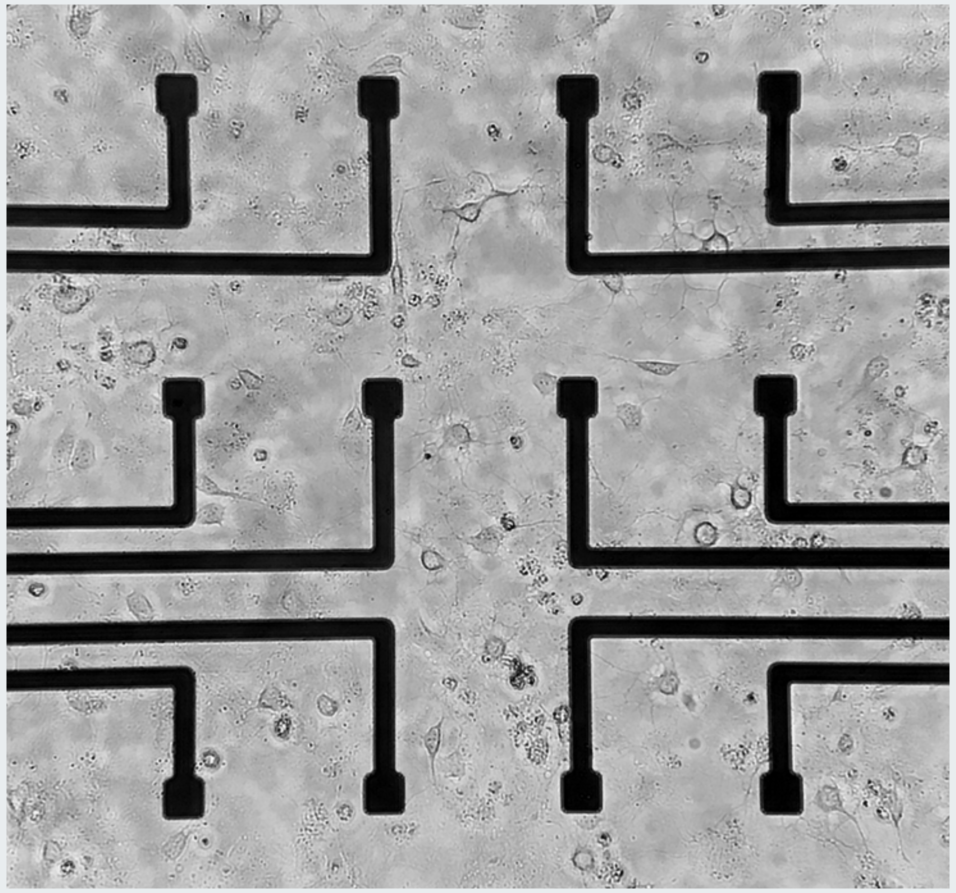
Although cutting-edge tools have been developed to study neurons (the basic working unit of the brain found within the nervous system), no tool has been specifically developed to study glial cell function. ASTROTECH will fill this gap. It aims to unravel the role of astrocytes in brain function and dysfunction by developing the appropriate technology to study these cells and unveil their implication in disease.

Professor George Malliaras, Prince Philip Professor of Technology, leads an interdisciplinary group of scientists, engineers and clinicians at the Bioelectronics Laboratory, University of Cambridge.

Professor Malliaras said: "There is increasing evidence to indicate that astrocytes play an important role in brain function, but without the appropriate technology to study these cells, scientists cannot unveil their implication in disease.

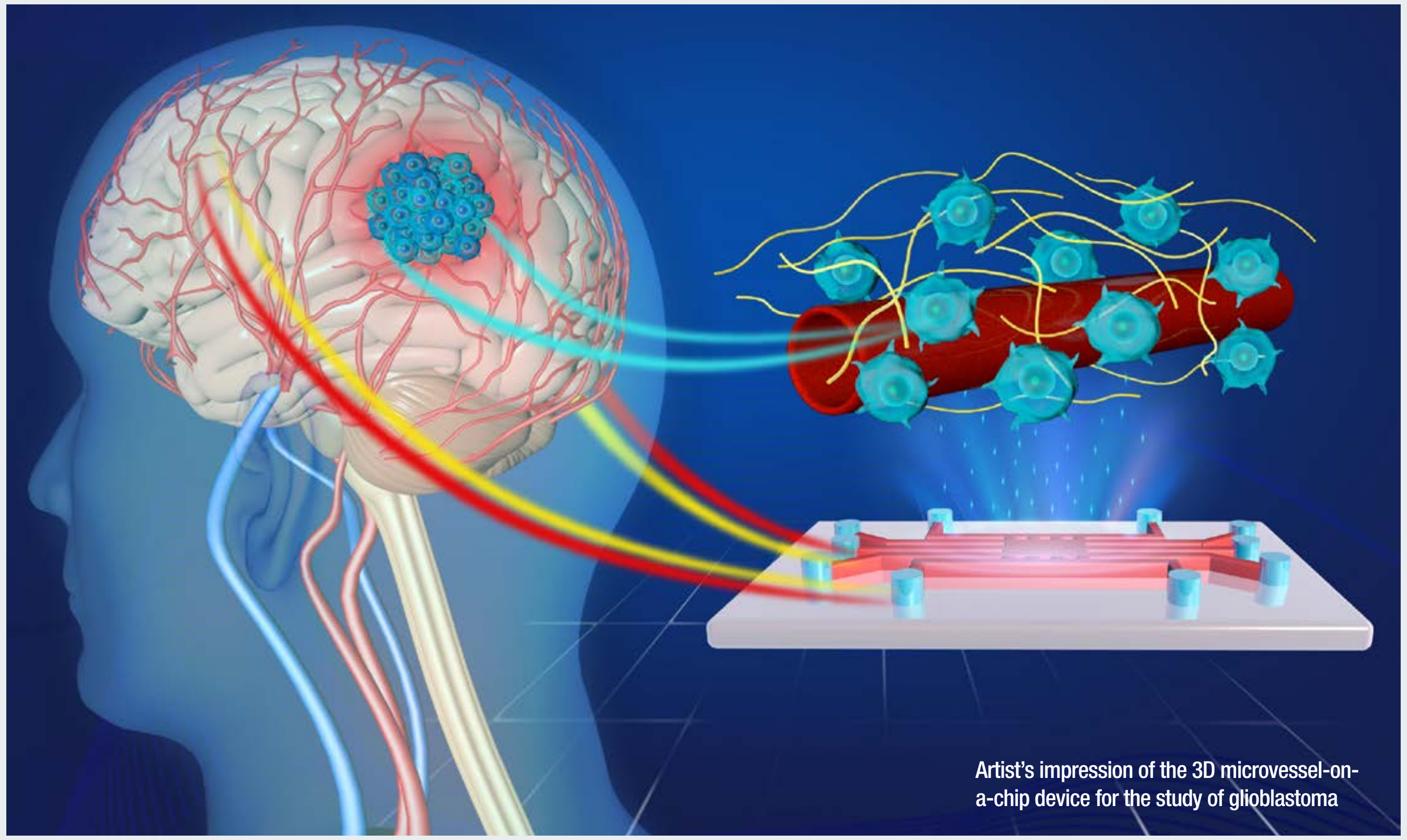
"The ASTROTECH project will provide a more complete understanding of brain health and disorders by developing tools for recording and manipulating astrocytes. Crucially, this project – supported by the Innovative Training Networks (ITNs) set up to drive scientific excellence and innovation – will fuel future astrocyte research and train the next generation of brain scientists. These Early Stage Researchers will gain training and complimentary skills in optogenetics, neuroscience, glial physiology and biology and computational methods, as well as knowledge in nanomaterial processing and device fabrication, equipping them with the skills they need to thrive in the supradisciplinary field of Glial Engineering."

