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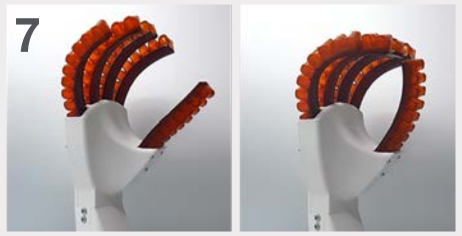
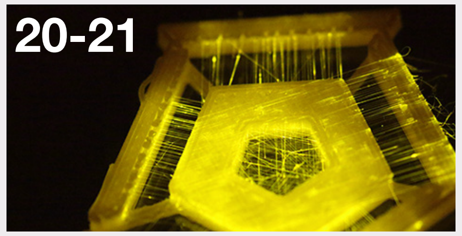
DEPARTMENT OF ENGINEERING NEWS

UNIVERSITY OF CAMBRIDGE

In this issue





Cover image: NASA astronaut and Cambridge alumna Kayla Barron. Credit: NASA/Bill Ingalls.

Note from the editors

We hope you enjoy this edition of the newsletter. The photographs on pages 20 and 21 show the prize-winning images from the 2019 Department Photography and Video Competition (kindly sponsored by ZEISS).

We hope that they inspire you to enter this year's competition.

Over the last 17 years that the competition has been running, we have built an incredible archive of images and video that we can use throughout our department communications and marketing work.

The images are also used by other departments, the central University and some of the colleges, helping us to keep engineering and all its varied beauty visible to many audiences. One of the photo entries was used, with permission and appropriate credits, as an album cover for a heavy metal band! The possibilities are endless.

We are always delighted to receive entries from you, our alumni, and we would like to encourage more of you to enter this year. No matter what your area of engineering interest is, please do keep your phone at the ready and keep those engineering stories alive with photography and video.

The adage "A picture is worth a thousand words" is very powerful and in this time of uncertainty, taking the time to inspire and encourage the next generations to consider engineering as a career is more important than ever. Photographs and video can be very much a part of that mission.

Entry details at: www.eng.cam.ac.uk/photography-competition

Charlotte Hester and Jacqueline Saggers

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Credit: Graham CopeKoga

Head's welcome

Reflecting on a year of the COVID-19 pandemic, there have certainly been significant challenges and numerous ways in which we have had to adapt to new, sometimes more difficult, ways of working. Nevertheless, there have also been a remarkable number of things that we have been able to celebrate and be thankful for.

The Royal Academy of Engineering recognised two of our teams in their President's Special Awards for Pandemic Service (**page 12-13**). The Industrial Hospital Logistics project used engineering techniques and systems to help local hospitals and healthcare organisations make efficient use of scarce resources. The Chief Executive of Addenbrooke's Hospital, Mr Roland Sinker, wrote specially to the Vice-Chancellor to thank him for their contribution and highlighted the way that (and I quote): "Institute for Manufacturing (IfM) staff and students consistently demonstrated commitment to use their engineering expertise and time to serve our patients and protect our staff in these challenging times."

The Royal Academy also gave a President's Special Award to the Open Ventilator System Initiative, based at the Whittle Laboratory. This project produced an open-source medical ventilator design that achieves high levels of performance while only using standard parts. This will save lives in the developing world where ventilators are scarce and many that exist cannot achieve the quality of performance that the Open Ventilator offers.

In September 2020, the Department was informed that it had been awarded an Athena Swan Silver Award for a further five years. This renewal is the result of work by many colleagues and marks our ongoing commitment to gender equality. In parallel, the Department is increasing attention to both gender and racial diversity and is strengthening collaboration with the rest of the University in both these areas.

In April 2020, Professor Vikram Deshpande and Professor Steve Young were elected to Fellowship of the Royal Society. Professor Daniel Wolpert has been awarded the Ferrier Medal and lecture by the Royal Society for his groundbreaking contributions to our understanding of how the brain controls movement. Professor Zoubin Ghahramani was given the Milner Award and lecture by the Royal Society for his fundamental contributions to probabilistic machine learning. In September 2020, Professor John Robertson was made a Fellow of the Royal Academy of Engineering. His work on electronic materials has had a significant impact on the ability to scale such fundamental things as CMOS transistors and magnetic disk storage density.

Two groups of our students were recognised in the Vice-Chancellor's Social Impact Awards 2020 (**page 11**). A team from the IfM used their knowledge of industrial processes to contribute to the design of COVID-19 testing strategies. A second-year engineer, Puria Radmard, won in the Undergraduate Students' category for his work on an innovative "Carbon Map" for Cambridge.

In January 2020, His Royal Highness the Prince of Wales launched the National Centre for Propulsion and Power at the Whittle Laboratory (**page 5**). This major initiative is focussed on the development of zero carbon flight and power generation. Solutions in this area cannot come from academia, industry or policy changes in isolation. We need new ways to work together and at greater speed. The Whittle has these skills, coupled with unique industrial partnerships to support practical progress.

Perhaps the most remarkable aspect of the last year is the way that Cambridge staff and students have found ways to continue with so much of the day-to-day work of the Department in extraordinary circumstances. Key professional support services have been maintained. The undergraduate and graduate courses have been delivered, albeit sometimes in an adapted form; and we have constantly reorganised our research to enable the maximum progress to be safely achieved.

It is wonderful to celebrate the remarkable achievements of our colleagues. It is also appropriate to recognise the remarkable collegial spirit and supportive culture that has enabled so much to be achieved by so many members of the Department in such strange circumstances.

Professor Richard Prager FREng, FIET, CEng

→ NASA astronaut Kayla Barron (left) and Canadian Space Agency astronaut Dr Jenni Sidey-Gibbons

Credit: NASA/Bill Stafford

Cambridge alumna could be the first woman to walk on the Moon

Gates Cambridge Scholar and NASA astronaut Kayla Barron has been selected for the Artemis Team, making her eligible for the next astronaut missions that could see her become the first woman to walk on the Moon.

The announcement was made during the eighth National Space Council meeting held at NASA's Kennedy Space Center in Florida. NASA has selected 18 astronauts from its corps to form the Artemis Team and help pave the way for the next astronaut missions on and around the Moon as part of the Artemis program. The agency's modern lunar exploration programme will land the first woman and next man on the Moon in 2024 and establish a sustainable human lunar presence by the end of the decade.

NASA Vice President Mike Pence, who introduced the members of the Artemis Team, said: "I give you the heroes who will carry us to the Moon and beyond – the Artemis Generation. It is amazing to think that the next man and first woman on the Moon are among the names that we just read. The Artemis Team astronauts are the future of American space exploration – and that future is bright."

The astronauts of the Artemis Team will help NASA prepare for the coming Artemis missions, which begin this year, working with the agency's commercial partners as they develop human landing systems; assisting in the development of training; defining hardware requirements; and consulting on technical development.

Alumna Kayla Barron was chosen as an astronaut in 2017, alongside Cambridge lecturer at the Department of Engineering, Dr Jenni Sidey-Gibbons (Canadian Space Agency). Prior to this, Kayla achieved a Master's degree in Nuclear Engineering from the University of Cambridge, where she conducted research on modelling the fuel cycle for a next generation, thorium-fuelled nuclear reactor concept. As a submarine warfare officer, Kayla was a member of the first class of women commissioned into the submarine community. She is a lieutenant commander in the U.S. Navy.

Meanwhile, NASA and the Canadian Space Agency (CSA) have announced that they will collaborate on the Gateway, an outpost orbiting the Moon. It will provide vital support for a sustainable, long-term return of astronauts to the lunar surface as part of NASA's Artemis program. Under this agreement, CSA will provide the Gateway's external robotics system, including a next-generation robotic arm, known as Canadarm3. The agreement also marks NASA's commitment to provide two crew opportunities for Canadian astronauts on Artemis missions, one to the Gateway and one on Artemis II – the first crewed flight test of the Space Launch System and Orion spacecraft around the Moon, that is targeted for launch in 2023.

Dr Sidey-Gibbons is among the CSA's active astronaut corp. At the time of going to press, it is not yet known which of the Canadian astronauts will be selected.

The Honourable Navdeep Bains, Minister of Innovation, Science and Economic Development, who is responsible for Canada's space programme and who made the announcement, said: "This is a significant moment in Canada's space history. The Canada–U.S. Gateway Treaty takes Canada to the Moon for the first time. Our country will collaborate with the most advanced space organisations in the world on cutting-edge science and technology for the benefit of humankind. As Canada joins the U.S. and other international partners in this great adventure, our continued leadership in space robotics will be a source of national pride – and all eyes will look to the sky as one of our astronauts becomes the first Canadian to travel around the Moon."

> "
> It is amazing to think that the next man and first woman on the Moon are among the names that we just read. The Artemis Team astronauts are the future of American space exploration – and that future is bright.
>
> NASA Vice President

Watch our interview with Dr Sidey-Gibbons: youtu.be/jbJAifR2lqE

→ The Prince of Wales pictured speaking with Professor Rob Miller, Director of the Whittle Laboratory

Credit: Nic Marchant

Prince of Wales launches new UK centre for low-carbon aviation

The Prince of Wales launched the National Centre for Propulsion and Power during a visit to the University of Cambridge in 2020. Based at the world famous Whittle Laboratory, the Centre aims to accelerate the development of decarbonisation technologies.

The Centre will bring together researchers from across UK Universities with industry partners such as Rolls-Royce, Mitsubishi Heavy Industries, Siemens and Dyson to accelerate the development of low-carbon technologies for the propulsion and power sectors.

Professor Rob Miller, Director of the Whittle Laboratory, said: "Our enemy is time. To achieve net zero by 2050 we have focused on accelerating the technology development process itself. The results have been astonishing, with development times being reduced by a factor of 10 to 100."

The Prince, who is patron of the University of Cambridge Institute for Sustainability Leadership (CISL), hosted a roundtable meeting of aviation and power generation business leaders, senior Government officials and researchers about how the UK can accelerate the development of decarbonisation technologies.

"We are at a pivotal moment, in terms of both Cambridge's history of leading technology development in propulsion and power, and humanity's need to decarbonise these sectors," said Professor Miller. "Fifty years ago, the Whittle Laboratory and its industrial partners faced the challenge of making air travel efficient and reliable. Now the new Whittle Laboratory and the National Centre will enable us to lead the way in making it green."

Simon Weeks, Chief Technology Officer of the Aerospace Technology Institute, said: "We are pleased to support the National Centre for Propulsion and Power with funding through the ATI Programme. The Centre will play a critical role in developing sustainable propulsion technologies – a key part of the UK's air transport technology strategy. It builds on the world-leading reputation of the Whittle Laboratory to create a globally unique capability."

