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TACKLING NOISE POLLUTION

TECHNOLOGY TO STABILISE MOVIE CAMERAS

HELPING DIVERS STAY SAFE

Royal Academy of Engineering

Royal Academy of Engineering

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Illustration of an underwater habitat
© Benjamin Leon

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WELCOME

Engineering often reveals itself in places you might least expect: beneath the waves, among the everyday sounds that surround us, in the films we watch, and in the medical devices keeping us healthy. In this issue, we explore the ingenuity and quiet brilliance of engineers who are transforming our understanding of environments both hidden and overlooked.

Page 10 looks at an invisible, yet pervasive, engineering challenge: noise pollution. Noise is now recognised as a significant threat to public health. We highlight innovators who are tackling this issue from all sides – whether it's building lightweight, transparent barriers that filter out unwanted sound, or reimagining infrastructure design to reduce noise at the source.

On page 16, our feature on underwater engineering delves into the challenges of working at depth, where engineers' pioneering work is allowing researchers to live and work beneath the sea for extended periods. Meanwhile, on page 21, we discover how advanced camera stabilisation technologies and robotics have revolutionised filmmaking, enabling smooth shots in diverse environments and enhancing storytelling.

This issue also highlights the award-winning engineering that is making an impact in healthcare. Professor Constantin Coussios CBE FREng FMedSci recounts the development of OrganOx – the perfusion technology that is transforming lives, while Occuity's handheld device to support glaucoma diagnoses could also be used to spot other conditions, such as diabetes and Alzheimer's.

This issue invites you to see engineering as a force for positive change – at depth, in the sounds we hear, in the entertainment we enjoy, and in changing people's lives. Is there some unexpected engineering you'd like us to cover? Then let us know at **ingenia@raeng.org.uk**

Professor David Delpy CBE FREng FRS FMedSci
Interim Editor-in-Chief

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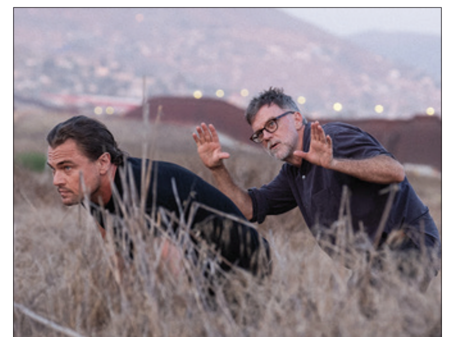

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IN BRIEF

ROYAL ACADEMY OF ENGINEERING LAUNCHES AI–Z CAREERS GUIDE TO INSPIRE FUTURE INNOVATORS

At 10 Downing Street (left to right): Yewande Akinola MBE HonFREng; Jonathan Narbett (Director of the QEPrize); Academy CEO, Dr Hayaatun Sillem CBE; Alice Kan; Dr Ishara Dharmasena; George Imafidon MBE; Susan McDonald; Dr Navjot Sawhney; Milly Hennayake; Academy President Sir John Lazar CBE FREng © Alecsandra Dragoi/ DSIT

NVIDIA CEO Jensen Huang, who is also a 2025 QEPrize Laureate (left) and Secretary of State Liz Kendall (right) © Alecsandra Dragoi/DSIT

This National Engineering Day, on 5 November, the Royal Academy of Engineering unveiled the *AI–Z of Engineering*, an online careers guide designed to showcase the breadth of modern engineering and its role in shaping the technologies of tomorrow.

To mark the day, the Academy also brought together engineers, policymakers, school students and the general public at events across the UK. Rising stars in engineering joined some of the 2024 and 2025 Queen Elizabeth Prize for Engineering Laureates at 10 Downing Street, asking how we can create the next generation of engineering visionaries.

The AI–Z is now live on the *This is Engineering* website. It maps over 200 current and predicted roles across sectors including tech, film, fashion, and sustainability. The initiative aims to challenge outdated stereotypes and inspire the next generation to turn science fiction into fact.

The launch follows new polling that reveals a disconnect between public perception and engineering reality. While 78% of Brits dream of sci-fi inventions, engineers are laying the groundwork for everything from quantum teleportation to invisibility cloaks.

Yet half of Brits admit they couldn't explain what today's engineers actually do. Almost half (46%) say engineering is barely visible in public life, and over two-thirds believe engineers work in traditional industries such as infrastructure and construction.

Developed with input from more than 100 engineers, the AI–Z guide highlights roles ranging from designing VR training games for athletes to creating smart water systems that minimise waste. Using artificial intelligence, the guide also imagines how these roles could evolve in decades to come, offering a glimpse into a future where engineers blend technologies to tackle global challenges.

"Nobody can be in any doubt that technology is transforming our world, and that means that engineering is also constantly evolving," said Dr Hayaatun Sillem CBE, CEO of the Royal Academy of Engineering. "We're delighted to be launching an AI–Z that highlights the role engineers play today, and how they're shaping the future, often without people even realising it."

KENYAN INNOVATOR WINS AFRICA PRIZE FOR AI-POWERED SIGN LANGUAGE APP

2025 Africa Prize for Engineering Innovation winner Elly Savatia, creator of the Terp 360 sign language app, celebrated as he was announced this year's winner © Vaud Photography

In October, Kenyan engineer Elly Savatia won the 2025 Africa Prize for Engineering Innovation for Terp 360, an AI-powered app that translates speech into sign language using lifelike 3D avatars. The award, presented by the Royal Academy of Engineering, includes £50,000 to help scale the innovation, which aims to tackle interpreter shortages and improve accessibility in classrooms, workplaces and public services.

The live final took place in Dakar, Senegal, the first time the Africa Prize has been hosted in Francophone Africa. Savatia's solution draws on a growing dataset of more than 2,300 locally recorded signs to ensure cultural relevance and natural expression. Developed with input from people who are deaf or hard-of-hearing, Terp 360 is designed to make communication more inclusive across sectors including education and healthcare. Savatia's win comes seven years after he attended an Africa Prize final aged 17.

Three other finalists, Vivian Arinaitwe (Uganda), Frank Owusu (Ghana) and Carol Ofafa (Kenya), each received £10,000 for their innovations: a neonatal care device, smart water-quality monitoring technology and a solar-powered charging hub for electric bicycles and motorbikes. A £5,000 One to Watch award, chosen by the live audience, went to Rui Bauhofer of Mozambique for Eco-Plates: biodegradable plates made from recycled maize husks and infused with seeds that germinate after disposal.