bioelectronics.eng.cam.ac.uk



Credit: Bioelectronics Laboratory

← Neurons (small cells with a tail and rounded head) and astrocytes (flattened, hexagonal cells) can be seen being both stimulated and recorded by electrodes, so as to build an *in vitro* brain injury model.



Artist's impression of the 3D microvessel-on-a-chip device for the study of glioblastoma

Credit: Yuanyuan Bei

New device to accelerate drug development in the fight against brain cancer

Researchers have developed a 3D microvessel-on-a-chip device for the study of glioblastoma – a fast-growing and aggressive form of brain tumour that develops chemo-resistance over current treatments. Creating 'humanised' *in vitro* models to study brain cancers using patient-derived cancer cells, could improve our understanding of how cancer sub-types and the microvessel environment drive chemo-resistance, leading to the rapid testing of new drugs and therapeutic approaches.

The current standard of care for patients diagnosed with glioblastoma – of which there are around 2,500 new cases every year in the UK alone – involves a combination of tumour resection surgery, chemotherapy and radiation that would give the patient an average survival rate of less than 15 months. Brain tumours are known to be highly heterogeneous among different patients; even for the same patient, the tumour composition can be very different depending on the tumour region, which means that different sub-types of cancer cells and their environment can respond very differently to the same drug.

In order to further understand the behaviour of patient-derived glioblastoma stem-like cells (GSCs) and their interactions with the blood-brain barrier – a key role in identifying new drug targets – there is a need to develop a microfluidic device to perform comparative studies in order to investigate how the types of GSCs and microvessels affect the cells' gene expression, cancer cell speed and direction of migration. These GSCs can migrate in the brain vasculature within or away from the tumour mass, increasing tumour resistance to treatments and contributing to relapses. The results of the study, involving the University of Cambridge, University of Toronto, Radboud Institute for Molecular Life Sciences, King's College London and the University of Edinburgh, are published with open access in the journal *Lab on a Chip*.

The researchers created flowable vasculature models generated from endothelial cells from the human brain, umbilical vein and lung, in order to study the characteristics of the microvessels and their interaction with GSCs derived from different patient cancer subtypes. The customisable nature of the device opens up the possibility for clinicians to be able to study tumour susceptibility to new treatments.

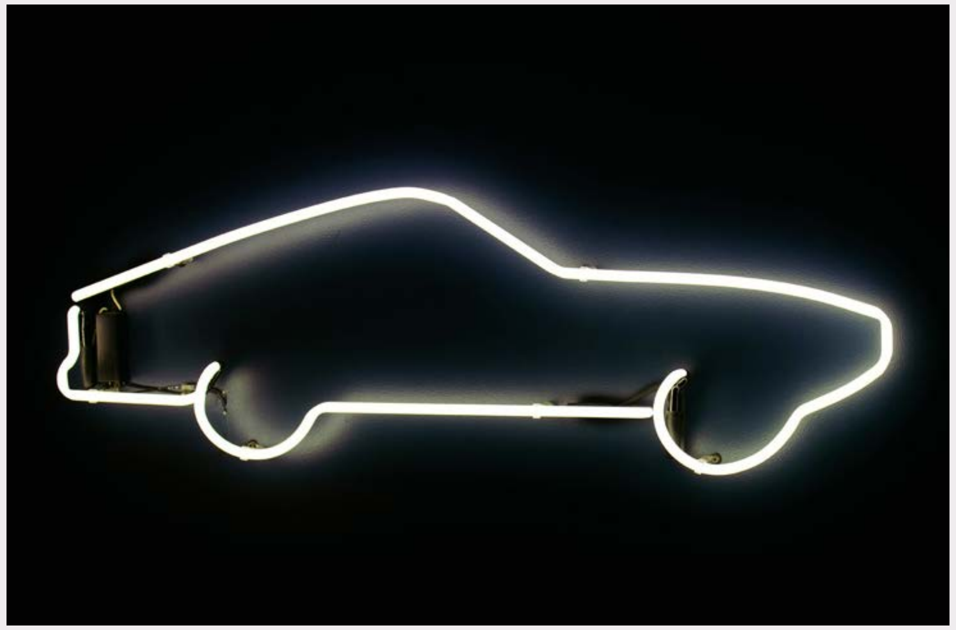
At Cambridge, this work was initiated between bioengineers Magda Gerigk, a recipient of the CRUK Multidisciplinary Studentship, and Dr Shery Huang from the Department of Engineering; neurosurgeon Dr Harry Bulstrode, from the Department of Clinical Neuroscience; and clinician lead Professor David Rowitch, from the Department of Paediatrics.

Corresponding author Dr Huang, Assistant Professor in Bioengineering and Group Leader of the Biointerface Research Group, said the novel creation of the flowable brain microvessel, the ability to perform gene expression analysis and the use of live-cell imaging and image analysis, aided understanding of brain tumour progression.

"We look forward to seeing engineering tool kits making an increasing impact on clinical treatments," said Dr Huang.

biointerface.eng.cam.ac.uk

Next-generation batteries to power up electric vehicles



Credit: Maksim Goncharenok from Pexels

Cambridge engineers will develop next-generation lithium-ion batteries with improved performance as part of a collaborative project to scale up production ahead of a predicted electric vehicle boom.