Business Minister Nadhim Zahawi said: "The new National Centre for Propulsion and Power will support the UK's thriving aerospace sector and help it develop cutting-edge technology at an even faster pace. By fuelling innovation we will ensure the UK remains firmly established as a world leader in low carbon technologies – as we make strides towards our goal of net-zero emissions by 2050."

The National Centre, supported by the Aerospace Technology Institute with funding from the Department of Business, Energy & Industrial Strategy, aims to scale agile technology development to around 80% of the UK's future aerodynamic needs. The process is described as 'tightening the circle' between design, manufacture and testing.

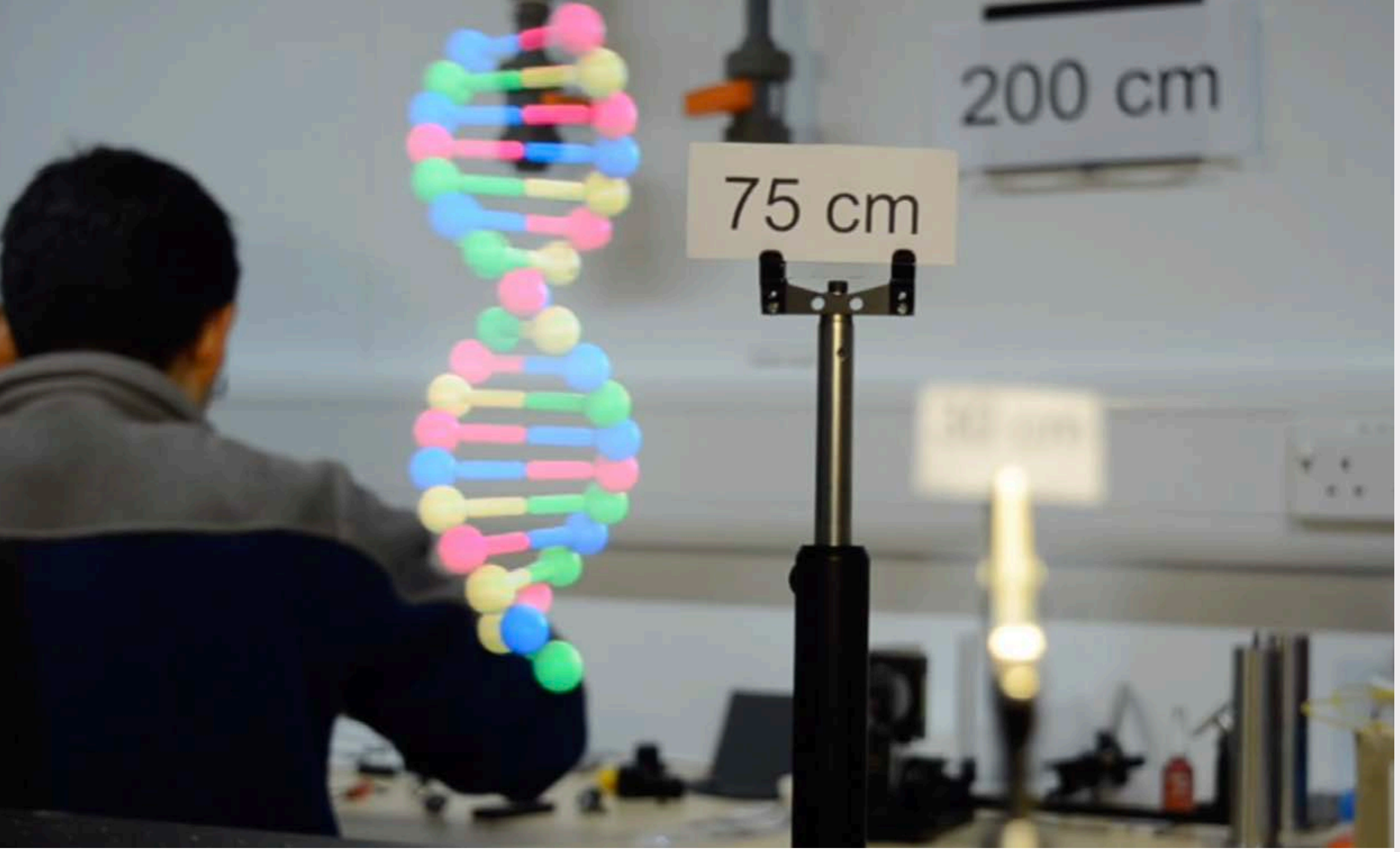
Design time has been reduced using AI and augmented design systems running on graphics processors, originally designed for computer gaming. Manufacturing times have been reduced by directly linking the design systems to rows of in-house 3D printing and rapid machining tools, rather than relying on external suppliers. Testing times have been reduced by developing rapid assembly and disassembly experimental test facilities, which can be operated by Formula One-style pit teams.

"There's a natural human timescale of about a week, in which if you can go from idea to result then you have a virtuous circle between understanding and inspiration," said Professor Miller. "We've found that when the technology development timescale approaches the human timescale – as it does in our leaner process – then innovation explodes."

The aviation roundtable was convened by the Whittle Laboratory and CISL, which share a common objective of developing new ways in which policy leadership, industry and academia can collaborate to accelerate innovation and achieve net zero by 2050.

The University launched Cambridge Zero in 2019 to bring together its research, policy and private sector engagement activities on climate change. The Whittle Laboratory and CISL are key partners in that initiative, and both demonstrate the importance of academia working with government and the private sector on the critical issue of our time.

whittle.eng.cam.ac.uk
zero.cam.ac.uk
www.re-tv.org/reinvigorate/reworking-innovation



New augmented reality head mounted display offers unrivalled viewing experience

↑ Pixel beam scanning ensures the image, such as this DNA helix, stays in focus regardless of the distance that the user is fixating on

Cambridge engineers have developed a new augmented reality (AR) head mounted display (HMD) that delivers a realistic 3D viewing experience, without the commonly associated side effects of nausea or eyestrain.

The device has an enlarged eye-box that is scalable and an increased field of view of 36° that is designed for a comfortable viewing experience. 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. Details are reported in the journal *Research*.

Developed by researchers at the Centre for Advanced Photonics and Electronics (CAPE) in collaboration with Huawei European Research Centre, in Munich, the HMD uses partially reflective beam splitters to form an additional 'exit pupil' (a virtual opening through which light travels). This, together with narrow pixel beams that travel parallel to each other, and which do not disperse in other directions, produces a high quality image that remains unaffected by changes in eye focus.

The results of a subjective user study conducted with more than 50 participants aged between 16 and 60[1] showed the 3D effect to be 'very convincing' for objects from 20 cm to 10 m; the images and videos to be of 'vivid colour' and high contrast with no observable pixels; and crucially, none of the participants reported any eyestrain or nausea, even after prolonged periods of usage over a few hours or even all day.

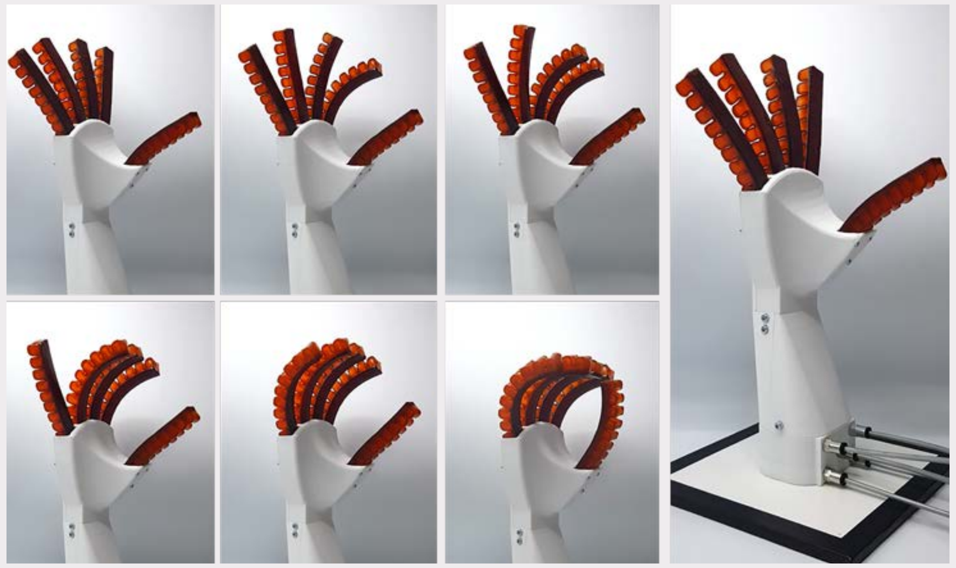
The HMD is of high brightness and suited to a wide range of indoor and outdoor uses. Further research is progressing on exploring its potential use in areas of different applications such as training, CAD (computer-aided design) development, hospitality, data manipulation, outdoor sport, defence applications and construction, as well as miniaturising the current head mounted prototype to a glasses-based format.

Professor Daping Chu, Director of the Centre for Photonic Devices and Sensors and Director of CAPE, who led the study, said: "Our research offers up a wearable AR experience that rivals the market leaders thanks to its comfortable 3D viewing which causes no nausea or eyestrain to the user. It can deliver high quality clear images directly on the retina, even if the user is wearing glasses. This can help the user to see displayed real world and virtual objects clearly in an immersive environment, regardless of the quality of the user's vision."

[1] Participants comprised of industrial representatives and academic researchers familiar with 3D display technology.

Experience the device – watch the video:
youtu.be/GPahi9_asYk

→ A self-healing hand consisting of two different materials that are combined



Credit: BruBotics

Machine learning to help develop self-healing robots that 'feel pain'

Researchers will use self-healing materials and machine learning to develop soft robotics as part of a new collaborative project.

The goal of the €3 million Self-healing soft robotics (SHERO) project, funded by the European Commission, is to create a next-generation robot made from self-healing materials (flexible plastics) that can detect damage, take the necessary steps to temporarily heal itself and then resume its work – all without the need for human interaction.

Led by the University of Brussels (VUB), the research consortium includes the Department of Engineering (University of Cambridge), École Supérieure de Physique et de Chimie Industrielles de la ville de Paris (ESPCI), Swiss Federal Laboratories for Materials Science and Technology (Empa), and the Dutch Polymer manufacturer SupraPolix.

As part of the SHERO project, the Cambridge team, led by Dr Fumiya Iida, Reader in Robotics, are looking at integrating self-healing materials into soft robotic arms. Dr Thomas George Thuruthel, Research Associate in Soft Robotics Sensing and Self-Healing at the Department of Engineering, said self-healing materials could have future applications in modular robotics, educational robotics and evolutionary robotics where a single robot can be 'recycled' to generate a fresh prototype.