Judges assessed finalists on impact, scalability and commercial potential, alongside their progress through the eight-month Africa Prize programme. "This is exactly what the Africa Prize is all about. It's showcasing cutting-edge innovations by Africans for the world," said Rebecca Enonchong FREng, Chair of the judging panel.

The Africa Prize, part-funded by the UK's Department for Science, Innovation and Technology, is the continent's largest dedicated engineering award. Since its launch in 2014, it has supported over 160 entrepreneurs whose ventures are creating jobs and delivering impact across Africa.

YOUNG ENGINEERS HONOURED FOR PIONEERING CONTRIBUTIONS TO SOCIETY

Three of the 2025 Young Engineers of the Year received their certificates at the Royal Academy of Engineering in London on 23 September 2025. (Left to right) Miguel Martinez Paneda from Arup; Jack Biltcliffe from The Washing Machine Project, and Andrei Feraru from Feraru Dynamics Ltd © Rob Lacey

In September, the Royal Academy of Engineering announced the winners of its 2025 Engineers Trust Young Engineer of the Year competition, recognising four exceptional individuals for their impact across fields from humanitarian design to advanced computing. Each recipient received a £3,000 prize, supported by the Worshipful Company of Engineers.

This year's winners are Jack Biltcliffe (The Washing Machine Project), Andrei Feraru (Feraru Dynamics Ltd), Miguel Martinez Paneda (Arup) and Dr Calvin Tsay (Imperial College London). Their work spans global challenges including sustainable energy, safer workplaces and resilient infrastructure.

Jack Biltcliffe leads research and development at The Washing Machine Project, scaling hand-cranked washing machines for communities without access to electric washing machines. His designs have allowed the company to increase production from tens to thousands of units, and he has led co-design with people using the machine in Kenya and India.

Andrei Feraru founded Feraru Dynamics to combat Hand–Arm Vibration Syndrome through wearable technology. His patented device, now protecting nearly 1,000 workers worldwide, has influenced official safety guidance and attracted £1 million in investment.

Miguel Martinez Paneda, Principal Structural Engineer at Arup, has contributed to landmark skyscrapers and developed a novel damping system for tall buildings, enabling more efficient and resilient designs.

Dr Calvin Tsay, Associate Professor at Imperial College London, is advancing optimisation and machine learning tools for energy systems. His open-source software and industrial collaborations are shaping sustainable technologies and AI security.

"I warmly congratulate this year's Young Engineers of the Year," said Luke Logan FREng, Chair of the Academy's Awards Committee. "Their pioneering work shows how engineering continues to have a positive impact on society and the environment."

Watch out for more about the career journeys of these young engineers in upcoming articles on the *Ingenia* website.

GET INVOLVED IN ENGINEERING

MATHSWORLD

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London
Whether you're a lifelong maths enthusiast, a curious sceptic or a reluctant engager with maths, MathsWorld's interactive exhibits will surprise, delight and challenge you. Step inside a giant soap bubble or a kaleidoscope. Laser-cut different shapes. Play pool on an elliptical table. Discover the hidden maths in everyday life. With over 40 innovative exhibits, MathsWorld is a place to see mathematics as you've never seen it before: fun, colourful, mind-blowing and deeply connected to the world around us.
For more details, visit **mathsworld.com**

DESIGN AND DISABILITY

Until Sunday 15 February 2026
V&A South Kensington, London
Design and Disability showcases the radical contributions of disabled, deaf and neurodivergent people to contemporary design and culture from the 1940s to now. The exhibition traces the political and social history of design and disability, showcasing how Disabled designers have shaped every aspect of life through lived experience and expertise. The exhibition also highlights the rich history of challenging ableism in design and the practitioners working today to 'hack' existing designs for greater usability. For more details and to book tickets, visit **vam.ac.uk**

NI SCIENCE FESTIVAL

11 to 22 February 2026
Belfast
NI Science Festival returns between 11 and 22 February 2026 with over 250 events celebrating the science of you, the universe and everything in between. Full programme revealed December 2025. To book, visit **nisciencefestival.com/events**

THE PRICE OF PIXELS: UNMASKING THE ENVIRONMENTAL IMPACT OF OUR DIGITAL LIVES

17 February 2026
Barnard's Inn Hall, London, or online
Our digital world's convenience masks a heavy environmental cost. This lecture explores the destructive rare earth mineral mining powering our devices, the vast energy consumption of data centres fuelling climate change, and the toxic e-waste contaminating our environment and harming human health.
To book, visit **gresham.ac.uk/whats-on/price-pixels**

© Jesper Lindborg, Visualising AI by Google DeepMind/Unsplash

MICHAEL FARADAY PRIZE LECTURE: THIS IS NOT THE AI WE WERE PROMISED

18 February 2026
The Royal Society, London, or online
In his talk, leading AI researcher Professor Michael John Wooldridge will look at how contemporary AI systems work, and why as a consequence they exhibit these weird, frustrating, fascinating behaviours. He will show just how far the new AI is from classical expectations and talk about the next frontiers for AI – and how far we are from the dream. Booking available on Eventbrite from the start of January.

HOW I GOT HERE

Q&A

CHRIS TAGNON
FORMULA 1 TECHNOLOGY TRANSFER ENGINEERING ASSOCIATE

Chris during his placement year at Red Bull Racing, when the team won the 2023 Formula One World Constructors' Championship © Chris Tagnon

After completing a master's in industrial systems manufacturing and management with a Royal Academy of Engineering and Mission 44 MSc Motorsports scholarship, Chris Tagnon is joining Aston Martin F1's Performance Technologies division.

WHY DID YOU FIRST BECOME INTERESTED IN SCIENCE/ ENGINEERING/STEM?

I started watching Formula One races with my dad and my whole family when I was about three years old. That was my first interaction with an industry that relies on engineering and can be considered as the biggest engineering competition in the world.

Completely separate from my interest to Formula One, I realised I really enjoyed figuring out how things worked. As a kid, when something broke down in the house, I liked to try and fix it. That interest and that curiosity for how things work and how things get built, as well as that separate passion for Formula One, joined up around high school. I really enjoyed maths and physics. So when I was trying to figure out what I would go and study, engineering made the most sense.