The electric revolution is already well underway in the car industry, with the UK Government announcing plans to ban the sale of new diesel and petrol cars and vans by 2030, putting the UK on course to be the fastest G7 country to decarbonise these vehicles. Globally, the number of electric vehicles (EVs) is projected to rise from about 1 million in 2015 to 300 million in 2040. Achieving these goals, however, requires low-cost batteries with dramatically improved performance for EV use.

Now Cambridge researchers Professor Simone Hochgreb, Dr Adam Boies and Professor Michaël De Volder will work alongside Professor Kai Luo, from University College London, on experimental and numerical tools as well as production techniques for enhanced materials for electrodes, especially the cathode (positive electrode) used in lithium-ion batteries (LIBs). These developments are required to meet the power density and cost requirements for the next-generation EVs and energy storage systems.

The research, funded by the EPSRC, will combine high-performance cathode materials for LIBs. These materials will be based on layered, multi-element metal oxides (MOs) and carbon-metal oxides (CMOs), with inherent potential for high-speed continuous processing for mass production. The main area of research will focus on nickel manganese cobalt oxides (NMCs) with various metal contents and surface features, which are favoured by mainstream automotive companies due to the high number of charge and discharge cycles the NMC battery can withstand. However, the research and production techniques explored – including flame spray pyrolysis (FSP) – will be applicable for a large class of MOs and CMOs.

FSP is a promising method used to produce a wide variety of functional materials in the form of powders (nanoparticles) and in large quantities. It is an effective and scalable industrial process that is easy to handle and one that maintains excellent product quality. Professor Hochgreb will work on flame synthesis; Dr Boies on nanoparticle synthesis; Professor De Volder on nanomaterial and batteries; and Professor Luo on modelling and simulation. Their work will be directly linked to battery performance metrics, in collaboration with four companies: Contemporary Amperex Technology Co. Limited (CATL), University of Cambridge spin-out Echion Technologies, TFP Hydrogen Products (formerly PV3 Technologies) and Shanghai Tang Feng Energy Technology (STFET).

Echion Technologies was founded in 2017, based on the PhD research of alumnus and now CEO Jean de La Verpilliere, and is focused on developing anode materials that will safely enable superfast charging LIBs. Other co-founders of Echion are Dr Boies and Professor De Volder, who were Jean's PhD supervisors, as well as Dr Alex Groombridge, a PhD graduate from the Department of Chemistry. Jean and Alex met as Nanoscience and Nanotechnology (NanoDTC) PhD students in the 2013 cohort. Echion Technologies has gone on to successfully demonstrate its superfast charging capabilities in 3Ah pouch cells as well as 12.5 Ah cells, its largest cells to date.

Professor Simone Hochgreb said: "The long-term outlook for electric vehicles (EVs) is strong, with the electrification of the transport sector considered a natural development in order to make use of energy from a wide variety of sources, and to reduce CO_2 emissions and combat urban air pollution.

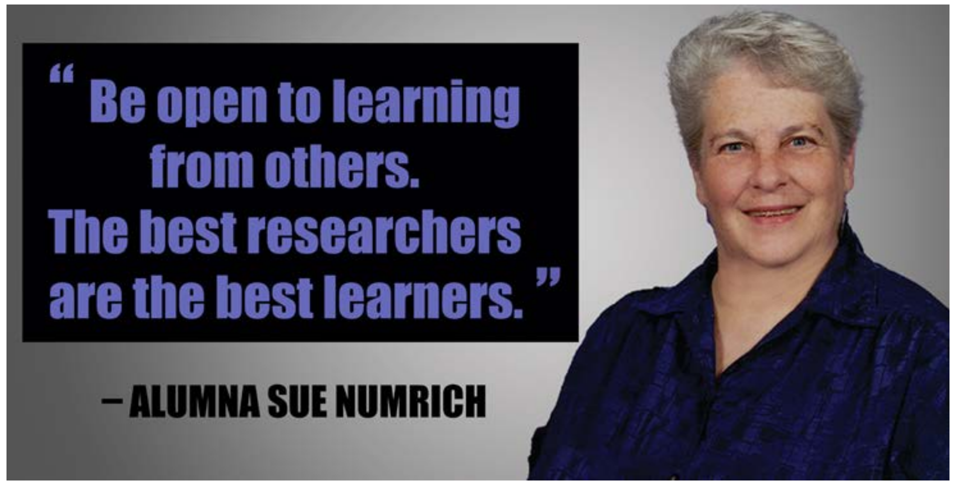
"One of the biggest obstacles facing us in making the transition to EVs is the charging infrastructure itself, which is why research is needed to ensure that the power density and cost requirements for next-generation EVs and energy storage systems are met.

"Our manufacturing technique for lithium-ion batteries using flame spray pyrolysis is a one-step continuous process with the potential to produce designer materials at scale and low cost."

> "Our manufacturing technique for lithium-ion batteries using flame spray pyrolysis is a one-step continuous process with the potential to produce designer materials at scale and low cost.
>
> Professor Simone Hochgreb

ALUMNI UPDATE

Meet the national security researcher and champion for women in leadership



Alumna Sue Numrich has enjoyed a long research career in the field of national security. Having started out as one of only a few female scientists working in her field, Sue has risen through the ranks to lead on and contribute to cutting-edge research, ranging from experiments on future defence concepts to assessments of the global war on terrorism.

Sue is a physicist and a member of research staff at the Institute for Defense Analyses (IDA), a non-profit corporation headquartered in Alexandria, Virginia, in the United States. She has dedicated many years to advancing the role of women in national security. More recently, her accomplishments and intellectual leadership within the IDA community have been recognised with the 2020 Goodpaster Award for Excellence in Research.

In addition to achieving a PhD in Physics, Sue earned a postgraduate certificate in mechanical engineering from the University of Cambridge in 1986. At the time of choosing to study at Cambridge, Sue was a research physicist employed by the U.S. Naval Research Laboratory in underwater acoustics and was looking forward to a sabbatical year to acquire additional expertise.

"I had read the work of Professor Shôn Ffowcs-Williams and had spoken with him about spending a year working with him on the scattering of acoustic waves from submerged shells," she said. "When I was at Cambridge, one of Professor Ffowcs-Williams' colleagues was Professor Dame Ann Dowling, so I also had the privilege of working in association with another woman professional. In my current work, I use my specialty in mechanical engineering only occasionally; however, I have found the intellectual stimulation of Cambridge to be a continuing factor in my analyses in many other fields.