"We will be using machine learning to work on the modelling and integration of these self-healing materials, to include self-healing actuators and sensors, damage detection, localisation and controlled healing," he said. "The adaptation of models after loss of sensory data and during the healing process is another area we are looking to address. The end goal is to integrate the self-healing sensors and actuators into demonstration platforms in order to perform specific tasks."

Professor Bram Vanderborght, from VUB, who is managing the project with scientists from the robotics research centre BruBotics and the polymer research lab FYSC, said: "We are obviously very pleased to be working on the next generation of robots. Over the past few years, we have already taken the first steps in creating self-healing materials for robots. With this research we want to continue and, above all, ensure that robots that are used in our working environment are safer, but also more sustainable. Due to the self-repair mechanism of this new kind of robot, complex, costly repairs may be a thing of the past."

Empa will focus on new flexible sensors and actuators that can be embedded into the self-healing polymers. Dr Frank Clemens, Group leader at the Laboratory for High Performance Ceramics, Empa, said: "In a first step, we will embed our piezoresistive soft material sensor fibres in the self-healing polymer to sense continuously the strain and to detect the region where self-healing process has to be activated. In a later step, other kinds of sensor and actuators will be integrated, depending on the final application."

ESPCI-Paris, where the first self-healing elastomeric materials were created, will also participate in the project. A spokesperson said: "We are excited to be part of this ambitious research project at the crossroads between soft matter physics, materials chemistry and information science. Soft robotics is an excellent opportunity for involving new materials."

Dr Bosman, from SupraPolix, said: "We feel privileged to be a partner in this consortium of Europe's top research groups on soft robotics. We are convinced that our self-healing materials can bring this field to the next level, thereby creating value for SupraPolix, robotics, and the community at large."

> "We will be using machine learning to work on the modelling and integration of these self-healing materials, to include self-healing actuators and sensors, damage detection, localisation and controlled healing.
>
> Dr Thomas George Thuruthel

Watch the video:
youtu.be/R7fZbYUFtc8
www.sherofet.eu

Credit: SpaceX

ALUMNI STORIES

Meet the principal rocket landing engineer at SpaceX

From a young age, Lars Blackmore was interested in space travel and had a goal to one day work on electronics for spacecraft. It's been a journey that's led him from studying Engineering at Cambridge to completing a PhD in Aeronautics and Astronautics at Massachusetts Institute of Technology (MIT), before going on to land engineering roles at both NASA and SpaceX.

From 2011 to 2018, Lars was responsible for the entry, descent and landing of SpaceX's Falcon 9 – the first orbital class rocket capable of reflight. He is now leading the entry and landing for Starship – SpaceX's next-generation, fully reusable rocket with room for up to 100 passengers. The destination? The Moon and Mars, of course!

We caught up with Lars for a chat about the world of precision rocket landing, his career to date, and why internships are so important.

I first became interested in rocket landing while working at the NASA Jet Propulsion Laboratory in California. My colleagues and I developed new techniques for precision landing on Mars. The idea was to give a Mars lander the sensors and algorithms it required to work out where it is and how to get to where it needs to be. This required new developments in the field of Guidance, Navigation and Control (GNC), which I specialised in at Cambridge and later in my PhD at MIT.

In around 2010, I heard that SpaceX was interested in making their new rocket reusable. It was already highly optimised for going into space, but not for coming back to Earth. To achieve this, SpaceX needed someone who understood how rocket landing worked (and in particular, someone with knowledge of precision rocket landing).

This became my job: figuring out how to turn a rocket – that only went up into space in one piece – into a rocket that could come back to Earth and be reused like an aircraft. This started out as mainly a GNC problem, but the scope quickly expanded once we realised we needed to make significant hardware changes to the rocket in order to make it land.

I was thankful to be able to lean on the General Engineering that I had learned at Cambridge. It was this foundation in General Engineering (Parts 1A and 1B), coupled with the ability to conduct novel research in my particular field, that enabled me to do my job as SpaceX's Principal Rocket Landing Engineer.

"The Falcon has landed"

How does it feel to be the person responsible for landing Falcon 9?

It's always exciting, and sometimes terrifying! From the moment the rocket lifts off there's nothing anyone can do, you just have to watch. In the early days, far too many rockets exploded. Sitting in mission control after an explosion trying to work out what happened was very stressful. But this job has given me more unforgettable moments than I could ever ask for: watching the first Falcon 9 land at Cape Canaveral, watching the first landing on a ship, and watching both of the Falcon Heavy side boosters land simultaneously.

The best part for me was when, as a team, we started to realise that landing was possible. We had all worked together to make a million individual breakthroughs and there was a moment when all these breakthroughs came together to show that, as long as everything on the rocket did what it was supposed to, we'd land. That was when it felt like everyone's work was eventually going to pay off, even though it still took us a few tries before it finally did!

I'm very proud of the innovations that have made landing possible, including adding steerable fins to the rocket and developing new algorithms for precision landing. There's a huge team behind these achievements – from those designing hardware on the rocket and the launch site, to those testing rocket engines, bringing the rocket home from sea, and ensuring the safety of landing for the general public. It has been a privilege to work with such talented people who have dedicated their all to landing Falcon 9.

Why did you become an engineer?

I always loved building things, especially electronic devices, and I had really great teachers at school that encouraged this. Even my fellow students started to appreciate what I could do after I invented the 'Teacher Detector', which used a pressure pad to give advance warning of when a teacher was approaching.

I was interested in space travel from an early age, especially the question of whether we are alone in the universe. Even now, this to me remains the most tantalising question of our time. Indeed, despite understanding vastly more about our solar system and our universe than we did 50 years ago, and despite discovering in the last few years an abundance of far-away planets that are similar to Earth, we still have no idea whether life exists elsewhere.

For years, I had hoped that I could work on electronics for spacecraft, but strangely I had no clue what an engineer did, or that being an engineer was the path to making that happen. It was only when I started looking at courses available at university did I realise that Engineering at Cambridge was the perfect fit.

Working for NASA seemed like an impossibly distant dream, until I spent my third year on exchange at MIT, where even undergraduates can work on satellites and rockets as a normal part of their education. It was then that I decided that being a NASA engineer was the path I wanted to pursue.

Making the most of internships

What is your advice for those considering a career in engineering who might be interested in following a similar route to you?

Engineering can be an amazing career, and I look back with sadness at the number of people from my year at Cambridge who switched from engineering to finance or consultancy and missed out on the opportunities that I had. Related to this, I think it's important to see engineering as more than a set of Tripos exams – extracurricular projects and good internships can encourage you to make real innovations and get excited about what's possible. It's amazing to see what undergrads can do on student rocket teams, race car teams, and undergrad research opportunities.

Internships are essential, especially if you can find one that will allow you to both make real contributions and prove to future employers what you can do. It is often surprising how much an intern can do under the right conditions. We have interns at SpaceX whose designs fly into space within a few months of their internship. I wish I had learned earlier that, to be successful, it's not enough to be excellent at what you do – you have to show the right people that you're excellent. Internships are a great way of doing that.

For people looking to go into the space business, it is unfortunately still very hard to work for any US aerospace organisation, including private companies and NASA, unless you have a US passport or Green Card. My route was to do a PhD at MIT, then try very hard to find someone to sponsor me for a Green Card. I will be forever grateful to the Jet Propulsion Laboratory at NASA for giving me that opportunity. I still tell people that this path is in no way guaranteed to succeed, but it is possible. There are also many European Space Agency centres, and some recent projects have been very exciting, such as landing on a comet or preparing to land a rover on Mars. This is an option that doesn't have the hurdles associated with US aerospace.

Never stop learning

What's next for Lars?

Sending people to the Moon and Mars! I'm now leading entry and landing for Starship, a fully reusable rocket that will one day be able to land up to 100 people on the surface of Mars. Because it lands vertically, like Falcon 9, it should be able to land almost anywhere in the solar system. The Starship's engines run on methane, this means we can refuel it using propellant generated on Mars and then fly back to Earth or fly further to more distant planets. The near-term goal is just to get Starship into Earth orbit and back with a 100% reusable vehicle, but even that is exciting, because the payload capacity will be far beyond that of any rocket that has ever existed – and with full reusability, the cost should be tiny compared to existing rockets.

For me personally, this is a great opportunity to continue learning, especially outside of my main field of expertise. Designing the rocket hardware from the ground up to be capable of landing, will require a much broader understanding of engineering, combined with all the lessons learned from landing Falcon 9. "Experience comes immediately after you need it," and many times I realised late in the game that our lives would have been much easier if we could have made simple changes at the start. This time around, I'm hoping to use that experience early in the design cycle, and perhaps save myself some grey hairs in the process!

Landing Starship will be much harder than landing Falcon 9, but if we can do it, it will be revolutionary. Let's see what happens!

Credit: SpaceX YouTube

↑ Lars celebrates the successful 2015 landing of the first stage of Falcon 9 back on Earth, following its delivery of 11 satellites to low-Earth orbit

Credit: Siemens

Electric roads will help cut UK road freight emissions, report says

Electrification of 7,500km of the UK's major road network would enable most lorries to be powered by overhead charging cables, resulting in dramatically reduced carbon emissions, a new report has found.

A team from the Centre for Sustainable Road Freight (SRF) – bringing together heavy vehicle engineering expertise from the Department of Engineering and logistics expertise from Heriot-Watt University and the University of Westminster and a consortium of industry partners – has proposed that building a so-called 'electric road system' could be used to decarbonise 65% of UK lorry kilometres travelled by 2040. The technology is not only feasible and scalable, but the infrastructure could be built at an estimated cost of £19.3 billion, using private finance. Full details are published in the White Paper entitled *Decarbonising the UK's Long-Haul Road Freight at Minimum Economic Cost*.

The report sets out the case for a nationwide rollout of the electric road system by the late 2030s, with the cost of the project (investment in electrification infrastructure such as catenary cables and substations) paid back over a 15-year period by charging hauliers for the electricity.

Powered by the national electricity grid, lorries driving on the inside lane would connect to overhead catenary cables through an automatic pantograph system – similar to those found on the top of electric trains. The electricity would power both the lorry's electric motor and recharge its on-board electric battery. The battery, which would be similar in size to an electric car battery, would enable the lorry to complete its journey away from the catenary system. Lorries would be free to leave the catenary wires to overtake, with the pantograph rapidly connecting and disconnecting automatically as needed.

The report's co-author David Cebon, Professor of Mechanical Engineering at the University of Cambridge and Director of the SRF, said there is now a clear trend towards battery electric vehicles for urban delivery. When combined with pantograph electric vehicles for long haul freight and a decarbonised electricity grid, it will be possible to achieve virtually zero greenhouse gas emissions – a move that is compatible with a zero carbon future.