HOW DID YOU GET TO WHERE YOU ARE NOW?

Curiosity was a big one. Throughout my studies, I tried to learn about a lot of different things. I went into my engineering degree with Formula One in the back of my mind, but also did research in EV (electric vehicle) batteries. I did some projects on hydrogen. Generally, I worked on a variety of things that allowed me to grow my network and adaptability as an engineer, as well as my fundamental understanding of first principles.

I've been fortunate that a lot of people gave me a chance along the way and then it was more a question of delivering on those opportunities and getting to the next step.

WHAT HAS BEEN YOUR BIGGEST ACHIEVEMENT TO DATE?

That's a tough one, but I think it was being able to have my first experience in motorsport: my placement at Red Bull. I got to do a lot of things that I dreamed of as a child. I got to go karting with racing drivers Isack Hadjar and Yuki Tsunoda. (My colleague and I were in first and second for a lot of the race, but towards the end I got caught up by Hadjar and Tsunoda, and ended up fourth.)

With the technical rigour and engineering excellence that surrounds that environment, being able to thrive – that was also something I'm quite proud of. My role involved a lot of data analysis and mathematical modelling, as well as working with the simulator and sometimes driving it to test some iterations of new vehicle models that the team developed. I love racing, so it's definitely an environment that was nice to be in.

Chris aged four, attending his first F1 race. It was the 2007 French Grand Prix, in which Sir Lewis Hamilton CBE HonFREng finished in third place © Chris Tagnon

WHAT IS YOUR FAVOURITE THING ABOUT BEING AN ENGINEER?

I think it's the creativity that's involved in engineering and the breadth of topics you can work in as well. It's being able to imagine what doesn't yet exist and bringing it to fruition, through engineering first principles and good design.

There's the rigour and science behind it, but there's also that element of creativity where you have to be able to dream the future a little bit. And I think it's a very cool frontier to be on.

WHAT DOES A TYPICAL DAY INVOLVE FOR YOU?

I'm about to start a new role, so I'm not sure yet, but I'm expecting it'll be similar to how it's been so far.

At uni, I worked on two different research projects this year including my dissertation, on applying quantum reinforcement learning – hybridising classical algorithms with quantum computers – to Formula One race strategy. And I've been working on spinning out a startup. This was my third-year project when I studied mechanical engineering at UCL: designing a sustainable, reliable power generation system that could support off-grid humanitarian missions for the UN World Food Programme. I designed a containerised solar power system, with an integrated battery pack. It has a deployment system, meaning you can drop the container wherever, pull the panels out and in less than an hour it will be readily available for whatever mission is planned. It's been a busy year!

For this role specifically, I'm not expecting to have a consistent typical day. The aim is to build up Aston Martin's special projects division. It's going to be doing a bit of everything to ensure the business thrives, and thinking about what industries we want to go into, which projects we want to do and with which partners, but also looking at which technologies we want to develop capability in, and how we operate as a business to ensure we deliver excellent, leading-edge engineering.

WHAT WOULD BE YOUR ADVICE TO YOUNG PEOPLE LOOKING TO PURSUE A CAREER IN ENGINEERING?

I'd definitely say go for it. There can be a lot of opacity around what engineers do. I think the Academy does an amazing job at trying to make it more clear and accessible, but be curious, ask questions and try and meet people. Engineers are some of the most passionate people about what they do, and will be more than happy to tell you about it if you prompt them.

It's a question of figuring out what you want to engineer, which industry you want to go into. And there's no better way than talking with people who have gone through those steps, had those experiences, to get a good view of what you need to do next.

WHAT'S NEXT FOR YOU?

I'll be starting a role as engineering associate to the managing director at Aston Martin F1's special projects division, AMPT (Aston Martin Performance Technologies). It's essentially a division in the F1 team that doesn't actually work on the F1 car but works to take the technologies and intellectual property that's developed, including processes and know-how, and bring it to other industries.

The aim is to partner with organisations across a wide range of sectors, from energy or automotive companies to those in the aerospace or defence sectors, that can benefit from the high-performance engineering expertise developed in Formula 1. The goal being to commercialise those technologies and bring them to the world, which could even include working with deep-tech startups.

QUICK-FIRE FACTS

Age: **22**

Qualifications: **Bachelor's in mechanical engineering with a year in industry (at Red Bull advanced technologies) from UCL; MPhil in industrial systems manufacture and management from the University of Cambridge**

Biggest engineering inspiration: **Caroline Hargrove FREng**

Most-used technology: **MATLAB**

Three words that describe you: **Dreamer, passionate and curious**

OPINION

RESILIENCE ENGINEERING WILL SUPPORT COMMUNITIES – AND INSPIRE THE NEXT GENERATION

Engineering must evolve to meet today's biggest challenges, from climate change to increased urbanisation and rapid advances in technology. At the same time, the UK is seeing a concerning decline in the number of engineers entering the field. A focus on resilience could help us solve both of these problems, writes Caroline Field.

Caroline Field

We need resilience to thrive in the increasingly volatile and uncertain world be find ourselves in. Resilient societies – able to absorb shocks and adapt in a changing environment – can better realise their strategic ambitions, protect critical resources and capitalise on investment. They can create and sustain opportunities for enterprise, and empower individuals, communities and institutions to adapt and prosper.

In short, societal resilience encompasses our transport systems, energy supply, food supply, and critical manufacturing components. It also includes the resilience of our workforce and the future skills it needs, as well as the cohesion of our communities in our increasingly polarised society. Stresses on these systems undermine their ability to weather adversity, change and challenge.

Engineering is at the heart of many of these systems and should be seen as an enabler for more resilient societies. Greater visibility of this underlying purpose could attract a new cadre of young people into engineering – which is sorely needed.

2023 projections from strategy firm Stonehaven indicate that the UK could face a shortfall of a million engineers by 2030, threatening critical infrastructure projects such as building new hospitals. The same research also indicates that young people seek careers in which they can contribute to improving society: 40% of Gen Z and millennials prioritise job opportunities that allow them to make a positive impact in their local communities. Articulating engineering in terms of its purpose and societal impact is key to enticing more interest and providing rewarding careers.

By making engineering a conduit for positive impact in communities, we can inspire the next wave of innovators.

