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DEPARTMENT OF ENGINEERING

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Cover image: Undergraduate Iga Ratajczak, the first female president of student society Cambridge University Spaceflight. Credit: University of Cambridge.

Note from the editors

Student aspirations and achievements feature loud and proud in this edition.

The Department's Helios Prize has been won by PhD student Parth Deshpande for a research paper he co-authored titled *A breakeven cost analysis framework for electric road systems*. (page 6)

Cambridge University Spaceflight society are planning to send a rocket into space next year. They are preparing to launch their 10-metre-tall Griffin I rocket more than 150km into the sky and past the Karman line, the 100km boundary between Earth's atmosphere and outer space. (page 8)

Cambridge University Robotics society have scooped a national award for their work in inclusion and diversity. (page 9)

Undergraduate Amanda Kangai recently became the first female recruit to be signed by an off-road electric racing team under the Racing for All initiative – providing a first step on the career ladder in motorsport. (page 11)

Meanwhile, PhD students Nirmani Rathnayake and Ali Niazi (Institute for Manufacturing), and Master's student Igor Sterner, were among 18 students and early-career professionals of all disciplines, who took to the stage at the Falling Walls Lab Cambridge. They were challenged to pitch their innovative ideas to an audience, including a panel of judges, in just three minutes – no easy task! (page 14)

We congratulate them all on their achievements and future endeavours.

Charlotte Hester and Jacqueline Saggers
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Head's welcome

Welcome to this latest edition of the Department of Engineering News for spring 2024. There continue to be many exciting developments in the Department.

For a start, I am delighted to be able to tell you that we have appointed a new Regius Chair in Engineering. This is a highly prestigious post, last held by the late Professor David MacKay. Professor Steven Barrett will be taking on this mantle from June 2024. Steven joins us from MIT, and has been carrying out transformative research on contrail formation and avoidance. This is one of the many approaches needed to tackle the climate crisis, and Steven's work has already led to changes in legislation around air transport.

Looking through this edition of the newsletter, you will see a series of stories on a variety of technical topics, but with clear underpinnings of working towards net zero in a multitude of sectors. For a start, on **page 4**, we are part of a new IKC REWIRE in semiconductor technologies, looking at the use of wide/ultrawide bandgap compound semiconductors, which are particularly suited for high-voltage applications – becoming ever more important with electrification of transport, as well as many other areas including high efficiency lighting and high-speed transistors.

Next you will see the story **on page 5** about work being carried out as part of an international programme of research looking into improving the efficiency of hydrogen generation. This is an area offering much promise but is currently hampered by the fact that although hydrogen has a high energy density, this is often outweighed by the costs and energy required to produce it at scale. New approaches that aim to also reduce the carbon footprint of its production are being looked into.

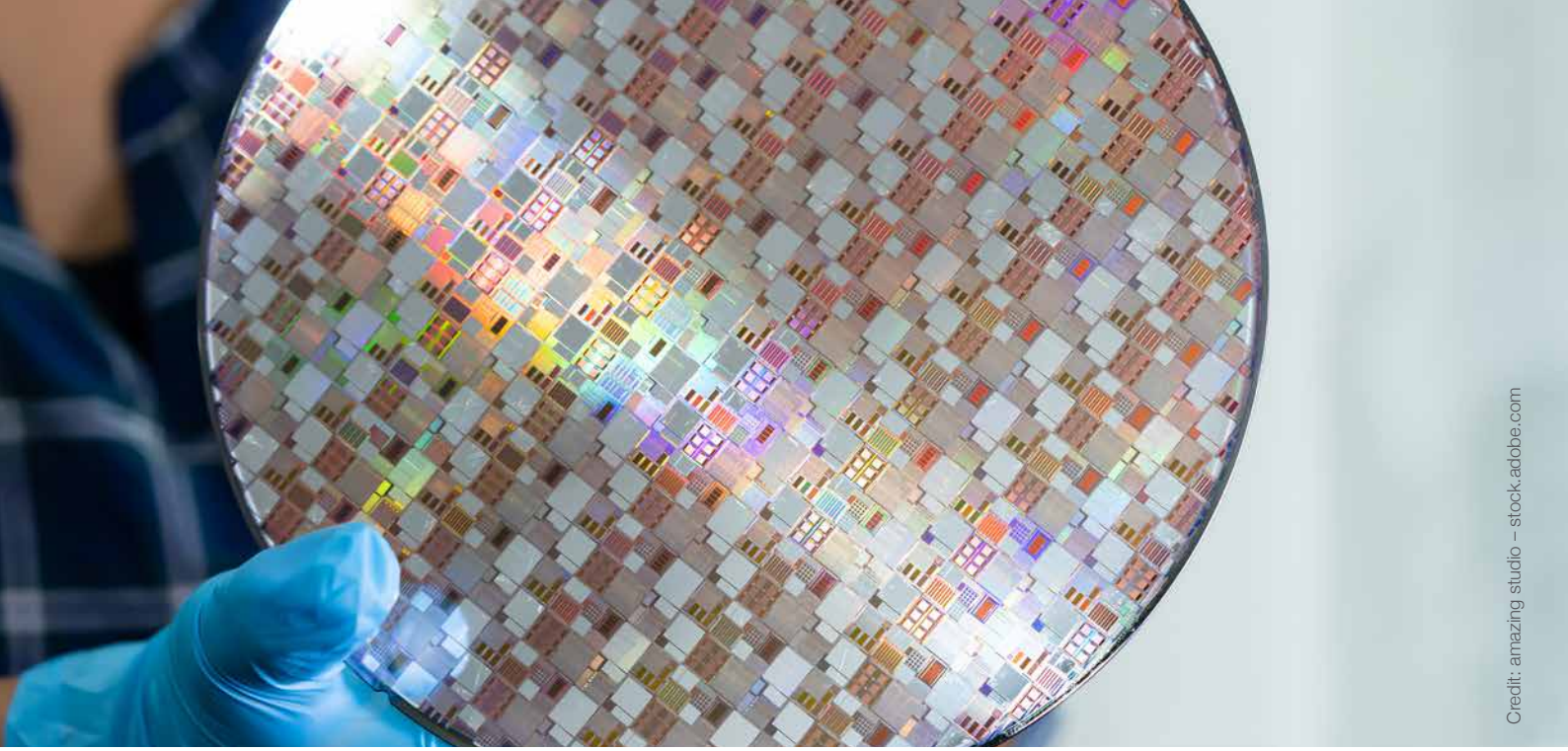
On **page 7** is some work carried out by Catherine Richards and others looking into the need to improve the monitoring and forecasting of weather events across Africa, as several African nations are particularly exposed to the effects of climate change, and some simple improvements could save many lives.

In the centre spread are two stories around COP28, including a piece on our journey towards net zero flight, and a satellite-based early warning system for monitoring tailings storage facilities, where waste from mining operations is stored – often in unmonitored sites.

Throughout the rest of this edition, you will find a mix of stories about some of our alumni, David Knight (**page 15**) and Nick Bailey (**page 19**). You will also see the next phase in the partnership between the University and Google at the Centre for Human-Inspired AI (**page 18**).

As mentioned in the last Newsletter, the academic year 2024/5 will mark the 150th anniversary of the Department of Engineering. There will be a series of events, starting with a talk in November by Alex Kendall, alumnus and CEO of Wayve, a company developing the next generation of embedded AI for automated driving. Keep an eye out for announcements.

Professor Colm Durkan FIET, FInstP



Credit: amazing studio – stock.adobe.com

↑ Silicon wafer for manufacturing semiconductor of integrated circuit

£11m semiconductor research centre could be key player in UK's net zero mission

The University of Cambridge is a partner in the new £11 million Innovation and Knowledge Centre (IKC) REWIRE, set to deliver pioneering semiconductor technologies and new electronic devices.

Semiconductors, also known as microchips, are a key component in nearly every electrical device from mobile phones and medical equipment to electric vehicles. They are increasingly being recognised as an area of global strategic significance due to the integral role they play in net zero, AI and quantum technology.

Co-created and delivered with industry, the IKC REWIRE is led by the University of Bristol in partnership with Cambridge and Warwick Universities. The IKC will accelerate the UK's ambition for net zero by transforming the next generation of high-voltage electronic devices using wide/ultra-wide bandgap (WBG/UWBG) compound semiconductors.

The project is being led by Professor Martin Kuball and his team at the University of Bristol. Cambridge members of the IKC team include Professor Rachel Oliver (Department of Materials Science and Metallurgy) and Professors Florin Udrea and Teng Long (Department of Engineering).

The Centre will advance the next generation of semiconductor power device technologies and enhance the security of the UK's semiconductor supply chain.

Compound semiconductor WBG/UWBG devices have been recognised in the UK National Semiconductor Strategy as key elements to support the net zero economy through the development of high voltage and low energy-loss power electronic technology.

"Power devices are at the centre of all power electronic systems and pave the way for more efficient and compact power electronic systems, reducing energy loss," said Professor Kuball. "The IKC REWIRE will focus on power conversion of wind energy, electric vehicles, smart grids, high-temperature applications, device and packaging, and improving the efficiency of semiconductor device manufacture."