"The economics are a triple win," he said. "The cost savings due to energy efficiency are sufficient to pay back the infrastructure investment in 15 years, the investment in pantograph electric lorries in 1.5 years, with enough left over for the government to replace its current income from diesel fuel tax with an excise tax on electricity sales."

The report suggests that work on the first phase of a four-phase programme could start with an £80 million pilot project in the North East of England, following in the footsteps of Sweden, Germany and Italy, where trials of electric road systems have already taken place. The trial would de-risk the policy, taxation, and implementation issues specific to the UK, prior to the first construction phase, which could start as soon as 2026.

> "The economics are a triple win. The cost savings due to energy efficiency are sufficient to pay back the infrastructure investment in 15 years, the investment in pantograph electric lorries in 1.5 years, with enough left over for the government to replace its current income from diesel fuel tax with an excise tax on electricity sales.
>
> Professor David Cebon

www.csrf.ac.uk

From left, Jack Levy, Fathima Nisha Begum Samad and David Cordova Jimenez

Engineering students' social impact recognised by the Vice-Chancellor

Some of our students are among the winners of the Vice-Chancellor's Social Impact Awards 2020. One prize went to a group of Masters students for their efforts in supporting Addenbrooke's Hospital during the COVID-19 pandemic, and the other prize was awarded to a student for his commitment to and involvement in sustainability projects.

Supported directly by the Vice-Chancellor of the University, Professor Stephen Toope, the Awards, organised by Cambridge Hub, took place virtually to recognise and celebrate exceptional achievement in social impact amongst the University's student population.

Among the winners of the Masters students' category were David Cordova Jimenez, Jack Levy and Fathima Nisha Begum Samad, who are all MPhil students in Industrial Systems, Manufacture and Management (ISMM) at the Institute for Manufacturing (IfM), part of the Department of Engineering. Together they applied their knowledge of industrial practices to assist the experts at Addenbrooke's Hospital and The Baker Lab at The Cambridge Institute of Therapeutic Immunology and Infectious Disease (CITIID), in streamlining testing for COVID-19.

"Dr Florian Urmetzer, our Course Director, worked closely with Addenbrooke's Hospital to determine where our skills and knowledge would be of most value and where we would have the most impact," said David.

"One of our tasks was to design and propose a layout of the new staff testing facility, where symptomatic or asymptomatic healthcare workers could be tested for COVID-19. What we created provided capacity for up to 300 tests per day.

"Another issue we tackled was the inconsistent flow of samples from swabbing stations to the labs, which was causing inefficient use of lab resources. After interviewing key personnel, carrying out observations, and applying industrial engineering tools, we created a production planning tool that used a series of algorithms to automatically create the most optimal test plan over a four-week period. We are pleased that our interventions have been successfully implemented and used at Addenbrooke's Hospital to maximise testing capacity.

"This experience has given us a great insight into managing the workflow of a temporary testing facility using academic laboratories. We have written a paper, supervised by Professor Stephen Baker, to design a testing framework so that other NHS trusts can replicate the successful procedures we have developed here to help speed up vital COVID-19 testing."

The team's nominator said: "The students have been involved in a wide number of tasks, such as optimising the swab drive-through testing facilities (front-end), planning layout changes' data management systems and optimising the labs for testing. They have been working with the The Baker Lab and Cancer Research Institute to help maximise capacity for COVID-19 testing. A report identifying the key issues of drive-through testing and a set of recommendations was submitted, and Addenbrooke's Hospital is implementing these straight away. This has also led to the manufacturing of key medical components for the machines used in the Quantitative PCR (qPCR) tests. Achievements include identifying opportunities and implementing changes to double the capacity of staff testing."

Meanwhile, Puria Radmard has been announced a winner of the Undergraduate students' category for his involvement in multiple sustainability projects across the University, including his work on the Cambridge Carbon Map. This is a project involving the local council and various other community partners across Cambridgeshire, which aims to plot the carbon emissions of buildings across the city.

Puria said: "It feels great to have won this award and I'm glad that I've been able to actively contribute to providing solutions to issues that are closest to me. I'm in an environment where the focus and hard work to do this, is fostered and supported by my colleagues. Going forwards, I'm looking to develop a career in machine learning and applying the cutting-edge technology in the environmental domain."

Puria's nominator said: "I first came across Puria volunteering as part of a group called The Sustainability App, whose main aim was to produce an app giving evidence-based advice on day-to-day sustainability choices to the student population. He has further been involved in the Cambridge Carbon Map and significantly, Puria has also been heavily involved in founding a group called ClimaTalk. It aims to facilitate national and international student conversations about climate change policy."

Professor Toope said: "We received extraordinary nominations and students showed great talent across all fields of endeavour, grappling with really difficult social issues. They showed creativity, commitment, of course, but also entrepreneurship. Our communities need ideas, they need the energy of students, perhaps more than ever before. It really is a difficult time and I think the resilience of our communities is being tested. So it is just marvellous to see the ideas that these students have generated."

Credit: Jude Palmer / Royal Academy of Engineering

↑ OVSI engineering team members embedded in the Whittle Laboratory

Cambridge engineers recognised with awards for pandemic service

Two teams of Cambridge engineers have been recognised by the Royal Academy of Engineering for their work during the COVID-19 pandemic with the President's Special Award for Pandemic Service.

The engineers, from the Institute for Manufacturing (IfM) and the Whittle Laboratory, were among the 19 winners announced in August 2020 for exceptional engineering achievements in tackling COVID-19 in the UK.

Open Ventilator System Initiative

The team behind the Open Ventilator System Initiative (OVSI) was recognised for their development of a high-performance ventilator for manufacture in low and middle-income countries that became the first intensive care quality ventilator to be manufactured in Africa.

In March 2020, as COVID-19 infection rates were rising dramatically in Europe, the number of infections in many low- and medium-income countries remained low. However, it was predicted that towards the summer of 2020 these rates would start to increase. This was especially worrying due to the low number of ventilators available in the developing world.

In response to these fears, a team at the University of Cambridge and a number of companies within the Cambridge cluster designed a high-performance intensive care ventilator for manufacture in low and middle-income countries. The aim was to develop a ventilator with a price point that was a factor of 10 lower than what was currently available, which could be manufactured in-country and from readily available components. The result was the first clinical grade ventilator to be manufactured in Africa.

An engineering team led by Dr Tashiv Ramsander at Cambridge Aerothermal Ltd was assembled at the Whittle Laboratory, and comprised people from several departments at the University of Cambridge and local companies including Cambridge Aerothermal, Beko R&D, Cambridge Instrumentation and Interneuron. Together, this multidisciplinary team was able to solve problems, such as the design of a pressure relief valve, inspired by the mixing nozzles on the Rolls-Royce Trent 1000 aircraft engine. The design removed flow instabilities, resulting in a more stable operation than any commercially available valve.

The clinically driven design was developed with the help of two senior intensive care clinicians with experience of treating COVID-19. They argued that a design for developing countries needed to be more versatile than the UK Government specification, with the final design able to operate in non-invasive, mandatory or patient-triggered ventilation modes.

For more than eight years, the Whittle Laboratory has been developing a rapid technology development process for the aerospace and power generation sectors. During the pandemic, this process was switched to develop a clinical grade ventilator within a week and allowing a rapid response to design changes driven by the pandemic, cost reduction and clinical demand.

The final Open Ventilator design can be manufactured mostly from standard parts, anywhere in the world that it is needed. This new design – the first intensive care quality ventilator to be manufactured in Africa – could prove to be a gamechanger when it comes to a host of conditions including pneumonia, as well as COVID-19.

There are very few ventilators in Africa, due to their high cost, inability to operate in harsh environments and a lack of local maintenance expertise. The team realised these problems could be solved by manufacturing the equipment in Africa. The Cambridge engineering team assembled a wider manufacturing team that includes Defy and Denel Land Systems in South Africa, Beko R&D and Prodrive in the UK and Arçelik in Turkey. This team delivered the first 20 preproduction ventilators in South Africa in June 2020.

"The result is a design that will save countless lives in the developing world where ventilators are scarce and many that exist cannot achieve the quality of performance that the Open Ventilator offers," said Professor Richard Prager, Head of the Department of Engineering. "It is a scalable solution. The high-performance open-source design will enable companies across the world to make systems wherever they are needed, and at a price that is compatible with the local healthcare systems."

Institute for Manufacturing

The IfM team, led by Duncan McFarlane, Professor of Industrial Information Engineering, helped local hospitals to make the best use of their resources, streamlining logistics for sourcing and storing vital personal protective equipment (PPE), informing decision-making on emergency demand, and developing a ventilator sharing system to be used in emergencies.

Working with clinicians and senior healthcare managers to assess the immediate and emerging operational challenges facing local hospitals, staff and students identified where these could be addressed through the application of engineering capabilities and coordinated the roll-out of solutions.

The IfM team addressed three groups of tasks between March and May 2020 in the areas of hospital logistics, PPE delivery and intensive care unit (ICU) equipment development.

In the hospital logistics area, the team applied industrial engineering approaches to COVID-related challenges including

Credit: Jude Palmer / Royal Academy of Engineering

↑ Duncan McFarlane, Professor of Industrial Information Engineering at the IfM

modelling in-hospital patient flows, redesigning COVID-19 testing procedures and managing oxygen supplies to the wards.

Understanding oxygen flow through the local hospital involved examining pipes and their layout, then analysing usage by ventilator type and patient need, as well as modelling supply and demand. The in-depth work of the IfM team enabled the hospital's clinical and estates teams to identify and address various bottlenecks and improve operational efficiency.

The team also looked at the design, setup and management of a temporary logistics hub for coordinating the delivery of millions of items of donated PPE and assessed the production capabilities of local manufacturers to increase flexibility of PPE supplies for local hospitals.

In conjunction with anaesthetists at Royal Papworth Hospital, they also devised an active ventilator sharing system in case there were not enough ventilators available during the COVID-19 outbreak. This involved the accelerated design, prototyping and in-hospital testing of an active ventilator sharing system in just four weeks.

In addition, the IfM provided analytical approaches for informing decision-making at Cambridge University Hospital (CUH) on emergency demand. The Trust is also using the team's findings to forecast changes to demand for beds, equipment and staff when social distancing measures are relaxed or modified further. The Hospital said the engineers brought diversity of perspective and a joint CUH–IfM panel has been initiated so that the hospitals and the IfM can continue working together for mutual benefit after the pandemic.