SHIFTING THE PERSPECTIVE OF ENGINEERING

To enable this shift in perception, engineers must first change the way we think and design. This requires not only adapting existing approaches and design standards but also cultivating a new generation of leaders who are

committed to resilience principles and societal outcomes.

For example, a new suite of resilience standards, led by the International Standards Organisation (ISO), provides a framework for engineers to help create environments that can anticipate and respond to challenges. The first of these, ISO 22371, focuses on urban resilience. Taken together, the suite will help ensure that our systems remain functional, equitable and sustainable in the face of adversity.

To incorporate resilience into our engineering, we need to embed some key principles into our design thinking:

1. **Outcomes not outputs**: understand the broader system value that is being delivered through engineering, for example, social, environmental and financial, and consider resilience as a strategic enabler of this value.
2. **Systems not silos**: you may only be responsible for engineering one part of a broader system. Make sure you understand the end-to-end system, interdependencies and how risk and vulnerabilities cascade across the system.
3. **Proactive vs reactive**: advocate for a proactive and targeted approach to resilience.
4. **Resilience value**: strategically designed resilient systems are not more expensive over whole-system life. Target interventions where they're most needed. Consider the full suite of resilience interventions from anticipation, prevention and mitigation to adaptation, response and recovery.
5. **Skillsets and mindsets**: empower others to own resilience and do their part. Develop resilient mindsets by encouraging systems thinking, complex problem-solving and self-leadership to navigate adversity, change and challenge.

ESTABLISHING THE RESILIENT ENGINEERING PROFESSIONAL

Resilience engineering is an emerging discipline that was developed initially as a new approach to safety. While traditional approaches to safety focus on what goes wrong when systems fail, resilience engineering investigates what goes right when systems are faced with surprises.

Resilience engineering acknowledges that humans design and manage critical systems, and considers the dynamic and complex ways that we interact with technology. It aims to make rigid systems more flexible by engaging people's adaptive capacity to solve new problems and to make over-extended systems more robust by providing rigour, process and risk mitigations. In practice, resilience engineering enables us to more effectively anticipate, adapt and learn from unexpected changes which impact operations and performance.

Resilience engineering theory, concepts and methods are being applied in many contexts, including emergency preparedness and disaster response, critical infrastructure (including energy, water, transportation, communications, and cybersecurity), health science, organisational development, urban systems, supply chain management, space exploration, military operations, and climate change, so we should apply this thinking in all aspects of engineering.

Resilience professionals are typically responsible for the operational aspects of resilience within cities, regions or organisations and their work tends to focus on response and recovery planning and business continuity. Existing approaches to training for resilience experts are unstructured, with no clear progression pathway or professionalisation for resilience professionals.

A new and integrated approach to learning and development is needed to advance resilience in critical infrastructure because of the increasing volatility, uncertainty, complexity, and ambiguity of the world we now live in. As we navigate this shift, it is important to incorporate key competencies and skills that will define the "resilience engineer" into education. These include technical abilities coupled with meta-skills such as systems thinking, adaptability and emotional intelligence. Resilient leadership, embracing collaboration, innovation and proactive problem-solving, will be essential for guiding teams and projects toward successful outcomes in an unpredictable world.

To realise this vision, we must examine our education system and its approach to engineering. The current curriculum often emphasises mathematics and science but neglects the socio-technical aspects of engineering and the societal outcomes that engineering enables. By integrating resilience concepts and systems thinking into education, we can broaden engineering's appeal to young people, illustrating that they too can contribute purposefully to resilience in their communities.

We are at a pivotal moment, where the future of engineering lies in our collective hands. By championing resilience, we can inspire a new generation of engineers who are not only technically proficient but also deeply connected to the communities they serve. Together, we can build a robust engineering profession capable of overcoming tomorrow's challenges.

BIOGRAPHY

Caroline Field is a Fellow of the Institution of Civil Engineers with over 30 years of professional experience specialising in the resilience of structures and infrastructure to extreme loads such as earthquake and bomb blasts. She bridges research, practice and policy through her roles as National Resilience Partner at PA Consulting, Co-Founder of the Centre for Whole of Society Resilience and her Visiting Professor roles at Loughborough University and Imperial College London. Caroline is accredited in resilient leadership and advises clients across government and critical national infrastructure on measuring, prioritising and building whole-system resilience. She is passionate about encouraging more diversity into engineering.

High-speed trains can cause significant aerodynamic noise. HS2, the new rail link being built between Birmingham and London, is employing a noise reduction scheme to ensure sound is at a minimum both during construction and operation © HS2

TURNING DOWN THE NOISE

Noise pollution is a widespread but often overlooked issue, affecting millions of people. From the constant hum of traffic to the clatter of construction and the whir of modern technology, unwanted sound is a growing public health concern. Lee Williams talks to the engineers who are working to reduce unwanted sound and create healthier, quieter environments.

Did you know?

- Environmental noise has a significant impact on public health, society and wildlife
- According to a 2020 report from the European Environment Agency, 22 million people are exposed to high levels of railway noise, four million to high levels of aircraft noise and almost one million to high levels of noise caused by industries
- While in England, road noise alone is estimated to cause £7–10 billion of health-related costs
- Engineers are developing advanced noise reduction technologies, addressing sources directly and implementing control measures, to create quieter, healthier environments

There is an unseen killer that causes 12,000 deaths every year across Europe according to a 2020 report from the European Environment Agency. The World Health Organization (WHO) ranks it as the second largest environmental cause of health problems after air pollution, and sustained exposure can lead to high blood pressure, heart attacks, stroke, type-2 diabetes, and even dementia.

The identity of this mysterious killer? It is – perhaps surprisingly – noise, such as that from road, rail, air traffic, and industrial activities [see 'Sources of noise pollution']. With one in five Europeans exposed to harmful noise levels, noise pollution is rapidly becoming a public health crisis that has for too long gone unnoticed.

But in the UK, things could be changing. Funded by the Engineering and Physical Sciences Research Council, Noise Network Plus was set up in early 2025 to re-engineer the discipline of engineering, making noise a consideration at all stages of the design process. This interdisciplinary group of engineers, policymakers, industry stakeholders and social scientists is focusing on noise resulting from engineering activities, such as roads, rail, construction, and aviation, as well as energy-generation activities and domestic heating and cooling (such as air source heat pumps). It aims to make consideration of noise a vital component of the design process.