"I am fascinated by how things work and how Mother Nature works in particular, even to the point of doing shipboard research in the Arctic at the edge of the ice pack (which is virtually non-existent now). These days, I can be handed work to assess in disciplines ranging from natural language processing and high performance networking to envisioning new ways of information flow in complex environments. I find applying my technical understanding and mental frameworks to each new situation exciting and see it as an opportunity for intellectual growth."

Women in leadership

"Part of the problem of attracting women to begin their careers and remain in STEM fields, is the absence of women role models, particularly in leadership roles," said Sue.

"Starting in our middle schools, the time when students encounter teachers with specialties in technical disciplines (in the U.S. this is the 7th through 9th grades), the teachers are almost exclusively men, with the greatest number of exceptions in mathematics and the biological sciences. Women are seen as physicians, as mathematicians and as computer scientists, but not as engineers and physical scientists or technologists. There have been barriers to women who have entered these fields in the past – barriers that have prevented them from having leadership roles. While many of these barriers have been identified, their removal will take time.

"Women are often lauded for their expertise in supporting roles and not given the opportunity or encouragement to move into leadership positions. One of the least recognised benefits of working in STEM fields is that there is generally always work, even if a woman chooses to take time out to raise children and then re-enter the workplace some years later. Re-entry is far easier than in many other fields."

As a mentor to early career staff and counsellor for many others at IDA, Sue enjoys the challenge of finding ways around problems and alternative perspectives on situations.

"To lead is to enable," said Sue.

Do your best, help others and never give up

Sue has been a teacher and lecturer for 20 years.

"My advice to other women is to always do your very best, give of yourself to help others, ask for advice from someone who seems to have it all together, and never give up. Do not be afraid to be an opportunist, even if you think you may not be qualified. Take the risk. Always provide what the employer (or sponsor or professor) asked for, but add to it what should have been requested. Unearthing new approaches and achieving better results demonstrates the best kind of initiative. Respect the capabilities of others and don't be afraid to admit your own limitations – but then extend your capabilities by being open to learning from others. The best researchers are the best learners."

Helping the UK to reach its net zero target

A new paper by leading UK scientists sets out key solutions and policy actions that should be implemented now, as well as priority research areas for the next decade, if the UK is to reach its net zero target by 2050.

Achieving this target will require a mix of technological, societal and nature-based solutions working together to enable systemic change. Research in the 2020s must be prioritised into solutions for sectors that are particularly difficult to decarbonise, such as aviation, electricity generation and storage, and maritime shipping.

The report, led by the University of Cambridge, also highlights net zero solutions that could be implemented now, such as the electrification of road freight, hydrogen produced using renewable energy instead of current carbon-intensive methods, and changes to land use planning to prioritise denser, mixed-use, low traffic neighbourhoods.

The briefing, *Net-Zero Solutions and Research Priorities in the 2020s*, is published by the COP26 Universities Network and brings together 26 leading scientists from 10 UK universities, including Cambridge engineers Dr Daniel Ainalis, Professor David Cebon, Dr Shaun Fitzgerland, Dr Samuel Grimshaw, Dr Hugh Hunt and Dr Maria Vera-Morales.

"It is abundantly clear from the recent IPCC report that the 2020s will be the crucial decade to reduce emissions in order to meet the Paris Agreement goals, and the decisions made at COP26 will be critical in achieving that," said co-lead author Dr Erik Mackie from Cambridge Zero, the University's climate initiative. "This cross-disciplinary report will aid decision-makers by identifying the key actions that we must take now, and the priority areas where we should urgently focus our research efforts to tackle hard-to-decarbonise sectors."

The paper highlights net-zero solutions in eight priority sectors, setting out actions to take now, research priorities for the next decade, and future benefits for each sector. These are: Electricity (generation, storage, system and networks); Buildings; Road transport; Industry; Land/sea use and agriculture; Aviation and shipping; Waste; and Greenhouse Gas Removal (GGR). Nature-based Solutions (NbS) – key actions that can work with nature to address climate change and biodiversity loss across all sectors, while also supporting economic recovery – are highlighted separately.

Additional solutions highlighted in the report include the retrofitting of buildings, increased R&D investment to bring low-carbon farming practices to market and the deployment of Carbon Capture Utilisation and Storage (CCUS) at scale by the mid-2020s to support the first low-carbon and net zero industrial clusters.

The authors stress that each solution should be assessed with respect to greenhouse gas emissions reductions, energy efficiency and societal implications to provide a basis for developing long-term policies, maximising positive impact of investment and research effort, and guiding industry investors in safe and responsible planning.


Science in HD on Unsplash

↑ Nordex USA manufacturing facility – Jonesboro, Arkansas, USA

Major study on proposed electrification of UK motorways

The Centre for Sustainable Road Freight – a collaboration between the University of Cambridge, Heriot-Watt and Westminster Universities and a consortium of industry partners – is part of a team that has been awarded government funding to design a large-scale electric road freight system demonstrator.

The feasibility study is part of £20 million funding awarded by the Department for Transport and delivered by Innovate UK to boost the UK's transition to zero emission road freight. The project team includes Siemens Mobility, Scania, Costain, The Centre for Sustainable Road Freight, ARUP, Milne Research, SPL Powerlines, CI Planning, BOX ENERGI and Possible.

The consortium will lead a major UK study on the electrification of long-range trucks with dynamic charging, using overhead wires on motorways.

The project will investigate the feasibility of building a 20km stretch of overhead contact lines on a UK motorway to power long-haul HGVs using Siemens 'eHighway' technology. The system will be connected to logistics facilities at either end, to demonstrate end-to-end electrification of logistics: from port to depot to city centre.

The consortium has proposed this system as the fastest, lowest carbon and most cost-effective route to decarbonising the UK road freight industry and to deliver cleaner air and quieter motorways. The nine-month study, which began in July 2021, could be the forerunner of a scheme that aims to see the UK's major roads served by overhead lines by the late 2030s. These eHighways allow specially-adapted trucks to attach to the overhead wires and run using the electricity, similar to rail and trolley-bus systems. The trucks come equipped with a battery that charges while they are in motion, so that they can detach in order to not only overtake vehicles, but also to reach their final destination with zero emissions from start to finish.