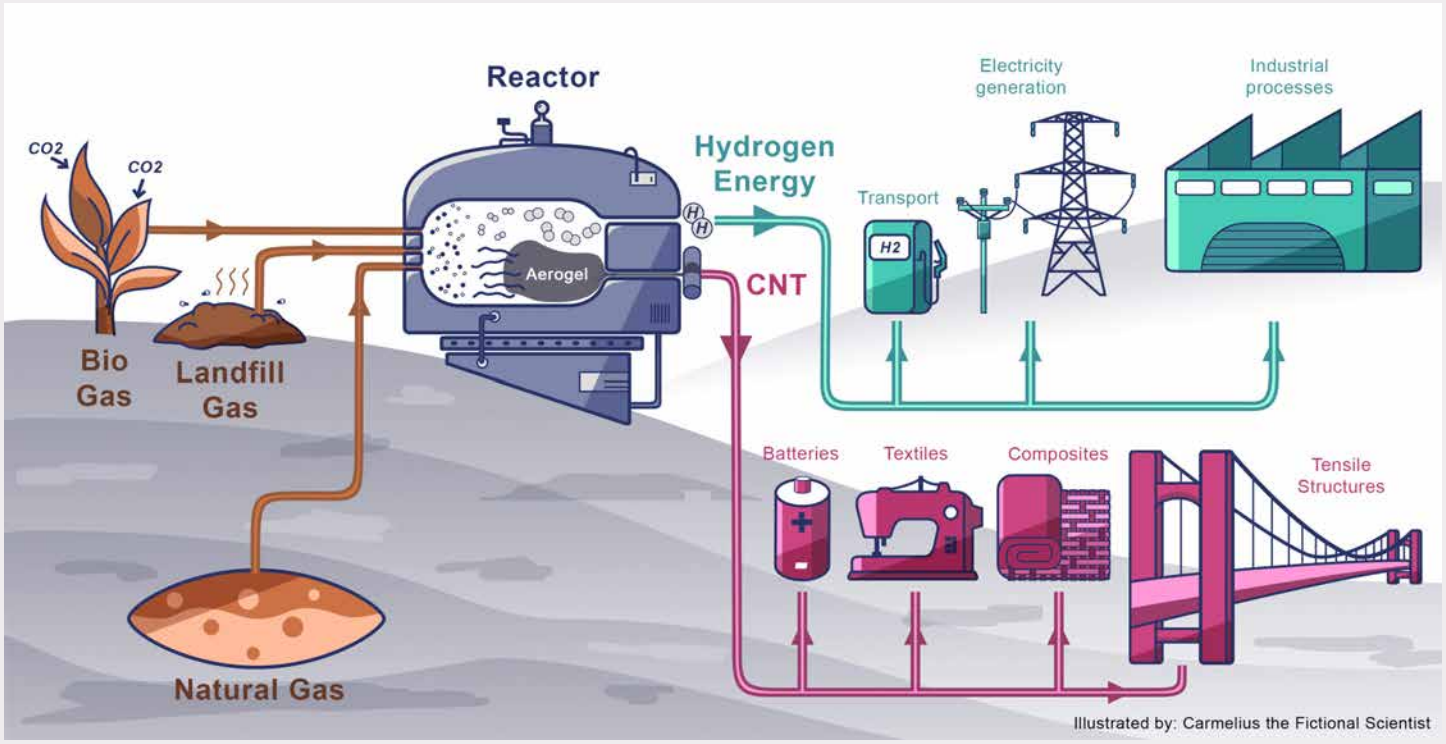
"Newly emerging ultra-wide bandgap materials have properties which enable them to handle very large voltages more easily," said Professor Oliver. "The devices based on these materials will waste less energy and be smaller, lighter and cheaper. The same materials can also withstand high temperatures and doses of radiation, which means they can be used to enable other new electricity generation technologies, such as fusion energy."

"I will be contributing my expertise in advanced power electronics packaging and power converter design," said Professor Long. "Power electronics is essential for green and sustainable energy; from renewable energy generation to electric vehicles, every watt of electrical power needs to be processed by power electronics-based power converters one to several times. High efficiency, high power density, high reliability, and low-cost power converters will fundamentally improve the green and sustainable energy industry."

"Wide bandgap semiconductors such as gallium nitride (GaN) and silicon carbide (SiC) offer a game-changing alternative to silicon in power electronics," said Professor Udrea. "The amazing physical properties of these materials translate into huge energy savings, and at the same time support a huge reduction in CO_2 emissions. The High Voltage Microelectronics and Sensors Group at Cambridge has been very active in promoting these technologies for more than three decades."

Speaking at the time of the announcement in February 2024, Saqib Bhatti, Minister for Tech and the Digital Economy, said: "Just nine months into delivering on the National Semiconductor Strategy, we are already making rapid progress towards our goals. This is not just about fostering growth and creating high-skilled jobs; it is about positioning the UK as a hub of global innovation, setting the stage for breakthroughs that have worldwide impact."

Read the full article at:
www.eng.cam.ac.uk/semiconductor



Credit: Jack Peden and Carmelius Cohen "the Fictional Scientist"

Cambridge joins new global initiative to transform net zero hydrogen production

↑ Illustration showing value-added carbons and turquoise hydrogen production to sequester carbon from natural and derived methane

Cambridge engineer Professor Adam Boies has been announced as a co-investigator of a new international partnership set up to make low-cost, large-scale, net zero hydrogen production a reality.

The Global Hydrogen Production Technologies Center (HyPT) is a £14.1 million five-year project led by Cranfield University, Arizona State University, the University of Adelaide and the University of Toronto. The University of Cambridge is a founding member in the UK, alongside Imperial College London, Newcastle University and the University of Birmingham.

The HyPT seeks to accelerate net zero hydrogen technologies to make them available at low cost – approximately one dollar per kg of hydrogen. Net zero hydrogen enables decarbonisation of many energy-intensive and hard-to-abate industries such as ammonia, steel, cement, aluminium, transportation and energy storage.

Professor Boies' contribution will be in turquoise hydrogen production. Turquoise hydrogen is made using a process called methane pyrolysis, which results in carbon instead of the CO_2 produced by blue hydrogen.

"Here at Cambridge, we are excited to contribute our efforts to jointly making functional carbons alongside hydrogen," Professor Boies said. "Our goal is to make carbon materials more valuable than heat and CO_2, thus providing the incentive for low CO_2 materials as well as turquoise hydrogen to replace grey hydrogen for the hard-to-decarbonise sectors."

He added: "This project provides a unique opportunity to collaborate with the top researchers internationally, developing and scaling these technologies for global impact in the energy and materials transition."

Large-scale hydrogen production with net zero emissions of greenhouse gases is essential to meet the Paris Agreement's climate targets and limit global warming to 2°C. However, net zero hydrogen is currently several times more expensive than hydrogen produced from fossil fuels, which hinders its widespread adoption.

HyPT seeks to develop three major net zero hydrogen production technologies:

1. Water electrolysis, where electricity is used to split water into oxygen and hydrogen

2. Methane pyrolysis, where a natural gas is heated to a high temperature and then splits into hydrogen and solid carbon

3. Photocatalytic solar water splitting, where sunlight is used help water break apart into oxygen and hydrogen.

HyPT will develop breakthroughs in these technologies, while assessing their impacts on local communities and ecosystems, so that the net zero hydrogen economy can develop in an ethical manner.

> Our goal is to make carbon materials more valuable than heat and CO_2, thus providing the incentive for low CO_2 materials as well as turquoise hydrogen to replace grey hydrogen for the hard-to-decarbonise sectors.
>
> Professor Adam Boies

hyptcenter.asu.edu

→ Parth Deshpande, right, accepts his award of prize money and a brass medal depicting the face of the sun god Helios from the Head of the Department of Engineering, Professor Colm Durkan

Credit: Charlotte Hester

Parth Deshpande
2023 Helios Prize winner

Parth Deshpande, a PhD student in the Centre for Sustainable Road Freight, has been announced the winner of the Department's 2023 Helios Prize – awarded for research on sustainable energy and/or energy efficiency.

The Helios Prize was launched in 2019 and is made possible thanks to a generous donation from Cambridge alumnus John Firth. John approached the Department specifically and asked that the prize be named after the Greek sun god Helios, because the world's renewable energy is fundamentally driven by solar energy.

Parth's winning co-authored research paper is titled *A breakeven cost analysis framework for electric road systems* and is published in the journal *Transportation Research Part D: Transport and Environment*.

With road freight emissions forming a significant part of a country's total emissions, one of the key steps for achieving net zero is to decarbonise road freight. In this paper, Parth and his co-authors investigate the feasibility and impact of electrifying HGVs using electric road systems (ERS), thus reducing the need for large (and heavy) batteries.

A cost breakeven analysis was formulated to identify the locations where an ERS is economically viable. The road networks in England, France, India and South Africa were analysed in terms of their financial breakeven period, for which the ERS would be economically self-supporting. The differences in these countries were observed in terms of their road freight distribution and price sensitivity.

This analysis revealed that up to 47% of the total road freight in England, 72% in France, 38% in India and 57% in South Africa could be electrified using ERS with a 15-year breakeven period.

It was established that the use of ERS reduces "windmill-to-wheel" emissions by approximately 10% compared to battery electric vehicles, and by varying amounts compared with diesel vehicles, depending on the grid carbon factor.

"I am glad that our research on electric road freight has been awarded the Helios Prize and I am thankful to my co-authors on this paper – Professor David Cebon, Dr Christopher de Saxe, Dr Daniel Ainalis and Professor John Miles – for their support and ideas," said Parth. "Electric road freight is a complex problem to solve, with a lot more still to be done, and winning this prize gives us even more motivation to continue working on it."

> "Electric road freight is a complex problem to solve, with a lot more still to be done, and winning the Helios Prize gives us even more motivation to continue working on it.
>
> Parth Deshpande

Philanthropy

The Department is actively supported as a result of many very generous philanthropic donations. This is at many levels, including support for PhD studentships, postdoctoral fellowships and faculty posts, as well as for some of our research activities. Coming into our 150th year, and with the introduction of our new Part I, in 2026, as well as the continued ambition for a complete move to Cambridge West to reintegrate the Department, there will be many opportunities for philanthropy to help support this, and to make a lasting difference.

www.philanthropy.cam.ac.uk

→ Windmill in Karoo during sunset in Eastern and Western Cape, South Africa

Credit: Arnold – stock.adobe.com

Death tolls from climate disasters will 'balloon' without investment in Africa's weather stations

Investment in 'hydromet systems' using technologies from AI to SMS would provide a nine-to-one ROI in saved lives and assets across African nations.

The climate crisis is increasing the frequency and intensity of floods, droughts and heatwaves, with Africa expected to be among the global regions hit hardest. Yet the systems and technologies across the continent that monitor and forecast weather events and changes to water levels are "missing, outmoded or malfunctioning" – leaving African populations even more exposed to climate change.