"Noise tends to be neglected," says Abigail Bristow, Professor of Civil and

SOURCES OF NOISE POLLUTION

Transport

On roads, vehicles generate noise through engines, exhaust systems, and the interaction of the tyres with the road. These are amplified by factors such as higher speeds, which increase tyre and aerodynamic noise; congestion, which adds idling noise and frequent honking; and rough or uneven surfaces that can intensify tyre friction noise.

Noise on railways is similarly caused by engine and mechanical noise, as well as wheel–rail interactions and vibration. High speeds can also cause significant aerodynamic noise.

Jet and propeller engines in aircraft produce intense noise during take-off and landing, and again airflow over wings and fuselage adds to the soundscape. Communities living near airports experience intermittent but high-decibel exposure.

Industry

Industrial noise pollution stems largely from heavy machinery, manufacturing equipment and construction activities, creating sound levels that often exceed 100 decibels. These include steel and metal works, with their forging presses and rolling mills; construction sites using pneumatic drills, jackhammers and other machinery; manufacturing plants operating compressors; and mining and quarrying with blasting and crushing equipment. Noise control measures are critical to protect workers, nearby communities, and ecosystems from the harmful effects of prolonged exposure.

Green technologies

Aerodynamic noise from wind turbines is created by rotor blades and mechanical noise from gearboxes. These low-frequency, continuous sounds are often described as 'swishing' or 'thumping'. Offshore wind farms also raise concerns about underwater noise affecting marine life.

Drones' rotor blades and electric ducted fans (EDFs) create high-frequency sounds that are perceived as more annoying than car or jet engine noise at the same loudness because of tonal and high-pitched qualities. Similarly, urban air mobility vehicles, such as flying taxis, create mid-frequency buzzing that varies with altitude and flight patterns.

Heat pumps' compressors and fans emit a low-frequency hum, especially noticeable in quiet residential areas, which dictates how close to property boundaries they can be installed in residential areas. And while electric vehicles are quieter than combustion engines, they still produce noise through tyre–road interaction and aerodynamic noise.

Environmental Engineering at the University of Surrey, and Project Lead at Noise Network Plus. "People don't tend to perceive it as a problem until they come up against it. Noise is all pervasive. It's everywhere. We can't get away from it. It affects people's health in ways they don't necessarily realise."

Noise can damage health by triggering stress. Annoying, sudden or overly loud sounds cause the release of stress hormones like cortisol and adrenaline, which alert the nervous system for fight or flight. This evolutionary response used to alert us to danger, but constant exposure to noise, and thus constant exposure to stress hormones, can cause a slew of health problems.

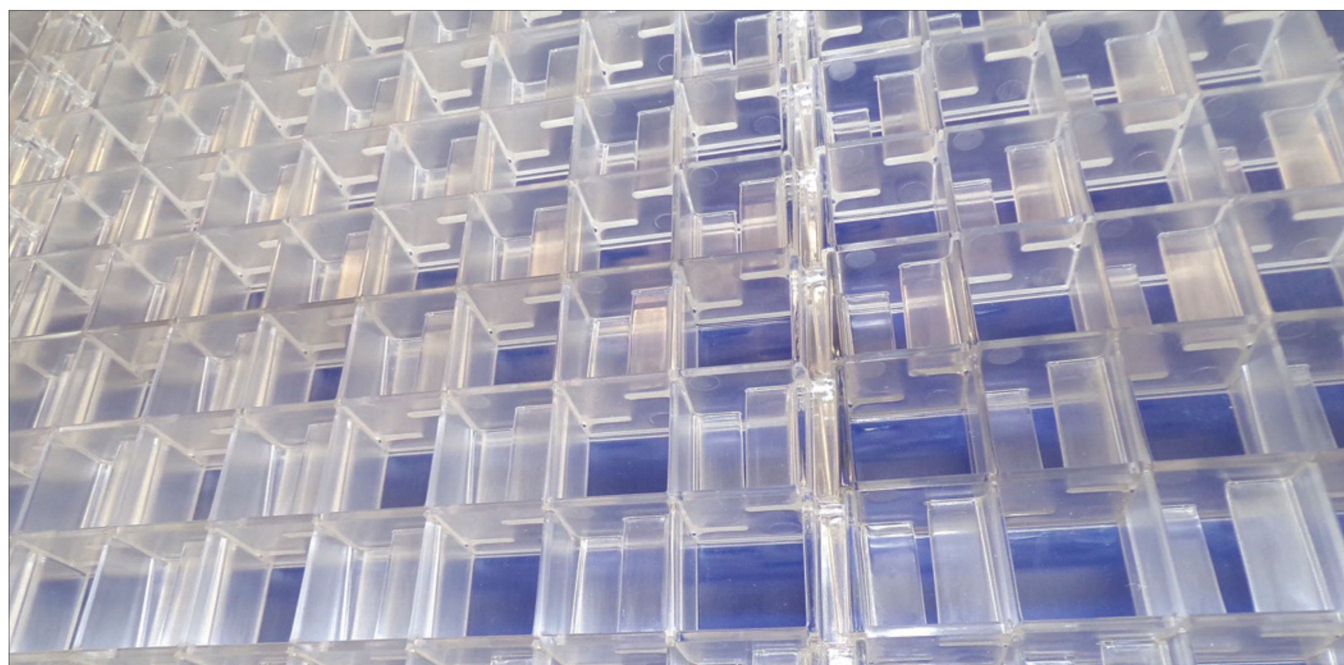
Noise Network Plus was established as part of the UK's effort to tackle this growing public health problem. The project uses cutting-edge research, engineering and technology to tackle environmental noise pollution. The systems-based approach includes seven working groups that aim to address the challenge from every angle: transport; health and wellbeing; sustainability; AI and digital; education, outreach and skills; inclusive engineering; and policy, law and standards.

According to Bristow, incorporating noise reduction into the design stage of everything – from products to buildings, infrastructure projects, transport and urban landscapes – is a challenge. This will involve reshaping how we educate engineers, architects and urban planners by including noise reduction on the syllabuses of all relevant courses. "I think it's going to be very difficult," says Bristow, "because there are so many different branches of engineering, and so many professional bodies who can give the title of Chartered Engineer. Noise doesn't really appear anywhere in the criteria that these professional bodies ask courses to tick."