Professor David Cebon, Director of the Centre for Sustainable Road Freight, said: "Our previous research indicates that overhead catenary power will provide the lowest cost, lowest carbon, and most rapidly deployable solution to decarbonise long-haul road freight in the UK. This project will test the concept at the next level of detail. Moreover, the technologies this consortium is working on could be deployed in most countries once demonstrated, supporting the global move towards greener logistics."

Gates Cambridge class of 2021 – Emma Houiellebecq

Emma Houiellebecq is the recipient of not one – but two – Gates Cambridge Scholarships. As she begins her PhD in Engineering this term, we caught up with Emma to find out more about her experience so far and the importance of 'dreaming big' and following your ambitions.

I feel incredibly honoured to be the recipient of two Gates Cambridge Scholarships, first for my Master's and now for my PhD. My MPhil in Engineering for Sustainable Development was fundamental in facilitating the advancement of my career and sharpening the analytical skills that have been essential to my role in the humanitarian sector.

It was during my MPhil dissertation research that I first focused on the topic of urban resilience. This, in turn, inspired my decision to work with the International Committee of the Red Cross (ICRC) and to undertake doctoral research, specifically exploring how to strengthen the resilience of critical infrastructure (such as water, electricity, and health services) in fragile urban contexts.

My doctoral research will build upon my recent work experiences in the humanitarian sector in countries affected by ongoing armed conflict and natural disaster. These fragile urban contexts in southern and eastern Africa and the Middle East, for example, are facing a convergence of protracted insecurity, climate risks and environmental degradation. My international experiences with non-governmental organisations (NGOs) and more recently with the ICRC, have been invaluable in providing me with a grounded understanding of the myriad daily challenges and complexities faced in such fragile, dynamic environments.

The University of Cambridge is an amazing place to study. It draws some of the world's most progressive and innovative thinkers and allows them to develop their ideas and flourish in a supportive environment. Such an environment fuels and inspires your own passions.

I was especially drawn to the Department of Engineering's Centre for Sustainable Development, which emphasises the broader role of an engineer – not only in that engineer's field of technical expertise, but also in navigating the complex dynamics between physical, natural and social issues. The Centre's focus on tackling some of the world's most critical challenges resonates with my own values and career ambitions. Since completing my MPhil at the Centre in 2017, it has been amazing to see the different directions people are taking in their careers and the impacts that they are already making.

For others who are looking to follow a similar route, I definitely recommend gaining some practical experience of the challenges being faced in real situations. It will help determine your level of interest and passion for undertaking research that addresses these identifiable issues.

I would also encourage others to dream big and be proactive. Studying at the University of Cambridge seemed like a far-fetched dream at the beginning. Nevertheless, I set it as my goal and took steps to try to make it a reality. In the end, I was very fortunate to have Cambridge believe in my vision and accept my application.

About the Gates Cambridge class of 2021

This year's cohort comprises 74 new scholars. They are joined by 10 scholars who are deferring from 2020. The 84 scholars, who come from 30 countries, began their studies in October. The class includes 42 women, 31 men and one non-binary scholar. The Gates Cambridge scholarship programme, which this year celebrates its 20th anniversary, is the University of Cambridge's leading international postgraduate scholarship programme.

gatescambridge.org
www-csd.eng.cam.ac.uk

→ Daniel Smith and Thea Krumins, two of the three Newland Design prizewinners

Academic prizes in memory of Professor David Newland

Professor David Newland is being remembered for his outstanding contributions to Mechanics, Materials and Design with a set of academic prizes. Three David Newland Prizes of £500 will be awarded annually to third-year students who have shown great distinction in these areas.

Mechanics, Materials and Design Division staff members, along with a member of David Newland's family, have endowed the academic prizes in his memory.

The prizewinners for the academic year 2020/2021 are:

Daniel Smith: Newland Design prize for Excellence in Design. "It is an honour to receive the first ever David Newland Prize for Design. It's so amazing to see all the hard work spent on my project get recognised like this," he said.

Thea Krumins: Newland Materials prize for Excellence in Materials. "I was thrilled to win the award; it feels great to have all of your hard work recognised," she said.

Isaac Brown: Newland Prize for Excellence in Mechanics. "It is an honour to receive this award in memory of a former Head of Department. I look forward to continuing my study of Mechanical Engineering over the coming years," he said.

David Edward Newland was one of the world's leading experts in vibration engineering and its application to mechanical design. He graduated from Cambridge in 1957, having read the Mechanical Sciences Tripos and winning the Rex Moir and Ricardo prizes. He worked at English Electric Company for four years, prior to studying for a PhD in the USA at MIT under DenHartog and Crandall. On return to the UK, he was briefly at Imperial College before being appointed Professor of Engineering at the University of Sheffield at the age of 31. He returned to Cambridge in 1976, as Professor of Mechanical Engineering and Head of the Mechanics, Materials and Design Division.

Professor Newland was Head of Department from 1996-2003. He was instrumental in establishing the Manufacturing Engineering Tripos, setting up the Engineering Design Centre and planning the transition to the four-year undergraduate engineering course. He died in 2020.

Professor David Cebon said: "These three prizes will recognise the top third-year students in the areas of Mechanics, Materials and Design. Students can demonstrate excellence in design in any engineering discipline: mechanical, electrical, civil, software, etc. This accords with David Newland's view of design as a multi-disciplinary, integrating aspect of the Engineering Tripos. These awards will keep his memory alive in the Department."

> Professor David Newland was a brilliant engineer. He was also a very dedicated teacher and made a huge contribution to the Department over a period of nearly 30 years.
>
> Professor David Cebon

Marie Skłodowska-Curie Individual Fellowship

Dr Gabriel Carmona Aparicio has been awarded a prestigious 24-month Marie Skłodowska-Curie Individual European Fellowship to quantify the circularity of an international steel company's products, from extraction to service, using the Stock-Flow-Service (SFS) Nexus.

Steel is the world's most recycled metal, yet only one-third of the global demand is met through scrap, thus highlighting the gap between the present reality and the ideals embedded in the circular economy. The latter is designed to increase material recoverability and product optimisation throughout the entire life cycle, resulting in less carbon emissions, waste and non-renewable resource dependency.

Within the steel industry, leading companies and professional bodies have sought to promote and embody the circular economy to advance sector sustainability. One way to achieve this aim is via a more holistic approach to resource management. This requires the development of alternative conceptual frameworks such as the SFS nexus.