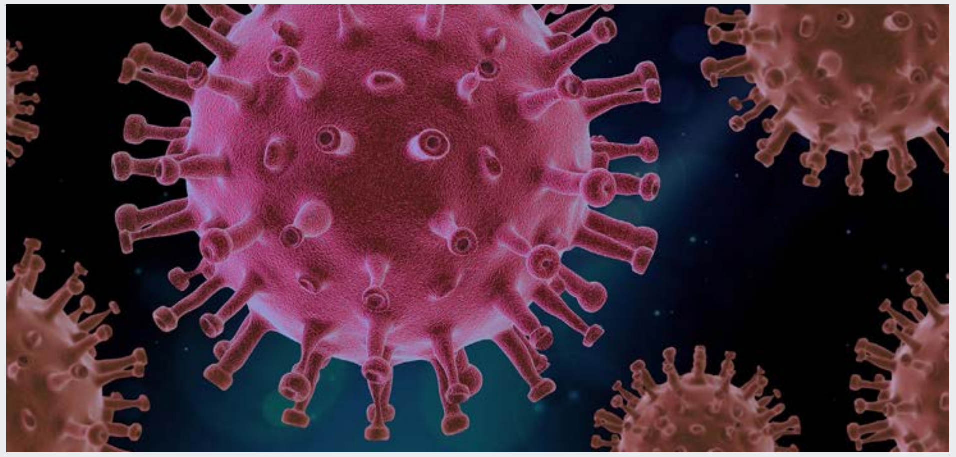
"The team gave key support efficiently and skilfully when it was most needed, with no fuss and maximum impact: engineering at its best," said Professor Prager. "The team found a way to work with the clinicians without taking up too much clinical time. They found the problems that needed solving and got on with solving them. They stepped up when they were needed and made a real difference. For this, we should be proud of them."

Professor Tim Minshall, Dr John C Taylor Professor of Innovation and Head of the IfM, said: "It makes me so proud to see the way in which our students and staff – academic, research and administrative – were able to rapidly understand and help address the operational challenges facing the amazing teams at Addenbrooke's and Royal Papworth during this crisis. We are also delighted that there is such enthusiasm from both CUH and the IfM to build upon this experience and to develop ongoing collaboration in applying industrial engineering capabilities to healthcare system needs."

> *It makes me so proud to see the way in which our students and staff were able to rapidly understand and help address the operational challenges facing the amazing teams at Addenbrooke's and Royal Papworth during this crisis.*
>
> Professor Tim Minshall

→ Coronavirus

How machine learning can help to future-proof clinical trials in the era of COVID-19



Credit: pixabay

The COVID-19 pandemic is the greatest global healthcare crisis of our generation, presenting enormous challenges to medical research, including clinical trials. Advances in machine learning (ML) are providing an opportunity to adapt clinical trials and lay the groundwork for smarter, faster and more flexible clinical trials in the future.

In an article published in *Statistics in Biopharmaceutical Research*, an international collaboration of data scientists and pharmaceutical industry experts – led by the Director of the Cambridge Centre for AI in Medicine, Professor Mihaela van der Schaar of the University of Cambridge – describes the impact that COVID-19 is having on clinical trials, and reveals how the latest ML approaches can help to overcome challenges that the pandemic presents.

The paper covers three areas of clinical trials in which ML can make contributions: in trials for repurposing drugs to treat COVID-19, trials for new drugs to treat COVID-19, and ongoing clinical trials for drugs unrelated to COVID-19.

The team, which includes scientists from pharmaceutical companies such as Novartis, notes that 'the pandemic provides an opportunity to apply novel approaches that can be used in this challenging situation.' They highlight the latest advances in reinforcement learning, causal inference and Bayesian approaches applied to clinical trial data.

The researchers considered it important to present the current state of the art in ML and to signpost how they used ML, not only to address challenges presented by COVID-19, but also to take clinical trials in general to the next level, making them more efficient, robust and flexible.

In their paper, the researchers say that COVID-19 is:

- Reducing the ability/willingness of trial subjects and staff to access clinical sites, disrupting timely data collection or necessitating a move to virtual data collection.
- In some situations, causing delays or halting of clinical trials altogether.
- Revealing how the standard approach to clinical trials – time-consuming and inflexible randomised controlled trials in distinct trial phases – is inefficient, and not sufficient in a crisis such as this.

However, they say that ML can:

- Support in the creation of 'virtual' control groups. By integrating data across hospitals, data-driven methods can identify patients who have received standard treatments but are otherwise similar to patients who have received experimental treatments.
- Extract knowledge from the data of clinical trials suspended as a result of the pandemic to adjust design elements such as recruitment plans, sample sizes and treatment allocations.
- Improve the design, execution and evaluation of large, adaptive clinical trials for evaluating repurposed medications for COVID-19. Trials such as Solidarity (WHO 2020) and RECOVERY (Oxford 2020), which are underway, recruit patients at a multitude of sites randomly assigned across available treatment arms.
- Play an important role in finding patterns and signatures in COVID-19's biomolecular behaviour, facilitating the identification and repurposing of existing drugs, as well as validating, in silico, whether new medicines may be effective.
- Exploit the large body of data generated by the experimental and compassionate use of drugs to treat COVID-19 to select future drug target for further clinical trials. ML methods for causal inference from observational data are especially well-suited to this task.
- Break the multi-phase paradigm of standard randomised controlled trials (RCTs) and convert the trial process into a more efficient, continuous and adaptive trial-collection-retrial loop. Use ML methodologies to learn simultaneously about toxicity and efficacy of a new drug, reducing learning time, making it particularly useful for time-sensitive clinical trials of COVID-19 treatments.

"The coronavirus pandemic represents the greatest global healthcare challenge of our generation," said Professor van der Schaar. "Now, and in the immediate future, the need is to identify, approve and distribute treatments and vaccines for COVID-19. Our recent work in ML for clinical trials has shown enormous promise. And while many of the technical issues discussed in our paper are particularly acute in the context of a pandemic, they are also highly relevant to ongoing clinical practice. It is my hope that ML will not only improve the execution and evaluation of clinical trials in the COVID-19 era, but also well beyond that."

https://ccaim.cam.ac.uk

Professor awarded the 2020 Rodney Hill Prize in Solid Mechanics

The International Union of Theoretical and Applied Mechanics and Elsevier jointly announced the award of the 2020 Rodney Hill Prize in Solid Mechanics to Professor Vikram Sudhir Deshpande.

Vikram Deshpande is Professor in Materials Engineering at the Department of Engineering. After obtaining a BTech from the Indian Institute of Technology, he moved to the University of Cambridge, where he received his PhD in Engineering in 1998.

During his distinguished career, Deshpande has made seminal contributions in mechanics of materials, ranging from the design of micro-architectured materials to modelling soft and active materials. He is the world-leading authority in his generation in the emerging subject of microstructural mechanics. His research output is prodigious, with a steeply rising profile, and he combines deep theoretical understanding with insightful experiments to unravel complex phenomena over a wide range of topics. These range from the impact on structures by the shock waves within a sand blast to the role of entropic forces in cell mechano-transduction.

A number of high-profile international researchers have worked with him, and in many of these collaborations he took the intellectual lead. Deshpande's breadth of interests, theoretical and experimental skills, and general influence on solid mechanics research worldwide make him one of the strongest contemporary contributors to the field.

An interview with Professor Vikram Deshpande:

Please tell us about your career path to date.

I was an engineering undergraduate at the Indian Institute of Technology, Bombay. I came to Cambridge as a PhD student with Professor David Cebon in 1994. My research field was quite different in those days. I was in the Transportation Group, but I started working on problems in Materials. My work with David laid the foundation for my research career. After my PhD I got a Research Fellowship at Pembroke College and that is when my collaboration with Professor Norman Fleck started which has continued extensively to date.

I spent a few years in the USA, a sabbatical at Brown University and another stint at the University of California at Santa Barbara. But other than that I have been mostly based here at Cambridge. I was appointed a lecturer in 2001 and promoted to Professor in 2010.

During my career, I have changed my research subjects a few times. I started in the Transportation Group, but I moved more and more into materials and mechanics. In mechanics, I first started in more traditional areas e.g. energy absorbing materials, foams, engineering solids, with applications for things like blast protection and lightweight structures. Over time, I moved into small scale materials looking at things from an atomic perspective and more recently it has been mainly biological topics.

The theme of my current research is the coupling of chemistry, biology and mechanics. Biology is a wonderful example where living systems, living cells, are doing chemical processes constantly, but they are being modulated by mechanical forces in a very interesting way. This is where most of my current work is.

What inspired you into your field?

Curiosity. Something catches my imagination and I think that maybe I can tackle that problem, this is what inspires me. I started my career in transportation, then I moved to materials as I saw that there were some interesting problems there. Similarly, the more recent shift into biology has been because there are so many unanswered questions with so many counter-intuitive things happening in living systems. This is what has really inspired my move. It is curiosity that really drives me.

What contribution to your field are you most proud of and why?

The things I am most proud of include my initial work with Professor Norman Fleck on micro-architectured materials. We started looking at lightweight topological design of materials using civil engineering as the motivator to design new materials. This was 20 years ago and that field has really evolved since those early days. Today it is one of the largest fields in Materials Science, they now call this field 'Materials by Design'. I am proud of this as we got into this research before anyone else, it is good to know that people caught onto our initial ideas.

Of my more recent research, it is too early to say whether it is going to catch on or not. Biological problems are extraordinarily complex, applying an engineering approach can simplify them to a level that they become tractable, as opposed to trying to understand all the complexity. If there is anything that engineers like me are bringing to this field, it is asking the question: "Do we really need to understand this system in all its complexity or can we simplify it to a level where it becomes tractable?"

What do you see as being the next big thing in your field?

The area that I am working on is the coupling of mechanical sciences, chemical sciences and biological sciences. I believe it is at the interface of these subjects that the next big breakthroughs are going to happen, and this is why I have placed myself at these interfaces.

ALUMNI UPDATE

Dr Ivor Day

Dr Ivor Day (FREng) has worked for 11 years in Industry and a further 36 in research. He has helped develop a new low emissions combustion system for Rolls-Royce Industrial gas turbines and is now working on by-pass duct aerodynamics. He is a Fellow of the Royal Academy of Engineering, has received the George Stephenson Prize, the Henry Royce Best Patent Award and the American Society of Mechanical Engineers' highest award in the field, the Gas Turbine Award, a record six times.

Ivor talks about his time at the Department's Whittle Laboratory.

My youth was spent outdoors riding a bicycle and playing with gunpowder. Later I went to university in Durban and was given a scholarship to study ship building in England. I managed to persuade the trustees of the scholarship that studying jet engines was more important than ship building. This is how I ended up in the Whittle Lab for the first time. After completing my PhD, I returned to South Africa to work in the power generation business.

My second sojourn in the Whittle Lab started eleven years later, when I was offered the chance to work on the active control of stall and surge in jet engines. The intention was that I would spend three years at the Lab and then return to my former job. The "return" never happened; I am still working at the Whittle Lab 32 years later.