This is according to a team of risk experts and climatologists from the UK and Africa led by the University of Cambridge, who warn that without major and rapid upgrades to "hydromet infrastructure", the damage and death toll caused by climate-related disasters across Africa will "balloon".

Writing in the journal *Nature*, the authors point to latest research showing that over the last two decades the average number of deaths caused by a flooding event in Africa is four times higher than the European and North American average per flood.

When investigating this disparity, the team looked at World Meteorological Organization (WMO) data and found the entire continent of Africa has just 6% of the number of radar stations as the US and Europe's combined total, despite having a comparable population size and a third more land.*

Radar stations detect weather fluctuations and rainfall as well as long-term climate trends, and are vital for the forewarning of impending floods and other meteorological events. The African continent has just 37 such stations.

Moreover, WMO data shows that more than 50% of the radar stations that do currently operate across Africa are unable to produce accurate enough data to predict weather patterns for the coming days or even hours.

The research team call on the international community to boost funding for systems that mitigate risks to life from climate disasters. Currently, just US $0.47 of every $100 spent on global development aid goes towards disaster risk reduction of any kind.

"The vast gaps in Africa's disaster reduction systems are in danger of rendering other aid investments redundant," said Dr Asaf Tzachor, co-lead author and research affiliate at Cambridge's Centre for the Study of Existential Risk (CSER). "For example, there is little point investing in smallholder farms if floods are simply going to wash away seeds, agrochemicals, and machinery."

He added: "We need to offer all Africans a chance to reduce their exposure to climate risks by fixing this glaring hydro-meteorological blind spot, before even more lives are lost to the effects of global heating."

To illustrate their point, the team compare two recent category 4 storms: Tropical Cyclone Idai hit southeast Africa in 2019, and Hurricane Ida swept the eastern US in 2021. Both had wind speeds of over 200km/hour. US populations received evacuation alerts before Ida hit land, but the limited hydromet capabilities meant Idai caught African nations by surprise. The US death toll was under a hundred, while over a thousand Africans lost their lives.

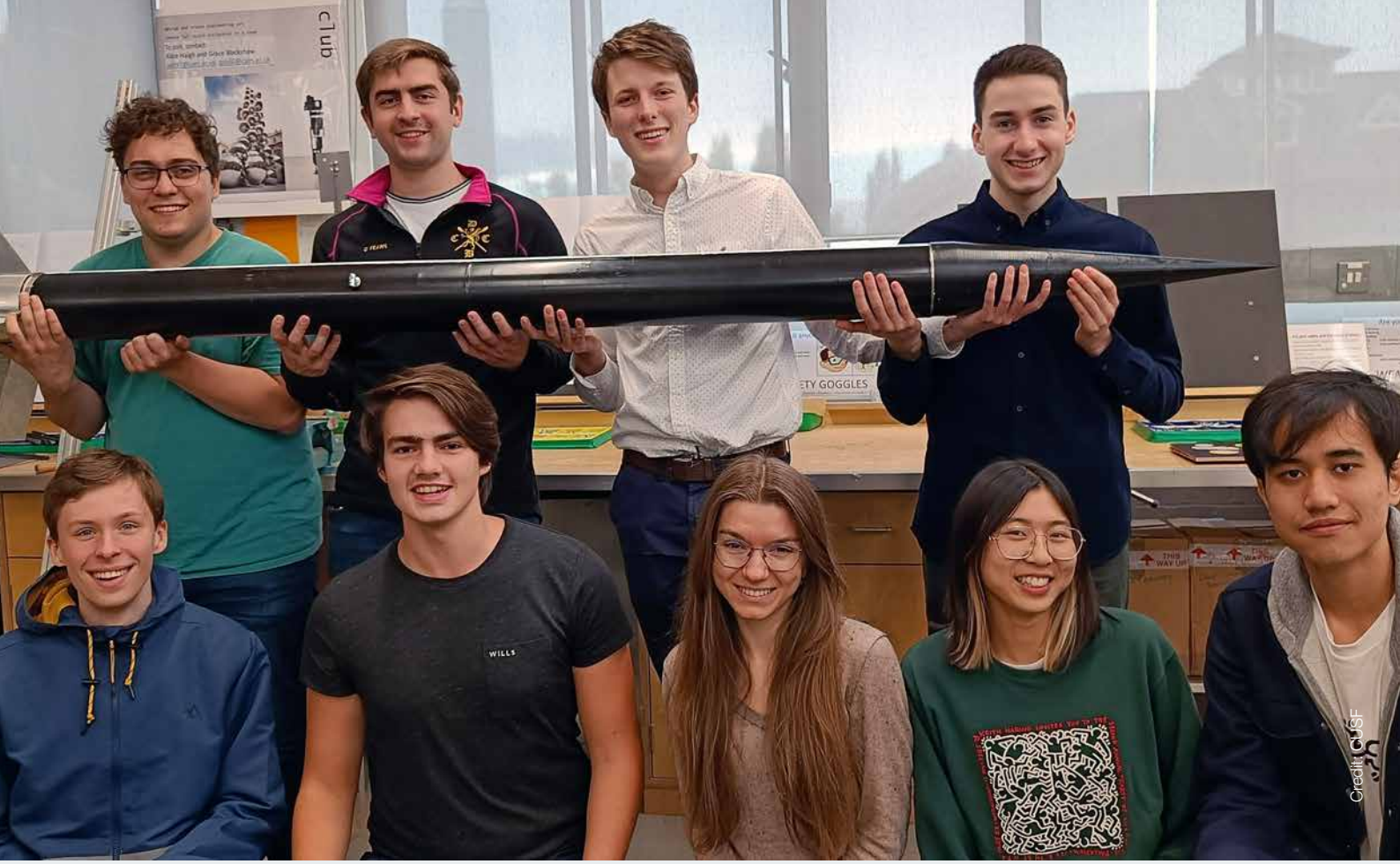
"Multilayered hydromet systems, including weather monitoring, forecasting and early warning, are taken for granted by the Global North, and have been for decades," said co-lead author Dr Catherine Richards, also from CSER, who completed her PhD at the Department of Engineering. "Meanwhile, the most foundational layer on which the others depend is often missing, outmoded or malfunctioning across Africa – more so than any other global region."

"Well-funded hydromet systems must become a priority to help at-risk populations mitigate and adapt to weather-related hazards as the effects of climate change take hold," she added.

Written by Fred Lewsey

* In Europe and the US, there are 636 radar stations for a total population of 1.1 billion and a landmass of 20 million km². In Africa, there are just 37 for a comparable population of 1.2 billion and landmass of 30 million km².

Open access paper:
www.eng.cam.ac.uk/africa-weather



Credit: CUSF

↑ Some of the Spaceflight team with the Aquila rocket, a sub-project of the Griffin I launch attempt

The Cambridge students aiming to send a rocket into space in 2025

Members of the Cambridge University Spaceflight society (CUSF) plan to launch their 10-metre-tall Griffin I rocket more than 150km into the sky and past the Karman line, the 100km boundary between Earth's atmosphere and outer space.

Abhijit Pandit, former co-president of CUSF, said outer space had always been the goal of the society – founded 18 years ago – but the pandemic had prompted a rethink of their ambitions and how quickly they wanted to achieve them.

"When COVID happened, we couldn't meet in person and we couldn't build anything. It was a challenge to progress our work. At the time, we were aiming to reach 20km, but we thought – if this small project is going to involve the same amount of effort as a way bigger project, why would we not do the way bigger project? Our goal 17 years ago was to get to the Karman line, so why don't we try going for that now?

"There's a push in the wider student-space industry to do these bigger projects, and it's not something that's really been done by students in the UK before."

The CUSF team – which in 2019 built the PULSAR engine, the largest nitrous oxide hybrid ever fired in the UK – have essentially taught themselves the specifics of rocket design and construction, and already have several launches under their belt. In 2017, their Martlet III rocket reached a height of 3.5km despite a malfunction in its engine – the only component of the construction not built by CUSF.

A number of Griffin I subprojects have also allowed the students to gain more practical experience in aerodynamics, avionics and recovery systems to take forward to the attempt in 2025. Current co-presidents Iga Ratajczak and William Yu are keen to push these projects further.

William leads the development of the next High-Powered Rockets. He shares his experience: "Last year, we successfully launched Aquila – the upper stage of Griffin – in California. Nothing compares to being in the desert and really feeling the impact of your rocket taking off. After our success, we're gearing up for more launches in July this year – if you want to learn more or support us, please do reach out."

Iga is the first female president of CUSF. She was part of the Aquila team and Technical Lead of the Engine Propulsion team.

"Leading the society at large and the propulsion team has been an incredibly challenging and fulfilling experience. I am lucky to be working alongside my talented team on White Giant, one of the largest liquid engines ever built by students anywhere in the world. It will blast Griffin I into space, packing a maximum thrust of 32 kilo-newtons for more than 40 seconds of firing at launch. The engine is going to

be hot fired by autumn this year, following provisional testing of White Dwarf, a scaled-down bi-propellant prototype."

Henry Free, White Giant team member, added: "We cover lots of things on our course, including aerospace, but there's no spacecraft design module. There's a lot of foundation knowledge that's relevant, but when it comes down to building this stuff, it's completely different. You can do hand calculations and work some of it out, but before long you're looking at research papers because you're suddenly dealing with the intersections of lots of different fields in a way that's not familiar at all."

Spaceflight website:
www.cusf.co.uk

Credit: University of Cambridge

Cambridge University Robotics crowned Engineering Society of the Year

Cambridge University Robotics (CUR) society has been named the Engineering Society of the Year 2023 in a national awards ceremony set up to celebrate the diversity of the engineering and technology profession.

CUR is a student-run society founded in 2015 by engineering students. With more than 60 active members, the society aims to make robotics accessible to all.

Kate Lucas, CUR Co-President External, attended the Engineering Talent Awards 2023, founded by EqualEngineers, to accept the award, given in honour of CUR's outreach activities.