The SFS nexus explicitly highlights the interactions, including trade-offs, between energy and material flows (e.g. coal, iron ore), material stocks (e.g. buildings, vehicles) and service provision (e.g. shelter, mobility). Dr Carmona aims to comprehensively evaluate the extent to which the SFS nexus can support the steel sector's positioning in the circular economy, determine the feasibility of achieving circularity for a specific Tata Steel product line and model future steel availability and demand under various circular economy scenarios.

Dr Carmona works within the Resource Efficiency Collective under the supervision of Dr Jonathan Cullen.

> Leading companies and professional bodies have sought to promote and embody the circular economy to advance sector sustainability.
>
> Dr Gabriel Carmona Aparicio

refficiency.org

Foundation industries green recovery research consortium

Resource Efficiency Collective's Dr Jonathan Cullen is joining Cranfield University and other collaborators in a research consortium examining how the foundation industries can grow and develop while helping achieve the net zero 2050 environmental targets.

TransFIRe (Transforming Foundation Industries Research and Innovation hub) was developed in response to the Industrial Strategy Challenge Fund (ISCF) call to transform the foundation industries (Chemicals, Cement, Ceramics, Glass, Metals and Paper). These industries produce 75% of all materials in the UK economy and are vital for the UK's manufacturing and construction industries.

Together, the foundation industries are worth £52 billion to the UK economy and produce 28 million tonnes of materials per year, accounting for about 10% of the UK total CO2 emissions.

The UK Government wants to make these industries more internationally competitive to secure jobs for these industries and help them grow. UK Research and Innovation (UKRI) through the ISCF has allocated £4.7 million for three years to work with universities, research organisations and industry to assist with technology development and transfer, new business developments and new opportunities in materials and technologies to help to achieve the net zero 2050 target.

TransFIRe is a consortium of 20 researchers from 12 institutions, 49 companies and 14 non-governmental organisations related to the sectors, with expertise across the foundation industries as well as energy mapping, life cycle and sustainability, industrial symbiosis, computer science, AI and digital manufacturing, management and business, social sciences and technology transfer.

TransFIRe is led by Professor Mark Jolly, Director of Manufacturing at Cranfield University, with Dr Jonathan Cullen as co-investigator, and others from Bangor, Cardiff, Durham, Edinburgh, Exeter, Leeds, Northumbria, Sheffield Hallam and York universities, as well as the British Geological Survey.

This programme will develop a self-sustaining hub of expertise to support the foundation industries' transformation into non-polluting, resource efficient, modern competitive manufactories, working in harmony with the communities where they are situated, providing attractive places to be employed with unparalleled Equality, Diversity and Inclusion (ED&I) performance.

refficiency.org

Software that can save up to 40% of embodied carbon on new build construction

The University of Cambridge has collaborated with UK structural engineering consultants, Price & Myers to develop PANDA (Parametric And Numeric Design Assessment) software that can save up to 40% of embodied carbon on new build construction.

Funded by the British government through Innovate UK, PANDA software can assess the embodied carbon in thousands of design options at concept stage, allowing clients and their project teams to make informed decisions on construction and materials. “We’ve been working with the University of Cambridge on the software for over five years,” Ian Flewitt, Partner at Price & Myers, points out. “It’s a serious bit of kit.”

Flewitt outlined the scale of the challenge and the importance of tackling embodied carbon in construction. “Around 40% of the UK’s total carbon emissions come from the built environment,” he explains. “As an industry, we’ve made great strides in reducing operational carbon production in buildings, which is produced by things like the lighting, heating and cooling, and technology.”

“Up to 50% of any new build’s emissions are embodied carbon – the carbon that’s emitted in the creation of the building’s fabric. That percentage will only rise as operational carbon emissions come down,” Flewitt warns. The development of PANDA is a response to this challenge.

With the government’s carbon target of net zero by 2050 on the horizon, it is imperative that inroads are made to reduce embodied carbon *before* it makes it into buildings. PANDA is a leap forward in that ambition.

Senior Research Associate in Material Efficiency in Construction in the UKFIRES research programme, Dr Cyrille Dunant, says that getting in early is the key. “Very early stage decisions are responsible for much – nearly all – of the ‘useless’ embodied carbon,” he says. “Useless in the sense that another design, providing the same value, was available for less carbon and/or less cost.”

Dr Dunant notes the difficulty in making informed decisions about embodied carbon before the development of PANDA. “In the past, these decisions have been frequently made blind. The impact was difficult to calculate, and therefore the trade-offs difficult to assess. PANDA works very quickly, so it can be used to explore options at the right moment.”

Design parameters can be changed in real time, allowing the design team to watch and were immediately see the impact of individual changes on the structure’s embodied carbon. When grid spacing is changed, loads on the building’s structure are altered, different materials are chosen, or the floor depths are manipulated, the impact on embodied carbon is immediately seen.

The benefits of PANDA are substantial – and not just for the environment. It also has the potential for savings in material costs too, because it identifies where any given design sits in relation to both optimum cost and carbon saving. And crucially, this is all done *before* the initial building scheme is finalised. Construction consultant Gardiner & Theobald has created a fully costed material model for PANDA.

Dr Dunant and his team made a study on 30 structures from Price & Myers and others, at all stages from early design to as built, showing that choosing the optimal decking solution could have saved an average of 25% of the carbon and 15% of the costs. “This doesn’t mean the structures were poorly designed; quite the contrary,” Dr Dunant notes. “They are close to the optimum, but it was impossible before PANDA to explore the full range of possibilities.”

PANDA even has a fully functional soil model, so it can include a realistic foundation design as part of the decision-making process for any particular project. By establishing its use early in the design process, project teams can progress knowing that their structures are already designed for maximum embodied carbon efficiency.

PANDA is an unparalleled industry tool with the ability to save huge amounts of embodied carbon in construction. Price & Myers is offering PANDA as a complimentary value-add to their existing engineering services. They can also be contacted to provide PANDA consultancy where another structural engineer has already been commissioned.

ukfires.org/panda-software/

→ Abigail Berhane, left, and Sofia Medina Cassillas in the Whittle Laboratory

Whittle Lab PhD students announced as 2021 Amelia Earhart Fellows

PhD students Abigail Berhane and Sofia Medina Cassillas from the Department’s world-famous Whittle Laboratory have been awarded 2021 Amelia Earhart Fellowships.

The Fellowship, established in 1938 in honour of famed pilot and Zontian Amelia Earhart will enable Abigail and Sofia to invest in state-of-the-art equipment needed to conduct their PhD research.