My time at the Whittle Lab has mostly been taken up with experiments. Doing experiments is always exciting – except when the sponsor sends someone to stand over you with a Gantt chart! Some experiments are exciting because they are physically dangerous and get your adrenalin going – these experiments are of the 'stand back and hope nothing goes wrong' type – like starting up a new compressor for the first time. Other experiments are of the high expectations type where, after months of preparation, you switch on the test rig and in the space of a few minutes you know if your long-cherished theory is right or wrong. Useful, though often less exciting, are experiments where detailed measurements are required to verify computational predictions. Even with this type of experiment, there is always a chance that the measurements will lead to a "eureka moment" and something that has been a mystery for years will now have a logical explanation.

When I started in the Whittle Lab, it had only been in existence for three years and was still settling down. There were about a dozen students, a handful of staff members and lots of empty laboratory space. Forty-five years later we have fifty to sixty students, ten staff members and virtually no free space. The Lab has always had an excellent crew of technicians and an enviable ratio of technicians to students. This means that the standard of experimental research at the Whittle Lab is second to none. From a social point of view, the Lab has always been a very friendly place with the experienced students helping the newcomers and with staff doors open at all times. In addition (pre-COVID times), there is the famous Whittle Lab tea table around which all gather for morning and afternoon tea – birthday cakes often add to the atmosphere.

Another thing that makes the Whittle Lab such a special place is the type of work that we do. Most of our research is sponsored by industry, with the projects directly linked to real problems – like low efficiency and environmental impact. From my own perspective, all my experimental work has been supported by Rolls-Royce, which means that I have worked on some interesting and sometimes crucial projects. I started out looking at the aerodynamic stability of aero-engine compressors (i.e. stall and surge) and then set about applying the new science of active control to these instabilities. This was an exciting time with big lab experiments and tests on real engines. After this came an unexpected project associated with unsteady combustion in power generating turbo-engines. In these engines, vibrations driven by the combustion process were often so severe that the engines had to be restricted to part-load operation. The result was financial penalties. A hectic project ensued which fortunately ended with a working solution and a patent for a new fuel/air mixing device.

In recent years, I have worked on the effects of heavy rain on aviation engines and have studied ways of getting rid of water once it has entered the engine core. In an ongoing study we are also looking at ways of reducing the adverse effects of sand and volcanic ash. More recently, I have been involved in a project aimed at reducing traffic emissions in urban areas by using battery driven air-taxis. These machines will need ultra high lift propellers and this has been the focus of my work for the past 12 months. All in all, I have thoroughly enjoyed my time at the Whittle Lab.

→ Ewan Kirk with the student team working on an idea to make sustainable bricks for the construction of buildings using recycled waste plastic

Students challenged by Cambridge alumni to boost economic growth in the developing world through new engineering ideas

The Department has teamed up with Dr Ewan Kirk and Dr Patricia Turner to challenge our undergraduates to help kickstart economic growth in the developing world through the development of new engineering ideas.

The Kirk Global Challenge, which was launched last year, will disburse research grants to undergraduate teams within the Department, to help them develop innovative new technology that can be used to help improve growth and solve infrastructure problems in less developed economies.

The Challenge was launched by Cambridge alumni Dr Ewan Kirk and Dr Patricia Turner, both of Queens' College, who provided a £20,000 philanthropic gift to the Department through the Turner Kirk Trust, a family foundation that supports STEM, early childhood development and conservation causes, and a long-term benefactor of the University.

Economic growth and development in many emerging economies is held back by poor infrastructure, lack of roads, ports, railways and airports, and unreliable electricity, energy and telecoms supply. In the past, it has been difficult to tackle many of these issues because of the unique engineering challenges of working in developing world environments. But, in many cases, if these bottlenecks were unlocked with pragmatic new engineering solutions, it would boost growth locally as well as create new jobs.

The Kirk Global Challenge seeks to engage students with these key problems and will fund them to develop radical, unique ideas that have the potential to solve one or more of these problems through engineering.

One of the student teams (pictured) being funded by the Kirk Global Challenge is currently working on an idea to make sustainable bricks for the construction of buildings using recycled waste plastic. The students have designed and manufactured a prototype and are now testing its usability and scalability.

Speaking at the launch last year, Ewan Kirk, Co-founder of the Turner Kirk Trust, said: "I have worked with technology all my life, and I have seen the transformative impact it has had on our economy and the lives of people. I am certain that if we get incredibly talented engineers thinking about the challenges facing the developing world, they will come up with new inventive ideas that we have not even thought about before."

The Challenge will fund six undergraduate teams across this academic year. To be granted funding, the teams will need to demonstrate that their engineering ideas not only solve a genuine, current need, but can be practically implemented on the ground in the developing world at a pragmatic cost and that it will have a quantifiable, large-scale impact. They will then present their ideas and prototypes to a judging panel of academics and other industry experts at the Department's Expo Day later this year.

The winning team will have the opportunity to develop their ideas further and will eventually take them into the field, as well as visit the areas their research projects are designed to support.

The Challenge is being led by Reader in Mechanics of Biological Materials at the Department of Engineering, Dr Alexandre Kabla. He said: "We are delighted to launch the Kirk Global Challenge with the support from Ewan and Patricia. We really want to encourage students to tackle challenges facing the developing world and to bring forward proposals that have the potential to achieve meaningful change. This generous donation will give our students the opportunity to bring their ideas to life in an experimental but purposeful way."

If you are interested in supporting research, teaching and the next generation of engineers please email victoria.thompson@admin.cam.ac.uk

The engineering student who gets his kicks from playing with the Pythons

Credit: Nick Saffell

Meet Gurkiran Singh Jolly – a running back with the University of Cambridge's American Football Club – who is learning about jet engines and who helped lead the Sikh Society.

If you'd asked me what I'd be doing at University a couple of years ago, I definitely wouldn't have said playing American Football and founding the Sikh Society. I thought I'd just be here for my engineering degree.

I'd never played American football before I came to Cambridge. I didn't even realise it was a sport played at universities until I saw the Pythons' stall at the Freshers' Fair. At the taster session, I realised I could catch quite well, so I decided to stay on.

I'm a running back—this means I get the ball and run up the field as far as I can, trying not to get hit! When the quarterback is passing the ball, my job is to block anyone who is trying to get to him.

I thought the Pythons might be intimidating but actually everyone is really down to earth and welcoming. You go through so many emotional highs and lows together that you form a close bond really quickly.

Training is a good way to unwind from academic studies. When you're playing, your mind has to be on the game so you're distracted from everything else that's going on.

I'm also a past President of the Sikh Society (CUSikhSoc). We connect Sikhs across the University and Anglia Ruskin University, as well as our alumni. Not all Sikh students know about us, so a large part of my role as President was to get the word out about the society. We also aim to teach people about Sikhism.

At the very centre of a Sikh's belief is the concept of *Langar*. In each and every Gurdwara (Sikh place of worship), there is a *Langar* kitchen, all run by volunteers. In essence, we provide a free meal to anyone, regardless of their background. *Langar* originated at the time of the Gurus. The first Guru, Guru Nanak Dev Ji, encouraged all people—from the richest of the rich to the poorest of the poor—to sit on the floor together and break bread. The message was that, for a Sikh, humility, generosity and good deeds are just as important and prayer and spirituality.

We thought it would be nice to give back and in a sense 'practice what we preach'. We went to the Gurdwara one Friday evening and, with the help of the volunteers there, made curry and rice to give out to the people who are homeless in Cambridge.

Out on the streets I felt so proud of what we were doing. People were very friendly. Many were keen to learn about who we were, as Sikhs, and about *Langar*, and they were appreciative of a simple conversation, let alone the food.

It was nice to be able to give, not only a meal, but a hot, freshly cooked meal. I think it makes the difference when you've paid for something in time rather than money—you have a more personal connection with the person you are helping. At the end of the evening everyone was tired but very happy. We all want to do it again.

There wasn't a specific point that I decided I wanted to be an engineer, it was more a natural progression. My parents really made me love learning. I remember my dad giving me an electronics kit with magnets—maybe this is why I'm really into electronics right now. Growing up in North London I'd always loved science. As I got older and the equations I learnt about became more intricate, I developed a passion for maths.

The first lab you do as an engineer at Cambridge is essentially playing with Lego. I don't know if Lego causes someone to love engineering or vice versa—but there's definitely a strong connection. Recently we've been learning about jet engines that were invented by Sir Frank Whittle, an alumnus of Cambridge Engineering. To think that I'm part of a University that has changed the world is amazing to me.

So many breakthroughs and advances in science and maths have happened here. When I first visited Cambridge on an Open Day I was mesmerised and immediately fell in love with the place.

Coming here as a student, I was no longer just looking on in wonder at all that has happened here—I was part of it myself. Studying here, you feel you have the potential to become part of the legacy Cambridge has left.

To everyone thinking of applying I'd just say: "apply!" If you don't apply you know you won't get in, so why not take the shot?

Written by Charis Goodyear

→ Helios Prize medal

Credit: William Playford

Department launches new prize for graduate research thanks to generous donation

The Helios Prize has been made possible thanks to a generous donation from Cambridge alumnus John Firth. He approached the Department specifically to set up the prize in honour of graduate work in sustainable energy or energy efficiency, and asked that the prize be named after Helios, because the world's renewable energy is fundamentally driven by solar energy.

The winners of the Department's inaugural Helios Prize in 2019 were Amanda Smyth and Lachlan Jardine, PhD students in the Whittle Laboratory, for their co-authored conference papers: *Three-Dimensional Unsteady Hydrodynamic Modelling of Tidal Turbines* and *The Effect of Heat Transfer on Turbine Performance*, respectively. The runner-up was Jeremy Watson, PhD student in the Control Group, for his co-authored research paper titled *Optimized Dispatch of Energy Storage Systems in Unbalanced Distribution Networks*.

The winner of the Department's Helios Prize 2020 is Matteo Craglia and the runner-up is Krishnan Chana.

Matteo Craglia, final year PhD student looking at energy efficiency in the transport sector, won the prize for his paper: *Do technical improvements lead to real efficiency gains? Disaggregating changes in transport energy intensity*.

Matteo summarises his paper: "Improving the energy efficiency of vehicles is urgent if the UK is to reduce its demand for fossil fuels and combat climate change. In this paper, we test whether policies aiming to improve the energy efficiency of British cars have been successful, using driver-reported data for the first time. This is particularly important now that it is increasingly clear that official fuel consumption values reported by vehicle manufacturers are unrepresentative of the real-world driving conditions reported by consumers.

"We firstly show that the real-world fuel efficiency of new cars in Great Britain has improved by far less than widely reported. Using a new method combining multivariate regression and decomposition techniques, we present estimates of the technical efficiency improvements in vehicles between 2001 and 2018 (from e.g. improved combustion, aerodynamics and lightweight materials). Rather than reducing energy use, we show that two thirds of these technical efficiency improvements were offset by increasing vehicle size and power. Strong policies are therefore necessary to ensure technical improvements lead to real energy savings."