These activities include Unibots UK, an inter-university competition for undergraduates that is hosted annually by CUR in the Department of Engineering, and Sparkbots, a day-long workshop teaching Year 9 to Year 11 pupils how to build robots using Arduino, an open-source electronics platform.

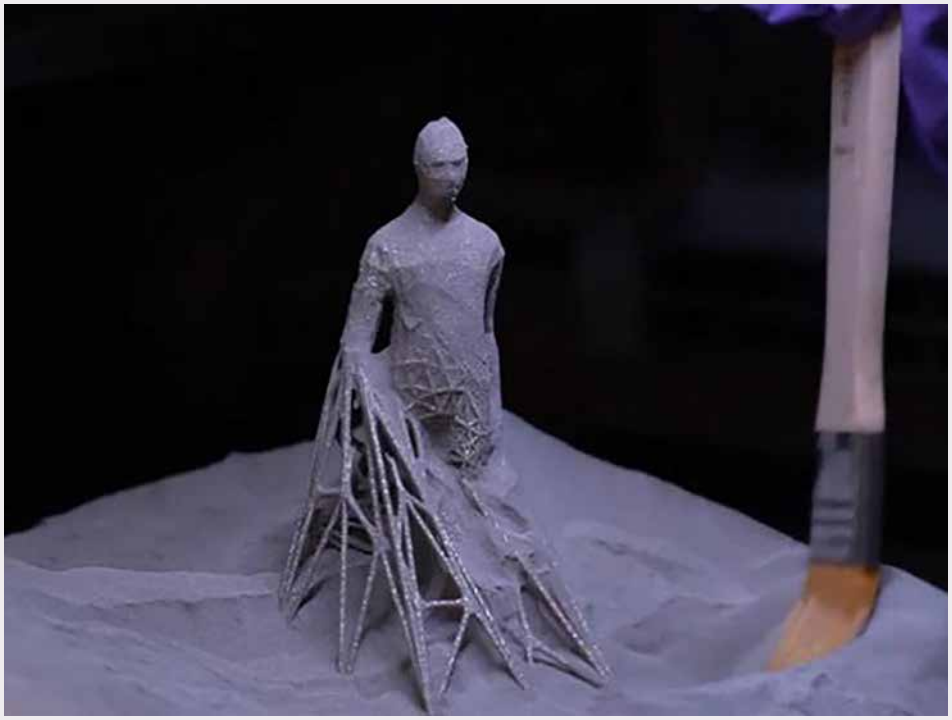
On announcing the award, the judges said: "CUR's collaboration with other universities, and outreach in local schools, demonstrates the impact of this group in sharing their love of robotics, and clearly is impacting and showcasing opportunities to future robotics enthusiasts, especially young girls."

Kate, a third-year Manufacturing Engineering Tripos (MET) student at the Institute for Manufacturing (IfM), part of the Department of Engineering, said it was exciting to attend the awards ceremony and for CUR to be recognised for its work in inclusion and diversity.

Kate added: "This award was achieved in part due to our outreach activities and the many events we have organised to inspire younger students. We have recently established a new education technology and outreach project to further develop our society's skills and knowledge in this area."

Credit: EqualEngineers

↑ Kate Lucas, CUR society Co-President External, accepts the Engineering Society of the Year 2023 award on behalf of CUR



Credit: Jude E. Fronda

→ Retrieval of a stainless steel part made by 3D printing

Using lasers to 'heat and beat' 3D-printed steel could help reduce costs

Researchers have developed a new method for 3D printing metal that could help reduce costs and make more efficient use of resources.

The method allows structural modifications to be 'programmed' into metal alloys during 3D printing, fine-tuning their properties without the 'heating and beating' process that has been in use for thousands of years.

The new 3D printing method combines the best qualities of both worlds: the complex shapes that 3D printing makes possible, and the ability to engineer the structure and properties of metals that traditional methods allow. The results are reported in the journal *Nature Communications*.

3D printing has several advantages over other manufacturing methods. For example, it's far easier to produce intricate shapes using 3D printing, and it uses far less material than traditional metal manufacturing methods, making it a more efficient process. However, it also has significant drawbacks.

"There's a lot of promise around 3D printing, but it's still not in wide use in industry, mostly because of high production costs," said Dr Matteo Seita, who led the research. "One of the main drivers of these costs is the amount of tweaking that materials need after production."

Since the Bronze Age, metal parts have been made through a process of heating and beating. The material is hardened with a hammer and softened by fire, which allows the maker to form the metal into the desired shape and at the same time impart physical properties such as flexibility or strength.

One of the major downsides of current 3D printing techniques is an inability to control the internal structure in the same way, which is why so much post-production alteration is required.

"We're trying to come up with ways to restore some of that structural engineering capability without the need for heating and beating, which would in turn help reduce costs," said Dr Seita. "If you can control the properties you want in metals, you can leverage the greener aspects of 3D printing."

Working with colleagues in Singapore, Switzerland, Finland and Australia, Dr Seita developed a new 'recipe' for 3D-printed metal that allows a high degree of control over the internal structure of the material as it is being melted by a laser.

By controlling the way that the material solidifies after melting, and the amount of heat that is generated during the process, the researchers can programme the properties of the end material. Normally, metals are designed to be strong and tough, so that they are safe to use in structural applications. 3D-printed metals are inherently strong, but also brittle.

The strategy the researchers developed gives full control over both strength and toughness, by triggering a controlled reconfiguration of the microstructure when the 3D-printed metal part is placed in a furnace at relatively low temperature. Their method uses conventional laser-based 3D printing technologies, but with a small tweak to the process.

"We found that the laser can be used as a 'microscopic hammer' to harden the metal during 3D printing," said Dr Seita. "However, melting the metal a second time with the same laser relaxes the metal's structure, allowing the structural reconfiguration to take place when the part is placed in the furnace."

Their 3D-printed steel, which was designed theoretically and validated experimentally, was made with alternating regions of strong and tough material, making its performance comparable to steel that's been made through heating and beating.

"We think this method could help reduce the costs of metal 3D printing, which could in turn improve the sustainability of the metal manufacturing industry," said Dr Seita. "In the near future, we also hope to be able to bypass the low-temperature treatment in the furnace, further reducing the number of steps required before using 3D-printed parts in engineering applications."

Written by Sarah Collins

Open access paper:
www.eng.cam.ac.uk/3Dprintingmetal

Watch the video:
youtu.be/SdDQXjBxkNg

How I got my first job in motorsport – meet student Amanda Kangai

Credit: Amanda Kangai

Undergraduate Amanda Kangai's goal is to become a strategy engineer for a Formula One team. Amanda recently became the first female recruit to be signed by an off-road electric racing team under the Racing for All initiative – providing a first step on the career ladder in motorsport.

The initiative, informed by the findings of The Hamilton Commission, was set up to create opportunities for a new generation of mechanical and engineering talent. The aim is to reduce barriers and offer opportunities to those who are female, minority ethnic, or from a lower socio-economic background.

Amanda, who is in the third year of her engineering degree, has joined Veloce Racing's British squad for Extreme E Season 3 – motorsport's first gender-equal and most radical off-road electric racing series, with an emphasis on sustainability.

As Veloce Racing's junior mechanical engineer, Amanda experienced the second X Prix of Season 3 earlier in 2023, the Hydro X Prix in Scotland – racing on the former Glenmuckloch opencast coal mine site in Dumfries and Galloway. This was Amanda's first race and she gained valuable experience shadowing the head engineer and learning what it takes to be part of a professional race team.

"I had a great time understanding how an Extreme E team works," said Amanda. "A typical day involves shadowing the head engineer, supporting drivers so that they can analyse their driving footage, and doing everything I can to help us be a couple of steps ahead of the other teams – whether that's analysing footage and determining the fastest and easiest track line to take, to supporting the head engineer live so that he can effectively communicate live to the drivers."

It is a role that Amanda says complements her undergraduate studies, allowing her to experience in real life some of the engineering theories that she has been learning.

"It has been so powerful seeing some of the engineering theory take place in front of my eyes," she said. "I am definitely implementing some of this learning in my junior mechanical engineering role, for example theory on springs and the importance of dampers, both of which have a very important role to play in race car vehicle dynamics and performance."

Amanda, whose future academic plans involve specialising in Aerospace and Aerothermal Engineering with electrical modules, has a message for women interested in motorsport:

"Believe in yourself and look for those opportunities that will bring you closer to your career goals," she said. "If you want to volunteer for your local racing team, look for work experience or internships, anything that helps you to decide if it is the correct career path for you."

She added: "Be as confident as you can when applying for jobs and reach out to other female engineering talent who may be able to help you."

> It has been so powerful seeing some of the engineering theory take place in front of my eyes.
>
> Student Amanda Kangai

Read the full article at:
www.eng.cam.ac.uk/amanda-kangai

Watch the video interview:
youtu.be/ZbpFsJ3JuAw

Raising ambition in net zero flight

A briefing from COP28

Written by Professor Rob Miller, Director, Whittle Laboratory, and Lead, Aviation Impact Accelerator (AIA)

I knew even before I arrived that COP28 would be critical in helping to raise ambition for zero emission aviation.

Then, at the opening reception, King Charles asked me about progress on a sustainable aviation initiative he had launched at Cambridge's Whittle Laboratory almost immediately after his coronation.

I had been invited by The King's Sustainable Markets Initiative to the Business and Philanthropy Climate Forum, an event hosted by the COP28 Presidency on the first two days of COP, with the aim of bringing together heads of state and CEOs to drive meaningful climate and nature action. I had been asked to co-chair the aviation round table with the Air Transport Action Group (ATAG).

Aviation is a major contributor to climate change: around 2-3% of global CO_2 emissions, and 6% once the non-CO_2 climate impacts are included.