Legislation is another area Noise Network Plus hopes to address. Unlike other environmental challenges such as climate change and air pollution, while regulations for noise exist, they are not joined up so there is no central oversight of how they are addressing the problem. As Bristow points out, efforts to tackle noise pollution are currently spread across several different government departments, so there is no single body taking responsibility. Noise Network Plus is looking to address this and has already contributed to this year's Sound Economics report, which reviewed the scale of the acoustics industry in the UK and found that it contributes £5.2 billion annually to the economy. "With this report, we can really start to say, right, how do we reduce noise at the design stage?" says Bristow. "We've got the industry here that can do that, and it's a growing industry."

SHAPING SOUND WAVES

Part of that industry is a Brighton-based company called Metasonixx. Founded by Gianluca Memoli, Associate Professor in Sound-Based Interactions at the University of Sussex, Metasonixx uses cutting-edge metamaterials to produce noise-reducing barriers for open spaces like offices and hospitals. Metamaterials are artificial materials whose properties arise from their engineered structure, allowing them to interact with waves (like light and sound) in ways not possible with natural materials. Metasonixx uses metamaterials made



The SonoBlind's transparent bricks let through light and gaps between them allow air movement but the way in which they are positioned reflect and refract sound waves © Metasonixx

out of recycled plastic bricks that can be assembled like Lego to form thin, lightweight partitions (SonoBlinds) that block noise while allowing light and air to flow freely. The resulting panels are positioned in such a way to cancel noise, while the bricks are transparent to light and gaps allow air to move through.

Inspiration for SonoBlinds first struck Memoli in 2019 on a long car journey with his family. "My kids at the time were very much into the song *Baby Shark*," says Memoli, "so that was when I realised I really want a possibility for them to listen to what they want, and for me not to listen."

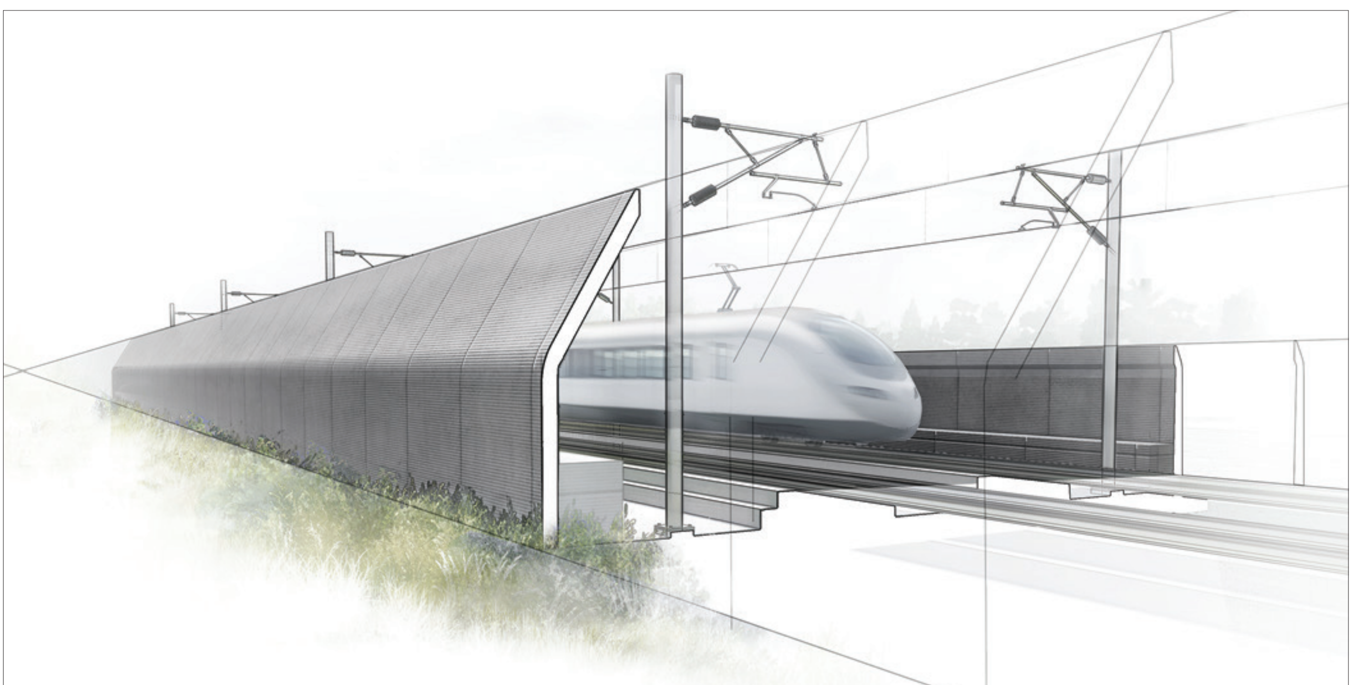
Soon afterwards Covid lockdowns arrived, and Memoli realised his idea for sound-reducing barriers would be perfect for lowering noise in overcrowded hospital wards. He approached Innovate UK for funding and developed barriers that could be wheeled into various configurations to provide quiet spaces for patients while allowing light and air to flow through.

Traditional methods for reducing noise rely on blocking it with thick, heavy barriers, absorbing sound with porous materials that trap sound waves, or electronically producing frequencies that cancel noise, as used in noise-cancelling headphones. Metasonixx's panels work by using the geometry of the structure of metamaterials to filter out unwanted sound waves. The size and shape of the material, which are at microscales, make the sound waves reflect and refract in ways that cancel out certain frequencies, much in the same way that sunglasses polarise out unwanted wavelengths of light. Because they use geometry rather than thickness or density, Metasonixx's panels are a third of the weight and about a fiftieth of the thickness of traditional barriers. And in 2.5 centimetres they reduce noise by at least 20 decibels, amounting to a 75% reduction in subjective loudness.