Krishan Chana, final year PhD student studying at the Department's Whittle Laboratory, won the prize for his paper: *The Effect of Reaction on Compressor Performance*.

Krishan summarises his paper: "During my PhD, my research has focussed on jet engine aerodynamics. In the field, little is known about the effect of the centrifugal force on rotating compressor blades. The paper develops a unique model in computational fluid dynamics which allows us, for the first time, to understand the effect rotation has on jet engine performance independent of other effects. What I have enjoyed most is being able to use a variety of mathematical tools and computer programs to create a novel solution to a problem that has not been understood before. I have collaborated with designers at Rolls-Royce plc. to implement the work in the analytical routines they run daily, which could significantly improve performance predictions made by their preliminary design systems.

"The work also lays the foundation for the development of a third generation of three-dimensional compressor blades. The Whittle Laboratory is responsible for developing the first two generations of compressor blades, which have involved the redesign of the stationary compressor blades. This third generation could allow the redesign of the rotating blades, likely to have a major impact in reducing CO_2 production globally. Addressing the pathway to climate change is something I am passionate about. In light of the annual funding gap of $2.5 trillion identified by the UN to achieve the Sustainable Development Goals, I am excited to continue to work on developing models to identify new opportunities in this area."

John Firth inspired the researchers with the thought that even a seemingly insignificant step in a research lab can ultimately have a profound effect on the generation of sustainable energy in the future, once it is implemented and rolled out across the world.

Professor Richard Prager, Head of the Department of Engineering and part of the judging panel, said: "It's wonderful to have a prize like this dedicated to research in sustainable energy and energy efficiency – a topic of great magnitude and significance, both to the University and to the whole of society. Many branches of Engineering in our Department are able to contribute in one way or another and we have several significant groups in the field already. This annual prize will help to build up enthusiasm and focus our research in this area."

All the winners received a cash prize and a brass medal depicting the Greek sun god, Helios (pictured above).

If you are interested in supporting research, teaching and the next generation of engineers please email victoria.thompson@admin.cam.ac.uk

Winners of the Department's Photography Competition unveiled

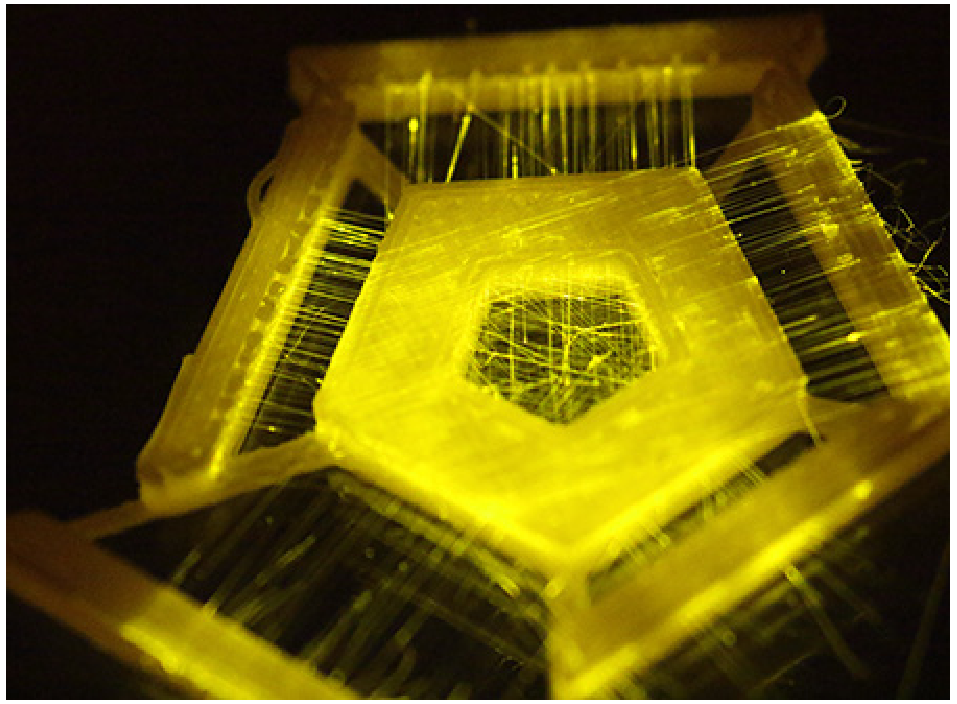
Imagery and video capturing 3D-patterned electrospun fibres, the real-time application of deep learning to a 'dancing man', and the flow structures and acoustic waves of a turbulent jet from an aeroengine, are among the prize-winning entries in the Department's 2019 ZEISS Photography Competition.

Sponsored by ZEISS (Scanning electron microscopy division), the winners of the Department's annual photography competition are announced as follows:

First Prize →

Awarded to PhD candidate Elisabeth Gill for her macro photo of complex fibrous architectures that can be designed with an electrospinning and 3D printing method that Elisabeth developed for her PhD. 3D-printed support pillars and applied voltage are used to pattern suspended gelatin microfibres with a technique called low-voltage electrospinning patterning.

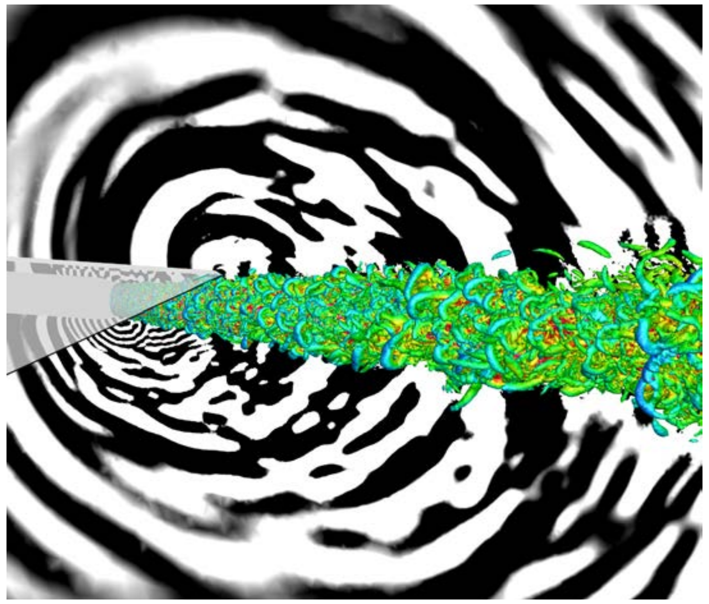
Elisabeth said: "Being able to design free-spanning protein fibres is of interest for tissue engineering as they can act as a simplistic template for cells to assemble into tissue-like structures. We have utilised such structures to observe the migration of cancer cells in 3D, which models aspects of the environment the cells encounter in the body. A motivation is to develop such models further for fundamental cancer research or as a drug screening application."



Second Prize →

Dr James Charles, Senior Research Associate in Human Pose Estimation and Tracking in Video, won Second Prize with his video demonstrating the real-time tracking and segmentation of a 'dancing man', resulting from his research group's real-time deep learning based system.

Dr Charles said: "When applied to video, tracking of individual people and their clothing items/body parts is accomplished by matching segments together along a temporal sequence. Our algorithm is also quite efficient and able to run in real-time live on a mobile phone. Such systems have many applications e.g. in making self-driving cars aware of the motion and behaviour of pedestrians."



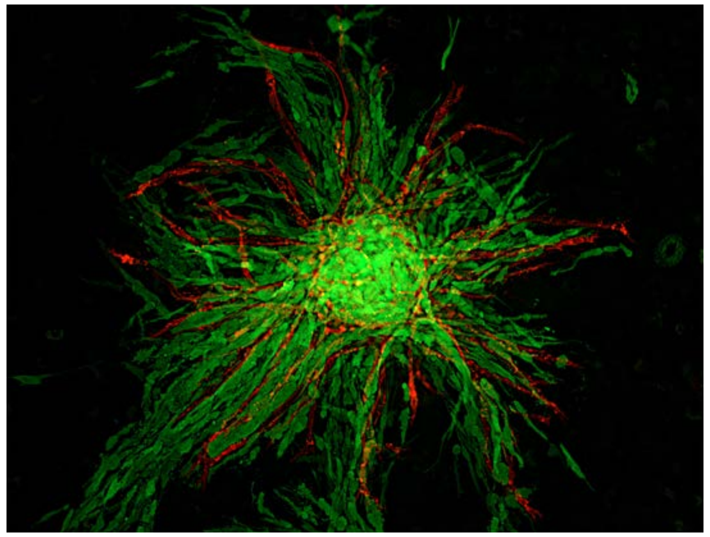
Third Prize ↑

'Turbulence and Sound' won Third Prize. This flow-acoustic simulation by Dr Zhong-Nan Wang, Research Associate in Computational Fluid Dynamics, shows the noise generated from a turbulent jet interacting with a surface. The coloured isosurfaces show the turbulent structures and the background grey-scale contour shows the acoustic waves.

Dr Wang said: "This is a flow-acoustic model for a modern aeroengine installed under a wing, revealing the installation noise generation mechanisms. In addition to the noise generated by the jet itself, a new sound source is produced by the jet-surface interactions with strong acoustic waves emitted at the surface trailing edge. The challenge is to reduce the level of this noise source."

The panel of judges for the 2019 Photography Competition included Roberto Cipolla, Professor of Information Engineering; Allan McRobie, Professor of Structural Engineering; Dr Kenneth Png, Senior Applications Engineer at ZEISS Microscopy Customer Centre Cambridge; Professor Richard Prager, Head of Department; and Philip Guildford, Director of Strategy and Operations.

Philip Guildford said: "These wonderful images show that Engineering has no boundaries – it reaches into all aspects of our world bringing understanding, progress and practical benefits."



Microscopy Prize ↑

Awarded to PhD candidate Agavi Stavropoulou-Tatla for an image of a mini brain tumour (tumouroid) with blood vessels grown in the lab. Tumouroids can be used to study the interaction between brain tumour (glioblastoma) cells and blood vessel forming (endothelial) cells, offering a robust platform for the development of personalised therapies.

Agavi said: "This type of brain tumour, glioblastoma, is able to grow so quickly because it has the power to produce new blood vessels when needed. Moreover, it is highly infiltrative, and this is partially because tumour cells use blood vessels as 'highways' for their migration to different parts of the brain. Thus, this biomimetic model could provide insight into the mechanisms that drive tumour new blood vessel formation and invasion along blood vessels, and serve as a personalised tool for targeted drug testing."