Rapid action is needed by industry and governments if we are to set a pathway to achieve zero emission aviation by 2050, and I knew this forum, which included industry leaders like Rolls-Royce, regulatory bodies like the International Civil Aviation Organization (ICAO), and sustainable finance executives from investment institutions like Bank of America, was a key moment to raise ambition.

Cambridge had been leading a team that was developing the 2030 Sustainable Aviation Goals, a set of actions that, if implemented by 2030, would significantly cut the time required to achieve zero emission aviation.

This forum offered a unique opportunity to persuade global leaders that the Goals must be implemented.

We had been working extremely hard since King Charles visited the Whittle Laboratory seven months earlier, as his first event post-Coronation to convene a group of aviation industry CEOs, alongside senior government representatives, to help work on the Goals.

The Goals had originated from a workshop one month earlier in Boston USA, co-hosted by the University of Cambridge and Massachusetts Institute of Technology (MIT) in partnership with senior government policy experts from the US, UK and EU.

The workshop provided the group with a set of advanced modelling tools developed by the AIA team, a sort of 'Minority Report' style tool that provided policy makers with a special ability to explore how policy, technology and system integration could be used to accelerate change.

↓ Professor Rob Miller gives His Majesty The King a tour of the Whittle Laboratory at an earlier meeting

Credit: Lloyd Mann – University of Cambridge

Each of the four 2030 Goals is specifically targeted to raise ambition in a particular area of aviation.

The first is designed to ensure that Sustainable Aviation Fuels (SAF) are delivered in a truly sustainable way.

Recently, Virgin flew the world's first 100% SAF transatlantic flight. However, the quantities of feedstocks, biomass and hydrogen required to scale SAF are immense, and if not properly regulated the aviation industry will steal scarce resources from other sectors resulting in their emissions rising. The Goal is to put in place by 2030 the global policies required to minimise the wider impact of SAFs on climate and nature.

The second is designed to drive a new business model in the aviation sector.

The current business model of aviation has resulted in the fuel burnt per passenger per km dropping by around 1% per year. By changing incentives and/or regulation the business model can be changed to accelerate this effect. The Goal is to put in place incentives by 2030 which drive demand and fleet management and operations which will deliver a 40% reduction in fuel burn per passenger km by 2040.

The third is designed to accelerate the demonstration of the key technologies required to develop a long-haul hydrogen aircraft.

The low weight of hydrogen fuel, even once the weight of the tanks is included, makes hydrogen advantageous for long haul flight and the introduction of hydrogen would remove CO_2 emissions from flight.

Demonstrating the underlying technologies would act to dramatically cut the time to deliver such an aircraft. The Goal is to setup a 'moonshot' style programme that would demonstrate several key underlying technologies and infrastructure by 2030.

The fourth would be to remove the clouds formed by aviation.

Around one in 30 flights produces a persistent contrail, a region of cloud that can trap in heat to the Earth, increasing the climate impact of aviation. This non-CO_2 emissions climate impact is estimated to be around the same size as the CO_2 emissions impact of aviation, though the scientific uncertainty of the magnitude of this effect is large.

However, this effect can be avoided if the aircraft changes altitude in regions of the atmosphere where there is a potential to form clouds. The Goal is to trial and then deploy a contrail mitigation system that can start operation before 2030.

At the opening reception, the King urged us to continue to raise our ambitions in driving change in the aviation sector.

The following morning at the aviation roundtable, I demonstrated the 2030 Sustainable Aviation Goals to the assembled CEOs and sector leaders, using the AIA tool. It was clear that they immediately understood the opportunity and discussion quickly shifted to what actions were required by 2030.

With the King's words from his opening speech at COP, "I pray with all my heart that COP28 will be another critical turning point towards genuine transformational action", it was clear that the assembled leaders in the aviation sector understood that now was the moment to raise ambitions.

aiazero.org

Dr Brian Sheil's research group win prize for mining alert system at COP28

Dr Brian Sheil, Laing O'Rourke Associate Professor in Construction Engineering, is a world-leading researcher in construction engineering, focusing on optimising the efficiency and safety of civil infrastructure construction.

His research group's project 'Digital Twins For Tailings Dams' won the Data Sciences & AI-Enabled Solutions prize at the COP28 Prototypes for Humanity initiative, which finds innovative solutions for social and environmental issues.

Digital Twins For Tailings Dams is a satellite-based early warning system to monitor the stability of tailings storage facilities (TSFs), preventing potential catastrophic failures. The World Bank highlights a need for 3 billion tons of metals for the energy transition, intensifying challenges for the mining sector. Remarkably, over 98% of materials like copper end up as waste, stored in TSFs. With over 30,000 TSFs globally, a quarter are abandoned and unmonitored. By integrating geotechnical engineering, satellite remote sensing, and machine learning, Digital Twins For Tailings Dams aspires to establish a Digital Twin system to monitor these critical infrastructures.

The research group is: PhD student Maral Bayaraa and Dr Cristian Rossi from the University of Oxford and Dr Sheil from the Laing O'Rourke Centre for Construction Engineering and Technology, University of Cambridge.

Dr Sheil says, "We are delighted to have our research on tailings dams recognised in this way. This award spotlights the transformative role of satellite monitoring, machine learning, geotechnical modelling and Digital Twin technology in how we manage tailings dams worldwide. This research has been intrinsic to the wider Digital Twins research that we are carrying out in the Laing O'Rourke Centre for Construction Engineering Technology at University of Cambridge, where we are working towards achieving step-change improvements in sustainability, productivity and safety for the construction industry."

Read the full article at:
www.eng.cam.ac.uk/cop28

Credit: Lloyd Mann – University of Cambridge

Competition challenges students and researchers to communicate impact of ideas in three minutes

↑ LEFT: Runner-up alumnus Robert Kunzmann accepts his certificate from jury chair and Emeritus Professor Dame Ann Dowling. RIGHT: The winner, Yizhou Yu, PhD student at the MRC Toxicology Unit

Science enthusiasts from diverse backgrounds gathered at the Department of Engineering to pitch their innovative ideas to an audience, including a panel of judges, in just three minutes.

The Falling Walls Lab Cambridge gave 18 students and early-career professionals of all disciplines, and from various universities and start-ups, the opportunity to showcase breakthrough research that creates a positive impact on science and society.

The winner was Yizhou Yu, PhD student at the MRC Toxicology Unit, with his presentation titled *Breaking the wall of dementia*. Yizhou went on to compete in the Falling Walls Lab finale, which was held in Berlin.

The runner-up was Cambridge Engineering alumnus Robert Kunzmann.

PhD student Ali Niazi from the IfM, part of the Department of Engineering, shared his proposal for an innovative framework that seamlessly integrates financial and impact considerations with regards to the Sustainable Development Goals (SDGs).

Dr Mohammad Saghafifar, Research Associate in Thermo Physical and Thermochemical Energy Storage, shared details of his project, which involved the development of a battery that operates by capturing CO_2 from high emitting industries such as cement and steel producers.

Engineering PhD student Nirmani Rathnayake pitched her research project to do with the development of a wearable device for exercise-induced heart sound monitoring, with embedded sensors that can simultaneously 'listen' to all of your heart valves. Data can then be transmitted to doctors.

Alumnus Robert Kunzmann, COO at AC Biode, a cleantech start-up based in Luxembourg and Japan, shared the news that the company has successfully depolymerised polyester terephthalate (PET) into methanol – a technology that he says "could turn the tide in plastic recycling".

Master's student Igor Sterner is specialising in Information and Computing Engineering. He shared details of his work on the linguistic phenomenon of code-switching – the process of shifting from one language or dialect (linguistic code) to another depending on the social context or conversational setting.

Dr Pawan Shrestha, Royal Academy of Engineering Enterprise Fellow at Cambridge, pitched a proof-of-concept wearable AR experience that keeps virtual objects in focus at different depths, offering comfortable 3D viewing that causes no nausea or eyestrain to the user. It displays images on the retina using pixel beam scanning, which ensures the image stays in focus, regardless of the distance that the user is fixating on.

The jury included Emeritus Professor Dame Ann Dowling (jury chair); Dr Sakthy Selvakumaran, Fellow, Newnham College, Cambridge; Dr Joseph Cheriyan, Consultant Clinical Pharmacologist, Cambridge University Hospitals NHS Trust; Professor Dr Jack Hawkins, University of California, Davis; Mr Alexander Bleistein, Deputy Head of the German Academic Exchange Service (DAAD), UK; Ms Andrea Noske, First Counsellor (Science), German Embassy London.

The Falling Walls Lab Cambridge was organised by the Department of Engineering, University of Cambridge; the Federal Foreign Office of Germany; and the DAAD.

Watch the pitches:
https://bit.ly/3TL1Cyu

Credit: Jim Stephenson.

ALUMNI UPDATE

Meet the structural engineer whose work bridges art, architecture and engineering

↑ LEFT: Alumnus David Knight. Credit: James Balston Photography. RIGHT: Cody Dock Rolling Bridge

"To be a structural engineer means to be a creator: our ideas become reality." These are the words of alumnus David Knight, Director of Design and Engineering at Cake Industries, who has been announced as the 2023 Early Career Prize winner by the International Association for Bridge and Structural Engineering (IABSE).

It is an accolade that David says is humbling, given that the prize is presented to an individual member 40 years of age or younger for outstanding achievement in structural engineering.

David, who studied a Master of Engineering (MEng) at Cambridge, from 2003-07, specialising in Civil and Structural Engineering, has also been a guest lecturer at the Department of Engineering.

He currently works with architects, designers, artists and contractors to create bridges, sculptures, staircases, pavilions and other architectural features. Among his designs are several award-winning bridges, many of which have been opening bridges.

We asked David of all his bridge designs, which one is his favourite?

He replied: "That's like being asked to pick your favourite child! I have two: the Bracklinn Falls Footbridge, spanning 22 metres across the Keltie Water at the Bracklinn Falls in the Loch Lomond and Trossachs National Park, Scotland; and the Cody Dock Rolling Bridge, a pedestrian bridge in East London spanning eight metres, which rotates via manual levers to let boats pass.