SonoBlind is already on the market as a barrier for sound privacy in open offices. Testing in different offices worldwide has shown that after an office has installed SonoBlinds, the workers that cannot concentrate because of noise drop from 70% to 10%. Other potential applications include barriers in factories that filter out machinery noise but allow the sound of fire alarms; windows that block noise but let in light and air; and inserts for ventilation systems to reduce the sound from air conditioners. Memoli is also working on hearing aid applications, and designs to reduce traffic noise by attaching panels to car grilles. These would reduce engine noise while still allowing airflow for cooling. Memoili is also working metamaterials for heat pumps

RETHINKING DESIGN

Transport is one of the biggest sources of noise pollution, especially in urban areas, and it doesn't just emanate from roads. Railways make a lot of noise, as do the projects to build and maintain them. HS2, the new high-speed rail link between London and Birmingham, is the UK's biggest intercity rail project for over a century, and planners are putting in place measures to reduce the noise created by the trains, once the line is operational. Railways are noisy affairs with engines, rolling stock and track all contributing to the overall sound. But on HS2, where trains will reach speeds as high as 360 kilometres per hour, another source of noise will become even more disruptive.



Concept design for a cranked noise barrier proposed for part of the HS2 route near West Ruislip, London © HS2

Transparent noise panels and absorption panels on the Colne Valley Viaduct, part of the new HS2 line © HS2

"The key difference between HS2 and a normal railway is the speed that we're going to run trains," says Dr Oliver Bewes, Head of Noise Assessment at HS2. "Noise goes up as trains go faster, but also the type of noise changes. When you're going at conventional speeds, you're generally hearing noise from the wheels and the rails. We call that rolling noise. But when trains start to approach 300 kilometres per hour, aerodynamic noise becomes really important – that's the noise of the air passing over the body of the train."

HS2 tested a high-speed train in Spain, taking it up to 350 kilometres per hour, and found that at that speed the aerodynamic noise – a loud whooshing sound – exceeded all other sources, coming in at over 100 decibels 7.5 metres from the track, equivalent to standing a metre away from a pneumatic drill. This sound will decay quickly with distance from the railway; however, without control it could still reach levels that will have negative effects on communities up to one kilometre away.

In addition to controlling noise from the train and track, Bewes and his team are designing a noise barrier to cover 48 kilometres of HS2 track in the most sensitive areas. They created a test site at Whittington Heath, just north of Birmingham, where they built a 60-metre mock-up train from shipping containers and a 90-metre concrete barrier. Similar noise barriers are common all over Europe on motorways and railways. The particular challenge for the HS2 team was to build one that could withstand the uniquely high forces coming from the aerodynamic loads of the train passing, caused by its unprecedented speeds, and ensuring the barrier is optimised to control aerodynamic noise. Using principles similar to metamaterials but at a larger scale, the team experimented with the shape and composition of the barriers to change the way they interact with the sound waves. Experiments included T-shaped and resonating tops to the barriers. Sloping the barrier inwards was also found to improve its performance. Running between three and five metres high, HS2's noise barrier will be made mostly of concrete but in particularly picturesque sections, such as the Colne Valley Viaduct, it will be partially constructed of transparent glass.

Bewes and his team have produced a prototype and expect to fit noise barriers across the HS2 track over the next two years. Bewes's research shows the barrier will reduce the sound of passing trains in built-up areas by about 10 decibels, halving its subjective loudness. With its extensive testing of designs and materials, the HS2 team hopes to make a lasting impact, not just on HS2 itself but on future projects. "We're leaving a legacy," says Bewes, "making sure that whatever we do now is not forgotten and is used elsewhere."

THE SOUND OF THE FUTURE

It's not just traditional transport that will cause noise pollution in the future. Technologies such as drones, flying taxis, heat pumps and wind turbines will all leave their mark on urban soundscapes. One expert researching the sonic effects of these technologies is Antonio Torija Martinez, Professor of Acoustic Engineering and Psychoacoustics at the University of Salford and co-lead of Noise Network Plus, in charge of the transport working group. We don't usually think of drones as sources of noise pollution but, according to Torija Martinez, as they proliferate they could become sonic pests. "For the same loudness, drones can be perceived as more annoying than jet engines," he says. "When you set those to the same sound level, or the same loudness, the character of the drone, which is more tonal and higher pitch, [usually causes] more annoyance."

Torija Martinez's research focuses on three methods for tackling drone noise. The first is reducing noise at

source by designing quieter drones through engineering solutions such as changing the geometry of the drone and the rotor blade design. He and his team found that increasing the angle of the rotor blades relative to the direction of rotation in co-axial rotors (two sets of rotors operating in front of each other with important aerodynamic benefits) reduced their perceived noise level. He has worked with electric aviation company, Greenjets, to study the noise signature of electric ducted fans (EDFs). These are electric-powered fans that produce thrust using electric-powered fans to accelerate air through a cylindrical duct. Using EDFs the propellers of the drone would be covered, thus reducing their noise.

Secondly, Torija Martinez is looking at improving the soundscapes of the future by reducing the noise of autonomous drones and other urban air mobility (UAM) vehicles like flying taxis by optimising their routes. In urban areas, UAMs could follow existing transport corridors so that their noise blends with existing traffic and their annoyance is limited to those areas.

Thirdly, Torija Martinez uses a cutting-edge area of research called psychoacoustics – the scientific study of how humans perceive sound – to model how people are affected by different variables such as drone design, proximity and routes. “Psychoacoustic models can be useful for decision-making,” says Torija Martinez, “and this can be used to optimise a given design or route so fewer people are affected by noise.” Torija Martinez’s research found that the sound of a quadcopter style drone hovering at low altitude in areas with low road traffic noise significantly increased noise annoyance in bystanders.

According to Bristow, the UK is already ahead of the curve in understanding the problem of noise reduction; now it’s time to turn understanding into solutions.

In the coming months Noise Network Plus will fund six pilot projects corresponding to its six working groups, pushing the noise reduction agenda forward in the UK. Bristow has an ambitious hope for the projects launched by Noise Network Plus – that they will “halve the damage caused by noise pollution” by 2040.

Reducing noise will be a real challenge but, as Torija Martinez points out, it has never been a more exciting time to be an acoustic engineer. “You are in this situation in history where there are new sources of noise,” he says. “There are drones, heat pumps, wind turbines. And you, as an acoustic engineer, can influence the design. It’s exciting times. You have the opportunity to do things differently.”