Head of Department Prize ←

An image taken of a world record-breaking Science, Technology, Engineering and Mathematics (STEM) outreach project, involving 88 primary school children, has secured the Head of Department Prize. Fran O'Neill Sergent, Design and Multimedia Producer for the project, 88 Pianists, captured a close-up image of one of the 88 mechanisms designed by children in order to allow 88 individuals to play the same piano at the same time – one person/mechanism for each piano key – from seven metres away. The mechanisms thought up by the children included giraffe and unicorn-inspired designs, which can be seen in the background of the image.

Fran said: "88 Pianists began life as an exercise in inspiring young children to become engineers and evolved into those children inspiring us. This photograph was taken two days before the world record-breaking performance in Birmingham. The world record was smashed by 88 pianists, 40 engineers and 2,500 primary school designers. I'm incredibly proud to have played a creative role in this project, which has had a profound impact on inspiring imagination in our wider work in climate change mitigation. I look forward to working on the development of our next exciting STEM engagement opportunity."

All of the photo and video entries can be seen on the Department' Flickr and YouTube pages:
www.eng.cam.ac.uk/Flickr
www.eng.cam.ac.uk/YouTube

Alumnus creates the perfect espresso using jet engineering

Credit: (product photo) Jonathan Knowles

The first jet-engineered stovetop espresso machine, developed by a Cambridge alumnus, uses a new thermodynamic system to create high pressure brewing conditions.

It was during his PhD in the Department's Whittle Laboratory eight years ago that William Playford's idea for 9Barista was borne. Inspired by his love for good coffee and his passion for jet engineering, William set about to create a new kind of stovetop espresso machine that could make the perfect coffee at high pressure, under controlled temperatures, and with precision engineered components to match – the same three elements required by a jet engine.

9Barista uses a unique, patented, twin-boiler system. One boiler sets the brewing pressure, while the second regulates the brewing temperature. It has no electrical components, and a spring-loaded valve is its only moving part.

In 2019, William launched 9Barista on global crowdfunding platform Kickstarter, and within just four days he had reached his funding target. The first batch of 170 machines were delivered to customers in December 2019. Since then, orders for a further 2,200 machines have been made through the online shop, and a further 1,500 machines are now at various stages of production. Around 90% of the machine is produced in the UK and William says that 85% of his machines are now exported internationally. The machines are being assembled and tested in Cambridge.

"The way 9Barista produces brew water at just the right pressure and temperature (9bar and 93°C) is completely new," he said. "It is a very simple system with no electronics and one moving part, and this is what excited me about the design. I wanted to design a small, portable machine that had the simplicity and robustness of a traditional Moka pot, but with the performance of a high-end café-style espresso machine, at a price substantially lower than the leading brands."

Life in the Whittle Laboratory

For his PhD titled *Well Conditioned Heat Transfer measurements on Engine Scale Gas Turbine Rigs*, William developed a measurement technique using infrared cameras that was used to measure heat transfer in an EU-funded (FACTOR framework) research turbine facility. The results from the measurements were used to fine-tune designs for lean-burn combustors in gas turbine engines, the overall aim being to reduce environmentally harmful nitrogen oxide (NOx) emissions.

"I gained a lot of experience in instrumentation during my PhD, which was helpful for measuring the performance of some of the early 9Barista prototypes," he said. "The Whittle Lab also has a fantastic workshop, and some of the later production samples were manufactured on Whittle computer numerical controlled (CNC) lathes and milling machines.

"In the Whittle Lab, we do lots of work which involves measuring temperatures and pressures in jet engines (or at least models of jet engine components, in wind tunnels). Computers are usually used to log and analyse these measurements, in order to help spot interesting correlations. I used similar tools and techniques to analyse several espresso machines on the market. That helped build up an understanding of how water pressure and temperature affect espresso quality.

"Several of the 9Barista prototypes were also heavily instrumented in this way, and the measurement results were fed back into computer simulations of the coffee machine. The main objective was to understand how the machine was behaving, so that I could find ways of increasing the precision in the water temperature and pressure, whilst also making the machine produce a coffee faster.

"The Whittle Lab is really good at supporting 'home projects' which aren't strictly related to the lab function. I think that's one of its great strengths and definitely something that makes it a fun and interesting place to work," he added.

An engineering mindset

William is no stranger to designing products and has a history of taking on engineering design projects at home for fun, including rocket engines, jet engines, a remote control hovercraft, and even a lawnmower engine powered tricycle.

"It's very exciting to see my idea for 9Barista come to fruition," he said. "It's taken a long time to develop it; the first sketch of the idea was back in 2013. During that development time there have been lots of really challenging engineering problems to solve, so I think one of the most pleasing things for me is to see all those solutions reliably working together, in what appears to be a very simple machine."

www.9barista.com

Honours, awards and prizes

Medical Research Council Fellow

Dr Flavia Mancini has been announced a Medical Research Council (MRC) Career Development Fellow and will establish her first independent research group, tasked with improving our understanding of the brain mechanisms that mediate pain.

The aim of Dr Mancini's Career Development Award is to understand how the brain computes and tries to control the evolution of pain over time. To do this, she will use a combination of mathematical models, behavioural and neuroimaging experiments in humans, to discover how the brain functions when we feel pain.

Clean Sky Academy Award

Dr Pedro Magalhães de Oliveira is a winner of the Clean Sky Academy Award for the Best PhD Thesis in Applied Sciences and Engineering for Aeronautics.

His thesis explored how small-scale droplet-induced flow phenomena influence the 'birth' of a flame. The formation of a flame kernel and its transition into a self-sustained flame – the process known as forced ignition – was investigated through experiments, from which physical insight was drawn to develop an ignition model. The model has been transferred to industry and the findings of his work have contributed towards international efforts to streamline the certification of alternative jet fuels.

Young Researcher Award

Dr Jingyuan Xu, a postdoctoral research fellow from the Reacting Flows group led by Professor Simone Hochgreb, has been awarded the Carl von Linde IIR Young Researcher Award for her outstanding research achievements in novel cooling technology.

Named after the prestigious pioneer of cryogenic technology, the Award was established by the International Institute of Refrigeration (IIR) to reward outstanding researchers under the age of 35 in the domain of cryogenic engineering.

Royal Society Fellows 2020

Professor Vikram Deshpande FRS (pictured left) has been elected a Royal Society Fellow for his seminal contributions in microstructural mechanics. His work includes developing 'metallic wood', sheets of nickel as strong as titanium, but four-times lighter, thanks to their plant-like nanoscale pores.

Emeritus Professor Stephen Young FRS has also been elected for pioneering the statistical approach to language processing – namely, treating conversation as a reinforcement learning problem – that made the speech-recognition products in millions of homes a reality.

David Phillips Fellow

Bioengineer Dr Christopher Proctor has been announced a David Phillips Fellow and awarded £1 million in funding from the Biotechnology and Biological Sciences Research Council (BBSRC) to establish his first independent research group.

The aim of Dr Proctor's Fellowship is to develop tools to understand the brain. This will include implants with neuron-like features that can safely deliver a wide range of chemicals in the brain with precise control of when, where, and how much chemical is delivered.

IET scholarship

PhD student Una Davies has been awarded a scholarship of £2,500 from the Institution of Engineering and Technology (IET) in recognition of her outstanding research in nuclear energy.

Her work within the Nuclear Energy Research Group focuses on sodium-cooled fast reactors (SFRs) – a type of nuclear reactor that is an advanced Generation IV (Gen-IV) design, with improved fuel efficiency, self-sustaining fuel breeding abilities (producing more fuel than it consumes), and reduced waste production. The Award will enable Una to extend the impact of her research to other types of Gen-IV reactors and develop research collaborations across the world.

Credit: pixabay

Green-sky thinking for propulsion and power

A rapid way of turning ideas into new technologies in the aviation and power industries has been developed at Cambridge's Whittle Laboratory.

Professor Rob Miller, Director of the Whittle, describes how researchers plan to scale the process through building the New Whittle Laboratory and the National Centre for Propulsion and Power. The New Whittle Laboratory will act as a demonstrator of this game-changing process, allowing it to be replicated to other sectors and around the world.

We're seeing a transformational change in the propulsion and power sectors. Aviation and power generation have brought huge benefits – connecting people across the world and providing safe, reliable electricity to billions – but reducing their carbon emissions is now urgently needed.

Electrification is one way to decarbonise flight. At short range of up to 200 miles, we are working on battery electric aircraft which will link city centres. At medium ranges of up to 2,000 miles, we are working on hydrogen-powered aircraft. If renewable electricity is used, then these will both completely remove CO_2. For longer range, the production of Sustainable Aviation Fuel will be required. To minimise the energy requirement, this will require radically new aircraft architectures, such as those developed by the Cambridge-MIT Silent Aircraft Initiative and the NASA N+3 project, which have the potential of reducing fuel burn by up to 60%.

The Whittle is also working on nearer term technologies for reducing fuel burn. A great example is Dr Chez Hall's research on a potential replacement for the 737. This futuristic aircraft architecture involves an electrical propulsion system embedded in the aircraft fuselage, allowing up to 15% reduction in fuel burn.

The decarbonisation challenge

A key element of meeting the decarbonisation challenge is to accelerate technology development. And so, over the past five years, our primary focus has been the process itself – we've been asking 'can we develop technology faster and cheaper?' The answer is yes – at least 10 times faster and 10 times cheaper. Our solution is to merge the digital and physical systems involved. In 2017, we undertook a pioneering trial of a new method of technology development. A team of academic researchers and industrial designers were embedded in the Whittle and given four technologies to develop.

The results were astonishing. In 2005, a similar trial took the Whittle two years. In 2017, the agile testing methods took less than a week, demonstrating a hundred times faster technology development.

We describe it as 'tightening the circle' between design, manufacture and testing. Design times for new technologies have been reduced from around a month to one or two days using augmented and machine learning-based design systems. These make use of in-house flow simulation software that is accelerated by graphics cards developed for the computer gaming industry.

Manufacturing times for new technologies have been cut from two or three months to two or three days by directly linking the design systems to rows of in-house 3D printing and rapid machining tools, rather than relying on external suppliers. Designers can now try out new concepts in physical form very soon after an idea is conceived.

Testing times have been reduced from around two months to a few days by undertaking a 'value stream analysis' of the experimental process. Each sequential operation was analysed, enabling us to remove over 95% of the tasks, producing a much leaner process of assembly and disassembly. Test results are automatically fed back to the augmented design system, allowing it to learn from both the digital and the physical data.

Just as 50 years ago, at the opening of the current Whittle Laboratory, industry and academia set out to ensure that the UK developed the technologies that would make low-cost air travel available to the masses, we believe that over the next 50 years, the New Whittle Laboratory will ensure that the UK leads the way in decarbonising aviation.

whittle.eng.cam.ac.uk
www.re-tv.org/reinvigorate/reworking-innovation

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