"Bracklinn Falls Footbridge is the most satisfying scheme, as everything needed to be so efficient and multi-use to suit a site that was incredibly difficult to access and build at. It also had to be beautiful to fit into the stunning natural site, and therefore we developed an innovative modular system that used the best of computer-controlled design, as well as being extremely structurally efficient (with very high sustainability credentials). I was also responsible as both lead designer and main contractor to actually get the bridge delivered, so it felt very personal!

"Cody Dock Rolling Bridge was a once-in-a-career experience because it was so unusual. It needed the whole team to step outside their normal responsibilities and try to make an idea work in reality. I led the fabrication and construction team alongside an architectural designer and a structural engineer, but we left our labels at the door, and the final scheme has all of us in every detail. Some of the most vital work was done by a more recent Department of Engineering graduate, Alfred Jacquemot, who developed the complex mathematical model of how the bridge rolled!"

So, what makes an award-winning bridge?

"Bridges often have to satisfy multiple constraints (usability and function, constructability, durability, sustainability, aesthetic quality) whilst remaining as simple and as light as possible (to minimise material use and/or cost). The highest-quality bridges satisfy all constraints and then have something more to give. There is nowhere to hide as a designer – all your decisions are on show!"

What is the best part of being a structural engineer?

"Our ideas become reality. It is a rush to touch something that you imagined and designed, knowing that your skills were instrumental in bringing it into being. It is really rewarding work."

How did Cambridge help set you up for your future career?

"The breadth of experiences at Cambridge and particularly the engineering course was vital. My career has taken many twists and turns, and the appreciation you get for other disciplines and the ability to understand enough about them to integrate them into the design, has proved really important.

"The other vital thing was being around others (both in the Department of Engineering and more widely in extracurricular activity) with diverse viewpoints who would challenge my way of thinking. It is a great place to learn to be collaborative."

Read the full interview at:
www.eng.cam.ac.uk/structural-engineer

Credit: Charlotte Hester

→ Dr Valentyna Shkuro and Professor Andrii Kondratiev

Cambridge University Help for Ukraine welcomes Professor Andrii Kondratiev and Dr Valentyna Shkuro

Two displaced scholars from Ukraine will continue their research in the Department of Engineering for a second year as part of the Cambridge University Help for Ukraine programme. Professor Andrii Kondratiev and Dr Valentyna Shkuro are visiting research fellows in the Biomechanics Research Group and Engineering Design Centre respectively.

The programme provides funding for up to 26 postgraduate research students and academics from Ukraine, irrespective of nationality, displaced by Russia's invasion. The programme enables them to continue their studies and research in Cambridge. The University's support has also included a partnership with Kharkiv University to provide clinical placements for medical students and help for academics still working in Ukraine.

Professor Kondratiev (O.M. Beketov National University of Urban Economy, in Kharkiv) and Dr Shkuro (Taras Shevchenko National University of Kyiv) have spent one year at Cambridge on a fully funded residential placement, and this has since been extended for another year. They recently joined their displaced scholar peers for an extraordinary interdisciplinary conference, held to showcase new research from across the Ukrainian Cambridge community, ranging from engineering and computer science to philosophy, history, ecology and more.

Professor Kondratiev's current research, in cooperation with Professor Michael Sutcliffe, is to do with the development of restorative structures such as implants, which are tailored to the individual. For the purpose of this research, the individuals mentioned refer to Ukrainian soldiers who have suffered serious injury as a result of the ongoing war, experiencing lost tissue function in the face, neck, scalp and cranium, as well as damage to dental arches.

Professor Kondratiev aims to boost surgical treatment of these severe injuries through reconstruction and recovery of lost tissue function, as well as the restoration of dental arches lost as a result of injury. His method, using computer-aided design, creates various restorative structures adapted to the patient's bone tissues to inform prostheses and implants, taking into account the necessity of individual anatomy considerations.

"The essence of the problem of patient-specific restorative structure is the need to create a favourable stress-strain state in the adjacent bone, as well as in the structure itself," said Professor Kondratiev. "Therefore, studying the mechanical interaction of a restorative structure, for example, a dental implant as the main supporting element of dental prosthesis, is a primary scientific and engineering task."

He added: "The aim is to develop methods of designing digital models of lost anatomical sites, as well as the establishment of the dominant biomechanical factors influencing the shape of the restorative structure and selection of its parameters. This will allow us to study biomechanical conditions of successful osseointegration – a type of implant, splint, plate or screw, which is permanently connected to the adjacent bone tissue. The bone then grows into the implant."

Dr Shkuro's current research, in cooperation with Professor John Clarkson and Dr Sam Waller, is to do with gaining a better understanding of the needs of people who use prostheses in an inclusive built environment. The focus is on the rebuilding and post-war development of Ukraine, ensuring that inclusivity and accessibility is discussed at the planning stage.

"According to the Ministry of Social Policy of Ukraine, during the full-scale war, 300,000 people became disabled. Now there are three million people with disabilities in Ukraine," said Dr Shkuro. "Increasing numbers of veterans who have served our country and returned to cities are excluded from buildings and spaces that were designed and built to be inaccessible."

She added: "Achieving inclusivity and accessibility at the planning stage requires methods to collect data about users, and tools to represent those users for planning decisions. This is what my research is all about. Currently, I have conducted surveys of people in Ukraine, primarily veterans, who are using leg prosthetics, as well as surveys of the professionals providing rehabilitation services, including physiotherapists, psychologists and social workers. In the future, we plan to cover a larger number of respondents, including those with hand prosthetics and those with more than one year's worth of experience using prosthetics."

Read the full article at:
www.eng.cam.ac.uk/ukraine

Credit: Kalyakan – stock.adobe.com

It's high time for alliances to ensure supply chain security, researchers urge

The COVID-19 pandemic highlighted the interconnected nature of global supply chains, and showed how a disruption in one part of the world can have global effects. In 2021, supply disruptions cost the global economy an estimated $1.9 trillion.

Researchers from the Institute for Manufacturing (IfM), part of the Department of Engineering, have joined an international team calling on government agencies and national banks to support an effort to map the billions of connections in the global supply network which, among other impacts, could reduce tax evasion by as much as €130 billion annually in the European Union.

The researchers say that understanding supply networks could also improve supply security, promote an objective monitoring of the green transition, and strengthen human rights compliance. They emphasise that international alliances, backed by government organisations and the research community, are needed for such an understanding.

Even though most companies know their immediate trading partners, they depend on countless other relationships up and down the supply chain. A shortage anywhere in the supply network may affect suppliers, suppliers of suppliers, and so on, as well as customers and their customers.

"Supply disruptions caused an estimated loss of 2% of global GDP in 2021 – approximately $1.9 trillion – and significantly contributed to the current high inflation," said lead author Anton Pichler from the Complexity Science Hub (CSH). "For a long time, it was unthinkable to analyse the global economy at the company level, let alone its complex network of supply interconnections. That is changing now."

"Understanding supply chain interdependencies between companies, sectors and countries is vital for many challenges, from identifying how disruptions may emerge and cascade across economies, through monitoring carbon emissions and ensuring ethical and sustainable practice," said co-author Professor Alexandra Brintrup from the IfM.

For almost a century, only aggregated data – such as the average values of entire sectors – could be analysed. Predicting how individual company failures would affect the system was simply not possible. What happens to the economy when a specific company stops its production? What if an earthquake paralyses an entire region?

"Now, a combination of new micro-datasets, methods based in machine learning, and multiple government initiatives are creating the ability to map entire economies, which can give us the tools to answer some fundamental questions with real and timely impact," said Professor Brintrup.

Although the volume of data is vast – there are approximately 300 million companies worldwide, each with an average of 40 domestic suppliers, resulting in up to 13 billion supply connections – researchers can map the connections between individual companies.

Currently, value-added tax (VAT) data is the most promising option for reconstructing reliable large-scale supply networks. Countries including Spain, Hungary and Belgium use standardised VAT collection that practically records all domestic business-to-business (b2b) transactions. With these, it's possible to map the entire national trade of a country.

In most countries like Germany, Austria, or France, where VAT is not collected for individual b2b transactions but only accumulated over a specific period, such mapping is not possible.

"The standardised b2b collection could reduce administrative overheads for companies and would contribute substantially to tax compliance," said co-author Christian Diem, also from CSH. Estimates suggest that VAT-related fraudulent activities in the European Union amount to €130 billion annually.

Beyond tax evasion, other global challenges also depend on the detailed knowledge of supply networks. "For individual companies, it's nearly impossible to ensure that all trading partners, their suppliers, and their suppliers' suppliers operate in an environmentally friendly way and in compliance with human rights," said Anton Pichler. "If this were centrally documented in a gigantic network, it could be more easily ensured."

Read the full article at:
www.eng.cam.ac.uk/supplychain

Credit: Copyright RT Corporation

→ "Foodly" (centre) is a robot designed to work with people. It is able to adapt to various challenging and novel environments and is the focus of Yi Zhang's PhD research project titled *Data-driven autonomous robotic food handling*

Cambridge and Google partner to facilitate AI research

The University of Cambridge and Google are building on their long-standing partnership with a multi-year research collaboration agreement and a Google grant for the University's new Centre for Human-Inspired AI (CHIA) to support progress in responsible AI that is inspired by and benefits people.

The new agreement creates the potential for researchers and scientists from Google and the University to more closely collaborate on foundational AI research projects in areas of shared interest across a range of disciplines, including climate and sustainability, and AI ethics and safety.

Google has also become the first funding partner for the University's CHIA, led by Professor Anna Korhonen, Professor Per Ola Kristensson and Dr John Suckling, bringing together researchers and experts from computer science, engineering and multiple disciplines to develop AI that is grounded in human values and benefits humanity.

Google's unrestricted grant is helping enable the Centre's AI research in areas like responsible AI, human-centred robotics, human-machine interaction, healthcare, economic sustainability and climate change. The donation is also funding students from underrepresented groups to carry out PhDs within CHIA to help broaden diversity in the AI research community.