Abigail’s research focus is on the impact of surface topography (roughness) on the aerodynamic performance of turbine blades – a contributing factor to the amount of specific fuel consumed by a gas-turbine aeroengine to generate thrust. Sofia’s focus is on the aerodynamic flow field of the fan stage in a turbofan engine experiencing ‘windmill’ condition – the point at which power to the engine is cut off during flight because of failure of or damage to the rotor blades, for example.

This highly sought-after $10,000 Fellowship, awarded by Zonta International, will also see both women present their research at international conferences and participate in specialised studies.

Abigail Berhane

Abigail is working in collaboration with Rolls-Royce on research that will have an impact on all stages of a gas-turbine engine, from design and development through to life-cycle management.

“An improved understanding of the aerodynamic loss processes that contribute to the inefficiency of turbomachines is an important step in reducing the specific fuel consumption of gas-turbine aeroengines,” she said. “Approximately one-third of the loss generated within an aeroengine turbine is associated with the aerodynamic friction or skin friction between the air flow and turbine blade surfaces. The skin friction is strongly dependent on the topography of the blade surface.”

Abigail will study the impact of roughness on skin friction via a series of fundamental experimental investigations in a wind tunnel. The wind tunnel reproduces engine representative boundary layers in conjunction with computational simulations. Her research will use recent advances in additive layer manufacturing to rapidly recreate the complex surface topographies of aeroengine turbine blades for testing, alongside advances in computational simulations and data processing.

“A better understanding of how surface topography affects the development of the blade surface boundary layer is not only necessary for current designs, but crucial for the successful implementation of novel materials and manufacturing processes,” she added.

Sofia Medina Cassillas

Sofia is also working in collaboration with Rolls-Royce on research that will lead to the development of a low-order model tool that will quickly assess the fan rotational speed and drag at the windmill condition for different turbofan designs. Applied in industry, it will pave the way for less conservative designs with improved efficiency.

“Windmill condition is characterised by large flow separation and high drag. Identifying the complex aerodynamic flow field at windmill is particularly important in the case of future turbofan designs that have increasingly low fan pressure ratios, high bypass ratios and large fan diameters to reduce greenhouse gas emissions,” she said. “I will use a combination of experimental measurements in an engine-representative rig and computational fluid dynamics to characterise the windmill flow field. My investigations will include steady and unsteady flow effects, as well as the design of damaged fan blades in order to assess the differences in the aerodynamics for a set of representative damage cases.”

A spokesperson for Zonta International said: “We are excited to welcome them into our community of Amelia Earhart Fellows and look forward to following their contributions to the fields of aerospace and engineering and space sciences.”

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Zonta International

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New Granta Design Lectureship in Engineering

Burigede Liu has been appointed to the new Granta Design Lectureship in Engineering.

Burigede joins the Department from Caltech Department of Mechanical and Civil Engineering. He is interviewed below:

What is the best career decision you have made?

Joining Caltech as a Postdoctoral Associate. It has been an eye-opening experience, as I had the opportunity to collaborate with world-leading experts in mechanics, applied mathematics and machine learning.

When did it become clear to you that you wanted to pursue a career in research?

During my PhD study at Cambridge. Cambridge provided an encouraging and supportive academic environment, which allowed me to pursue any directions that were of interest to me. I truly enjoyed working as a scholar and solving challenging engineering problems that have important real-life applications.

How did you get interested in the field of mechanics of materials?

I developed an excitement for mechanics when I was learning the Ashby plot as an undergraduate student, majoring in the field. I was fascinated by the fact that a combination of rigorous mathematical analysis and deep physical insights can result in simple, yet powerful, mechanical principles that govern complicated material behaviours. I love the fact that research in mechanics of materials has substantially changed the world and is continuously driving the development of novel materials/structures that meet the grand challenges in our society.

What are the potential applications?

Development of cutting-edge material/structural systems (e.g. high entropy alloys, architecture materials and next-gen armours/engines) as well as quantifying the associated uncertainties in integral material response.

Field theory has provided a mathematically rigorous ground for predicting the complex behaviour of solid materials, but lack of precise knowledge on the relations between the conjugate fields (e.g. stress and strain), together with uncertainties originating from and propagating through different length scales, can lead to poor/unsafe designs. Data-driven methods provide a new avenue to address these challenges. Nowadays, rich data is available from advanced experimental measurements and multi-scale computations. By identifying and formulating the appropriate data-driven frameworks and algorithms for the mechanical problem, we can significantly reduce the cost of the development and increase the fidelity of our design.

What motivates your work more – the experiments or the applications?

The motivation of my work is always applications. As my mentor Professor Michael Ortiz once said, "Solid mechanicians act as a bridge between fundamental science and industry". As an engineer, my motivation is the end application. We always start with a clear goal on the application and use advanced tools originated from applied mathematics, machine learning and computational mechanics to solve these problems.

How has working in this field affected your career decisions?

Data-driven methods in mechanics of materials is a new and rapidly developing field. It forces us to rethink/re-evaluate our approach to mechanical problems from a different perspective. For example, a traditionally-considered 'bad experiment' that generates an inhomogeneous displacement field, might become favourable in the data-driven world, as it generates rich data and provides more information on the material. Working in this field is challenging, as we have to think outside of the box and come up with novel/creative solutions to well-established problems that will last for decades. I therefore decided to pursue my career as an academic, because I see that working in this field is stimulating and intellectually rewarding.

Granta Design Limited was spun-out of the Department in 1994 to develop materials information software, based on the work of Professor Mike Ashby and Professor David Cebon. The company was acquired by Ansys Inc. in 2019.

Burigede Liu's lectureship is one of two posts endowed by Ashby and Cebon. The bequest is to enhance teaching and research as well as to recognise the contribution of the Department and the University to the formation and development of Granta Design.

Honours, awards and prizes

IET Postgraduate Prize

PhD student Stephanie Adeyemo has been announced a winner of the 2021 IET Postgraduate Prize that will allow her to explore new ideas through the course of her research.

Stephanie is a member of the Joyce Group, based in the Department's Division of Electrical Engineering. Her PhD research involves using terahertz spectroscopy – a contact-free and non-destructive optical characterisation technique – to study the electrical and optical properties of nanomaterials that will guide the development of new optoelectronic devices.

International recognition

Julian Allwood, Professor of Engineering and the Environment, has been awarded the highest international recognition for research related to metal forming – the 2021 JSTP International Prize for Research & Development in Precision Forging.