The expanded partnership builds on years of collaboration between Google Research, Google DeepMind and the University of Cambridge. Google provides funding for academic research, facilitates collaboration between faculty and Google researchers, and supports exceptional computer science students through its PhD fellowship programme. Google DeepMind funds scholarships for students from underrepresented backgrounds studying AI-related fields, as well as a postdoctoral fellowship, to help build a stronger and more inclusive AI community.

Speaking at the time of the announcement in October 2023, Michelle Donelan, Secretary of State for Science, Innovation and Technology, said: "AI can offer us enormous opportunities – growing the economy, creating new jobs and making lives longer, healthier and happier for British people. To seize those opportunities, we must bring together insights from business and academia to encourage the safe and responsible development of AI. That is why we are welcoming the partnership which Google and the University of Cambridge have announced."

Professor Anna Korhonen, Director of CHIA, said: "Here at the CHIA our researchers are dedicated to making sure that people are put at the very heart of new developments in AI. As our first funding partner, Google has been with us from the start of our journey, helping enable the breakthrough interdisciplinary research that we do. Partnerships like this – between academia and industry – will continue to be vital for the successful development of human-inspired AI."

Zoubin Ghahramani, VP Research, Google DeepMind is a Professor of Information Engineering at Cambridge and has spearheaded this expanded partnership. He said: "Google and the University of Cambridge share a deep commitment to developing AI responsibly, which means grounding innovation in scientific research, human values and our AI principles. We're excited by CHIA's potential to set new standards in responsible and human-centric AI development, and unlock AI discoveries that could benefit everyone."

Meanwhile, Engineering PhD student Yi Zhang is collaborating with RT Corporation to research an AI-powered robotics solution for food handling and processing. Using computer vision, feedback control and learning, "Foodly" (pictured) is an RT Corporation robot that is able to adapt to various challenging and novel environments.

Written by Hilary Fletcher

Read the full article at:
www.eng.cam.ac.uk/cambridge-google
www.chia.cam.ac.uk

ALUMNI UPDATE

Meet Nick Bailey – founder of Boost Bikes

Alumnus Nick Bailey has launched Boost Bikes, a new business to convert road bikes to electric bikes at a fraction of the cost of buying an e-bike.

Nick graduated in 2002, followed by a varied and distinguished career in businesses such as Cambridge technology consultancy Sentec, Deloitte, Centrica and Shell. In January 2022, he founded Boost Bikes.

The company launched its first product in autumn 2022 with an Indiegogo crowdfunding campaign and subsequently raised significant investor funding.

In 2023, Boost Bikes' first full year, the company sold hundreds of conversion systems, and more than 100 bike shops around the UK have joined a Boost Bikes network enabling anyone to get the kit fitted without needing DIY skills.

We caught up with Nick to find out more.

What was the inspiration behind Boost Bikes?

A lot of the systems to convert bikes to electric bikes are fairly basic. Most of the companies making e-bike conversion systems buy pre-packaged parts from overseas; there's not really any engineering added to them in the UK. I wanted to build something not necessarily 100% from scratch, but where I had added a significant benefit into the product.

I believe strongly that the UK needs to do more grassroots and practical engineering, not just relying on China and the USA to design things for us. We need to have a framework for helping engineers and inventors to get on and make things.

The projections of growth three years ago for e-bikes and electric mobility were spectacular and these have turned out to be accurate, and the market is due to double in size by 2028.

Arduino is a popular hobbyist engineering software and hardware collection of products that makes it relatively easy to create small devices running proper software that can be run from batteries. I then made the jump to design a single integrated circuit board that contained an Arduino computer combined with power supplies and a motor controller using high-end automotive electronic switches. The high level of integration makes the Boost brushless DC motor controller much smaller than other conversion products. It took five versions of the circuit board to perform reliably under load. Once the circuit design was proven, I've since been able to quickly change the shape of the board to fit in enclosures for other types of bikes.

Over the course of 2022, I started looking for investors. The government SEIS scheme was developed to help small, early-stage companies raise funds by providing a number of tax reliefs on investments made into qualifying companies. It took about a year while developing the product to raise several hundred thousand pounds from early-stage private investors ('business angels') who provided the seed funding for stock and marketing.

The investment enabled me to create the basic structure of a company. In May 2023, we sold 90 kits. Obviously, I cannot individually build 90 kits, so I had to have a production line. I found a local assembly company who could grow our capacity. In parallel, we created an ordering and fulfilment system to manage the lifetime of the items we build, and track them all the way to the customer.

Our next big investment goal is to raise a larger sum as necessary to expand into Europe in 2025. We aim to at least double our 2023 revenue in 2024. There is a step-change in scale between 100 a month and 1,000 a month and we intend to reach this scale in 2025.

We currently have around 100 bike shops across the UK supplying and fitting the system.

We have just created a brand new conversion system for Brompton bikes, which is selling very well.

Read the full interview at:
www.eng.cam.ac.uk/boostbikes

Gemma Bale appointed as a Founding Programme Director at ARIA

Dr Gemma Bale has been selected as one of eight founding Programme Directors of the Advanced Research and Invention Agency (ARIA) – a new governmental research and development funding agency built to unlock scientific and technological breakthroughs for everyone's benefit.

Dr Bale will co-direct a programme with Sarah Bohndiek, Professor of Biomedical Physics at the Cavendish Laboratory and Group Leader at the Cancer Research UK Cambridge Institute. Together, they will be responsible for designing and overseeing ARIA's initial programme to explore the use of optics for planetary and human health.

They will be looking to accelerate the use and applications of optical technologies, initially by exploring ideas around non-invasive optical mapping and sensing across a range of applications, from monitoring human health to climate change.

Over the next three years, Dr Bale and Professor Bohndiek will develop a concrete programme around their visions and build the multidisciplinary communities to make them a reality. ARIA will be seeking input and inspiration from the community as it drives towards launching formal programmes in the coming months.

Dr Bale, Gianna Angelopoulos Assistant Professor of Medical Therapeutics at the Cavendish Laboratory and the Department of Engineering, said: "Working in the health tech space, we have created new tools to allow us to safely see inside humans in new ways using light. We believe that there are emerging optical technologies at the edge of the possible, which will disrupt the current landscape."

As both contribute to shaping the strategic vision of ARIA, their respective research groups will continue their crucial work at the Department of Engineering, the Cavendish Laboratory, and the Cancer Research UK Cambridge Institute.

For more information, visit:
www.aria.org.uk/what-were-working-on

Emeritus Professor receives Structural Dynamics award

Emeritus Professor Robin Langley has received the European Association of Structural Dynamics award for outstanding and sustained contributions to structural dynamics.

Professor Langley received the award at the EURODYN 2023 International Conference on Structural Dynamics, at which he gave the main keynote speech titled *Efficient methods of computing the steady state and transient response of random dynamic systems at high frequencies*. The citation refers to "his ingenious breakthroughs in vibro-acoustics, non-linear dynamics, uncertainty quantification, energy harvesting, electromagnetism and many more".

Professor Langley said: "The Department has a long tradition of work in the field of dynamics, and it has been a privilege to have been a member of the Dynamics and Vibration Research Group (founded by the late Professor David Newland) since my arrival here in 1998. Aside from my own work, the group addresses problems across the whole range of industrial sectors and covers both fundamental and applied topics.
The scale of application ranges from micro-mechanical systems to heavy trucks to aircraft and beyond. It has been a constant inspiration to observe the work of my fellow group members, and the supportive and collaborative research environment afforded by the group has been of great benefit."

Professor Langley has extensive contacts with industry and he is a co-founder of Wave Six (now owned by Dassault Systemes), a company that has developed engineering software for noise and vibration analysis that is used by a wide range of industries.

He retired from the University in 2022, but is continuing with aspects of research as an Emeritus Professor. He is a recipient of the Rayleigh Medal from the Institute of Acoustics and a Fellow of the Royal Academy of Engineering.

Read the full article at:
www.eng.cam.ac.uk/robinlangley

The quiet AI revolution in weather forecasting

Richard Turner, Professor of Computer Vision and Machine Learning, recently gave a talk for the Cambridge Philosophical Society discussing the quiet AI revolution that has begun in the field of numerical weather prediction.

Over the last 18 months, a quiet AI revolution has begun in the field of numerical weather prediction. Medium-term weather prediction involves forecasting several days to a couple of weeks in the future and these forecasts are critical for making many social and economic decisions.

The standard approach to this problem is to run detailed global simulations of the Earth's atmosphere using a supercomputer, so-called numerical weather prediction (NWP). As little as one year ago, researchers in this field had thought it unlikely that machine learning approaches would be competitive with numerical weather prediction any time soon.

However, over the last year, the same advances that underpin large AI language models like ChatGPT have been applied to weather prediction. Surprisingly, these models achieve a performance which is already competitive with standard NWP, but with a computational cost that is thousands of times cheaper.

The deep learning-based forecasts have also been shown to be surprisingly robust, performing reasonably, even when faced with rare or extreme events. Consequently, weather prediction centres like the World Meteorological Organisation and the European Centre for Medium-Range Weather Forecasts (ECMWF) are now racing to build machine learning teams and publicly testing AI forecasts.

Professor Turner's talk describes this quieter AI revolution, giving an introduction to medium-range weather forecasting and a brief history. The talk then describes how machine learning methods can be applied to this task and gives a quick introduction to transformers – the new machine learning technology that underpins large language models like those used in ChatGPT and that can also be applied to forecasting. The talk ends by showing AI forecasts and comparing them to the conventional approach.

The machine learning methods in the talk accelerate the forecasting step of weather prediction. However, weather predictions involve a second step called data assimilation in which observations of weather from satellites, weather stations, ships, balloons and aircraft are incorporated. This takes roughly half of the computational effort in forecasting, but has not been touched by AI methods. Professor Turner's group is working on an even more ambitious approach that will use AI to accelerate and improve both the forecasting and assimilation steps of weather prediction, producing a fully end-to-end trained system.

Richard Turner is Professor of Computer Vision and Machine Learning in the Department of Engineering at the University of Cambridge and a Visiting Researcher at Microsoft Research Cambridge. He was co-director of the UKRI Centre for Doctoral Training in the Application of Artificial Intelligence to the study of Environmental Risks (AI4ER CDT).

His work has been presented at top machine learning conferences including AAAI, AIStats, ICLR, ICML and NeurIPS and he has given keynote lectures and tutorials at the Machine Learning and Signal Processing Summer School; the International Conference on Machine Learning, Optimization & Data Science; and the Machine Learning Summer School.

He has been the lead supervisor for 20 PhD students (13 now graduated) and 10 Postdoctoral Research Associates. He has received over £10M of industrial funding from Microsoft, Toyota, Google, DeepMind, Amazon, and Improbable, and over £15M of funding from the EPSRC. He has been awarded the Cambridge Students' Union Teaching Award for Lecturing. His work has featured on BBC Radio 5 Live's *The Naked Scientist*, BBC World Service's *Click* and in *Wired* magazine.

Watch Professor Turner's talk:
youtu.be/JGn18WH0d6s



↑ From left, Professors Vikram Deshpande, Bill O'Neill and Ashwin Seshia

Royal Academy of Engineering announces new Fellows for 2023

Professors Vikram Deshpande, Bill O'Neill and Ashwin Seshia have been announced as Fellows of the Royal Academy of Engineering in recognition of their outstanding and continuing contributions to the profession.

Vikram Deshpande, Professor of Material Engineering, has made seminal contributions to the mechanics of engineering materials. The scope of his impact spans design of high-strength, lightweight micro-architectured materials, to the invention of blast-resistant sandwich panels in commercial and military ship hulls, and the prediction of the multi-physics response of a wide range of engineering materials including soft and active solids.

He has made fundamental discoveries of direct industrial application by combining novel experiments with deep theoretical insights on material and structural response. His work defines the modern frontiers of mechanics with an impact on engineering science.

Bill O'Neill, Professor of Laser Engineering, is widely acknowledged as a leading expert in the field of high-power lasers and their use in materials processing. He founded the Centre for Industrial Photonics at Cambridge, focusing on delivering new laser-based manufacturing solutions to industry.

His innovations have led to successful industrial applications in metal-based additive manufacturing, biomedical engineering, advanced coatings, carbon nanotubes, ultra-fast holographic imaging, high-strength super magnets, in-process diagnostics, and ultraprecision engineering.

Inspired by rapid development of lasers in the 1960s and 1970s, he established a distinguished research career that led to a series of roles as engineer, educator and entrepreneur. He has founded two Cambridge spin-outs and is a board member of the Laser Museum of America.

Ashwin Seshia, Professor of Microsystems Technology, has made significant contributions to the fields of microelectromechanical systems (MEMS) and sensor systems. His research has led to the design and implementation of high-performance inertial sensors, differential gravimeters, and energy-harvesting-enabled wireless sensing solutions, with technology translation through two spin-off companies.

His translational leadership has led to the development of cutting-edge sensor technologies, enabling a diverse spectrum of applications including the remote condition monitoring of industrial equipment, geotechnical surveying, carbon sequestration monitoring, and inertial navigation. He has also led several higher education and research outreach and dissemination activities internationally.

Alumnus Dr Sabesan Sithamparanathan has also been announced as a Fellow of the Royal Academy of Engineering. Sabesan is founder and president of PervasID, a company providing best-in-class passive Radio Frequency Identification (RFID) reader systems for automating inventory and asset tracking.

Professor Sir Jim McDonald FREng FRSE, President of the Royal Academy of Engineering, says: "Engineering is everywhere, but nowhere the same, and our new Fellows represent the great breadth and diversity of engineers who are striving to address some of the world's most complex challenges – benefiting society and the economy in the process. From next generation power networks and water systems to quantum computing and artificial intelligence, our new Fellows are shaping the future.

"We live in an era of rapid change across our communities, our country, and of course our planet. Today we welcome to our Fellowship an inspiring group of people who are harnessing their creativity, courage and commitment to drive positive change in the world around us and we look forward to their contribution to our work."

Honours, awards and prizes

RAEng President's Medal

Professor John Clarkson has received the Royal Academy of Engineering President's Medal in recognition of his enormous contribution to the Academy's work, particularly in healthcare systems policy.

Professor Clarkson, Head of the Department's Engineering Design Centre, is an international leader in systems thinking, especially in healthcare. His work is a core element of the Academy's flagship Policy Fellowship programme and has placed the Academy at the centre of systems thinking in government.

His involvement with the Academy's policy work began in the mid-2010s when he chaired the Engineering Better Care Working Group. This brought healthcare and engineering communities together to develop a framework for embedding the key engineering principles of inclusive design, risk and systems thinking into healthcare improvement practices.

ICE Fellow

Professor Gopal Madabhushi, Director of the Schofield Centre and Head of the Geotechnical Group, has been elected to the Fellowship of the Institution of Civil Engineers (ICE).

Professor Madabhushi's research focuses on earthquake risk mitigation of geotechnical and structural systems. His research has led to a better understanding of the response of these systems under extreme earthquake loading and soil liquefaction.

Two of his former students have also been presented with 2023 ICE awards. Alumni Professor Jonathan Knappett and Dr Barnali Ghosh were awarded the ICE Geotechnical Research Medal and the ICE John Mitchell Award respectively.

Double award winner

Douglas Brion has received two prestigious awards, one for his PhD research and the other for his start-up Matta – a spin-out company working to create artificial general intelligence for the manufacturing sector.

Douglas is from the Computer-Aided Manufacturing Group at the Institute for Manufacturing.

He has been recognised for his exemplary PhD research with the IET Postgraduate Scholarship for an Outstanding Researcher. He has also been awarded an RAEng Enterprise Fellowship, funded by the Royal Commission for the Exhibition of 1851, just one year after starting Matta.

Early Career Fellowship

Dr Lefan Wang has been awarded a Leverhulme Early Career Fellowship to support her research project titled *New insights into foot biomechanics via personalised multimodal sensing insole*.

Dr Wang, from the Institute for Manufacturing, says: "Recent advances in 3D printing technology have created an opportunity to develop a more personalised and skin-conformal sensing insole. The information gathered from such a device can provide a more comprehensive understanding of foot biomechanics, with significant implications in various areas such as athletic performance optimisation, footwear design, biorobots, and injury prevention."

RAEng Research Fellowship

Dr Demetrios Lefas, Research Fellow at the Whittle Laboratory, has received a Royal Academy of Engineering Research Fellowship to investigate how he can enable the design of future engine architectures by pushing the limits of jet engine design, whilst preventing aeroelastic instability.

Aeroelastic instabilities in jet engines occur when changes in aerodynamics amplify a fan blade's vibration. Dr Lefas' research aims to understand the driving mechanisms behind these aeroelastic instabilities to develop new technology at the pace required for a net zero carbon transition, while keeping flying accessible to all.

ASCE Moisseiff Award

Dr Jurgen Becque has won the Moisseiff Award from the American Society of Civil Engineers. The award recognises substantial advances in the field of structural mechanics and design. Dr Becque received the award for providing approximate yet highly accurate solutions to the Föppl-von Karman equations. These equations describe the stability of compressed plates and have many practical applications. However, they have been unresolved for more than a century.

Credit: Professor Graham Treece (LEFT and BOTTOM). TOP: Fitzwilliam Museum.

LEFT: A zoomed-in fragment of one of the silver-headed copper alloy rivets using Micro-CT. RIGHT: TOP – Tamassos Sword (6th century BC). BOTTOM – Micro-CT image showing the underneath layer of the sword to reveal metal work

Inner secrets of Iron Age sword revealed for the first time using cutting-edge research

The internal structure of an Iron Age sword has been understood for the first time, thanks to scientific imaging and analysis techniques involving a Cambridge engineer, resulting in a virtual dissection of the artefact.

The Tamassos Sword is a silver studded iron sword dating from the 6th century BC, discovered in Tomb 12 of the early Iron Age necropolis of Tamassos, in central Cyprus.

While extensive research on the sword, undertaken at the Fitzwilliam Museum in 1998-99, revealed more about its physical components, less was known about how each component was made and how the sword would have been assembled – until now.

Helping to 'peel back' the layers of the sword using micro-computed tomography (micro-CT) is Professor Graham Treece, from the Department of Engineering's Medical Imaging Group, part of the Machine Intelligence Laboratory. Micro-CT is a non-destructive imaging tool that enables the visualisation of materials of different densities.

Using a visualisation and analysis package for 3D imaging data[1], Professor Treece was able to create hi-res 3D images of the sword showing the internal structure of the artefact, as well as the various components of its decorated, flat, semicircular hilt section with rectangular grip.

From these images, composed of 2D trans-axial projections or 'slices', more could be learned about the condition of the iron, for example, and what technologies may have been employed to transform a bar of iron into the leaf-shaped blade and hilt section that we see today. On closer inspection, the micro-CT imaging also revealed copper alloy rivets with silver heads holding the carved ivory plates onto the hilt. The edges of the iron hilt were decorated with sheet metal: two thin layers of silver lie over a layer of tin.

This cutting-edge research has shed new light on the materials and technologies used by ancient craftspeople and provides insights into the relationship between the people and communities who lived on the Mediterranean islands.

The Tamassos Sword was on display at the Fitzwilliam Museum last summer as part of an exhibition titled *Islanders: The Making of the Mediterranean*. The sword is now located in the Fitzwilliam Museum's Cypriot Gallery.

Professor Treece said: "The Tamassos Sword has been a fascinating project to be involved in. I enjoyed paying careful attention to getting as much detail as possible into the 3D visualisation process. The ability to make a difference in this way, and get the absolute best out of the data, allows you to see things that have not been seen for a very long time and in a way that has not been possible before."

[1] Stradview, the visualisation and analysis package used for generating the 3D images, is written by Professor Treece and Professor Andrew Gee, also from the Medical Imaging Group.

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