The award, presented by the Japan Society for Technology of Plasticity (JSTP), recognised Professor Allwood's work on innovative metal forming process inventions, on the science of metal deformation and related to the holistic analysis of energy and metal use. Also mentioned was his work through outreach to schoolchildren, 10 years as joint editor-in-chief of the *Journal of Material Processing Technology*, and his chairmanship of metal forming activities at the International Academy of Production Engineering.

Women in Engineering Awards

Dr Kristen MacAskill, Lecturer in Engineering, Environment and Sustainable Development, has been named a winner of the 2021 *Top 50 Women in Engineering: Engineering Heroes Awards*.

Awarded by the Women's Engineering Society (WES), in recognition of women who have made a significant contribution to helping their organisation, community or indeed the world to function during the last year, Dr MacAskill was nominated for her "outstanding leadership, intellect, ingenuity and perseverance" demonstrated throughout her career. She became Director of the Construction Engineering Master's course for senior professionals at Cambridge following completion of her PhD in 2016, a position she held until 2020.

Alumnus wins international prize

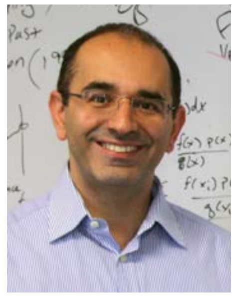
Cam Millar, who graduated in 2020, has won the 2020 Hangai Prize of the International Association of Shell and Spatial Structures for a paper about structural stability. It describes the results of Cam's fourth-year project, conducted under the supervision of Professor Allan McRobie and structural engineer Bill Baker.

Titled *A graphical method for determining truss stability*, the paper investigated new graphical methods for determining the stability of structures, such as tensegrities. The aim is to allow the designer to intuitively see why a structure is stable or unstable and adjust the design accordingly.

Biomedical Engineering Award

Shreya Singhal won the IMechE Vicon Best Biomedical Engineering Undergraduate Award 2019 for her project developing a platform for the study of cochlear implants (CIs).

Shreya completed the prize-winning project whilst studying for a Master's in Engineering, which she did in-between her medical studies. The objective was to develop an 'artificial cochlea' platform with which to test CIs. CIs are electronic devices used to provide a sense of sound to a person who is profoundly deaf by stimulating the auditory nerve. The platform – which anatomically and electrically mimics the human cochlea – and data obtained, provided novel insight into different stimulated modes delivered by CIs.



World-leading AI researcher

Zoubin Ghahramani, Professor of Information Engineering, has been awarded one of the first Turing AI World-Leading Researcher Fellowships to conduct groundbreaking work on artificial intelligence's (AI) biggest challenges.

Dr Ferenc Huszár, from the Department of Computer Science and Technology, will join Professor Ghahramani as co-investigator in the project titled *Advancing Modern Data-Driven Robust AI*. It has UK Research and Innovation (UKRI) support of £2.6 million and a total project partner contribution of £1.45 million. The team aim to develop the new algorithms and applications needed to address limitations faced by the AI systems that underpin many technologies, such as speech recognition and autonomous vehicles.

Credit: MX3D / Adriaande Groot

During the opening of the bridge by Her Majesty Queen Máxima of the Netherlands

World's first 3D printed steel bridge monitored by sensors and 'digital twin' tech

The world's first 3D printed steel bridge has been installed and unveiled in Amsterdam – with the potential to revolutionise how urban infrastructure is designed, built and maintained. Project lead Professor Mark Girolami led the structural integrity testing as well as the design and installation of the bridge's sensor network. The team from the Department of Engineering and The Alan Turing Institute are currently working on developing and deploying a 'digital twin' of the bridge.

The futuristic multi award-winning bridge, designed by Joris Laarman Lab with Arup as lead engineer, has been placed over one of the oldest canals in Amsterdam's city centre, the Oudezijds Achterburgwal canal. The bridge was officially opened on 15 July by Her Majesty Queen Máxima of the Netherlands.

Printed by Dutch technology MX3D using robotic arms, the 12 metre-long bridge is equipped with an innovative sensor network, linked to a mathematical computer model forming a 'digital twin' of the physical bridge and its digital representation. The 'digital twin' monitors the bridge performance in real-time. The 'smart' bridge, in effect, serves as a living laboratory, with pedestrians, cyclists and runners generating data every time they cross it. This data will help to monitor the bridge's structure and provide information about how it is being used.

More than 100 sensors attached to the bridge will monitor strain, movement, vibrations and weather conditions as people cross it. The data collected will be sent to a 'digital twin' of the bridge, which will help engineers assess how the bridge is faring, alerting them if problems occur and when maintenance might be required. The data will also provide input and lessons learned for future builds, helping designers understand how 3D printed steel could be used in more complex projects. Statistical methodology will be utilised to understand more about the material itself and machine learning will be used to spot trends in the data pointing to potential changes, issues of maintenance or necessary modifications.

The sensor network was designed and installed by a team from the Turing Data-Centric Engineering (DCE) programme that comprised structural engineers, mathematicians, computer scientists and statisticians, including researchers from the Cambridge Centre for Smart Infrastructure and Construction (CSIC).

Dr Mohammed Elshafie, CSIC Co-Investigator, has been collaborating with the DCE and MX3D to measure, monitor and analyse the performance of the bridge. The overall project was led by Professor Girolami, Sir Kirby Laing Professor of Civil Engineering, Royal Academy of Engineering Research Chair at the University of Cambridge, Academic Lead for CSIC and Programme Director for Data-Centric Engineering at The Alan Turing Institute.

"3D printing is poised to become a major technology in engineering, and we need to develop appropriate approaches for testing and monitoring to realise its full potential," said Professor Girolami. "When we couple 3D printing with 'digital twin' technology, we can then accelerate the infrastructure design process, ensuring that we design optimal and efficient structures with respect to environmental impact, architectural freedom and manufacturing costs."

3D printed steel is a new material, which may have the power to radically change conventional construction and overhaul the building industry. Load testing and materials testing conducted by the Turing DCE team proved that the bridge is able to hold at least a 19.5 ton load, well above its ultimate design load.

smartbridgeamsterdam.com

UNIVERSITY OF CAMBRIDGE

Department of Engineering
University of Cambridge
Trumpington Street
Cambridge CB2 1PZ

Telephone: +44 (0)1223 748228
Email: marketing@eng.cam.ac.uk
www.eng.cam.ac.uk