GLOBAL PIONEERS TACKING NOISE

Several countries have adopted structured approaches to curb noise pollution. Across the EU, the Environmental Noise Directive requires member states to produce noise maps and implement action plans targeting major transport and industrial sources, often integrating measures with urban planning and air quality strategies. Cities employ noise barriers along motorways and railways and use porous asphalt to reduce tyre–road noise. Smart monitoring systems with Internet of Things sensors are increasingly used for real-time noise mapping, alongside other technologies and incentives. Paris, for example, has a noise radar system to ‘catch’ overly loud vehicles. The Netherlands has strict noise requirements for new railway lines and operators who retrofit existing trains with noise-reducing technology are eligible for financial levies. In the US, noise control largely falls under state and local jurisdictions, with some implementing soundproofing grants for homes near airports. Japan enforces strict national limits through its Noise Regulation Law, setting daytime and nighttime limits and requiring active noise control systems in construction, alongside promoting quieter technologies such as acoustic panels along highways and quieter road surfaces.

BIOGRAPHIES

Dr Oliver Bewes is a chartered acoustic engineer. As Head of Noise Assessment at HS2 Ltd he is responsible for developing and implementing HS2’s route-wide noise and vibration policies in design, construction and operation of the railway.

Professor Abigail Bristow has extensive experience in the conduct and leadership of research in transport management and policy, most notably appraisal of the environmental effects of transport with a particular focus on noise and climate change. She currently leads Noise Network Plus, one of six networks funded by the Engineering and Physical Sciences Research Council to address tomorrow’s engineering research challenges.

Professor Gianluca Memoli has been working in acoustics since 2005, starting with noise and soundscape mapping, then moving to acoustic metrology. His research now focuses on using sound techniques and methods previously used only for light. He is CEO of Metasonixx and Associate Professor in Sound-Based Interactions (Informatics) at the University of Sussex.

Professor Antonio Torija Martinez is an expert in environmental acoustics and pioneer of perception-driven engineering, placing human noise perception at the centre of design for sustainable mobility and decarbonisation. He has led major EU, UKRI and industry-funded projects, and has published in journals including *Nature*. His expertise has earned him international recognition and invitations, such as providing evidence to the UK House of Lords on noise and health.

STAYING SAFE UNDERWATER

Engineering has revolutionised our ability to access and study one of Earth's most challenging environments – the ocean. Jasmine Wragg explores how engineers have developed innovative equipment and habitats, such as advanced diving systems and subsea living modules, to overcome the ocean's challenging environment and also keep divers safe.

Recreational divers use wrist-worn computers to manage their time and depth underwater © Lieke Ortmans

Did you know?

- Seawater is about 800 times denser than air, and pressure increases by one bar every 10 metres of depth, making the ocean an extremely challenging environment for humans to explore
- Specialised equipment, such as breathing apparatus, diving fins inspired by nature and wrist-worn computers, have transformed how long divers can stay underwater
- Saturation diving allows divers to live at the same pressure as their underwater work site, sometimes for weeks, so they only need to decompress once at the end of the mission, making deep-sea construction and research much safer and more efficient

Engineering has enabled humans to achieve feats and access environments once beyond our natural reach. Cars have allowed us to travel faster and further than we could on foot; with planes we've overcome gravity and with rockets, we've escaped the atmosphere. However, despite covering roughly 71% of the surface of the planet and hosting most of its animal biomass, the ocean remains one of the least observed environments on Earth.

Seawater is roughly 800 times denser than air, and pressure rises by one bar every 10 metres of depth, making it an inhospitable environment for humans. A combination of currents, reduced light penetration and sea floor sediment hamper visibility, while naturally occurring minerals and ions dissolved in seawater corrode metals and short-circuit electronics. To study this environment, engineers have helped to develop sonar-equipped ships, autonomous submersibles and satellites to help map the seafloor; and sensors that can track everything from temperature and salinity to the movements of animals such as whales to further increase our understanding of the ocean. However, all these technologies map, count and track from a distance – comparable to studying the Amazon rainforest from a helicopter in the tree canopy, as opposed to on the forest floor. Direct observation without the barriers imposed by ships or submersibles requires immersion, which in practice, means diving.

Over the last century, engineers have developed equipment that allows humans to interact with the ocean through diving. The most well-known of these are self-contained underwater breathing apparatus (scuba) systems that let people carry an independent air supply on their backs. These offer more freedom for divers than being tethered to a surface supply of air, or relying on holding their breath, as freedivers do. In its simplest form, an open-circuit regulator ('How does scuba gear work?', *Ingenia* 102) delivers air from a high-pressure cylinder on diver's backs and vents exhaled gas into the sea. More advanced systems, such as rebreather units, capture and remove carbon dioxide from exhaled air using an absorbing material and add oxygen to the recycled gas, allowing for longer dives. Inventions such as these have transformed safe interaction with the underwater world, and what divers can achieve, but they can't overcome the physiological limits that present one

DE(FIN)ING UNDERWATER MOVEMENT

In nature, different fin shapes have evolved to allow animals to move through water. Bumps along a humpback whale's front flipper, called tubercles, are one example. The tubercles help to guide the flow of water over the flipper and maintain lift at sharp turning angles – enabling the whale to keep 'its grip' on the water and turn in small circles to catch prey. Engineers have studied this principle to improve the performance of marine propellers, such as ducted propulsors.

Early diving fins were simple paddle shapes, similar to the enlarged webbed feet of animals such as ducks, giving a larger surface area for divers to push more water backwards with each kick. Webbed gloves use the same idea for divers who can't rely on strong leg kicks because of limited lower body mobility. Modern fins have various features to manage water flow and reduce resistance as a diver kicks: vents let water pass through on the recovery part of the kick to reduce drag, while side rails and channels help keep water from spilling off the edge, reducing wasted effort. Split fins have a slit down the centre so each half can flex into a small wing-like shape, reducing drag and funnelling water backwards more like a propeller than a solid paddle, which can make them easier to kick with.

The type of fin selected by a diver may depend on the conditions. For precise control in tight spaces such as caves or wrecks, many divers favour shorter, stiffer blades that respond quickly to small leg and ankle movements and make it easier to turn or reverse. For covering distance in open water or swimming in currents, longer blades that channel more water with each stroke can deliver more thrust per kick.

of the biggest challenges in human underwater exploration regardless of how much breathing gas someone can carry with them – time spent underwater.

HOW LONG TO STAY UNDERWATER?

Mathematical tables developed in the early 1900s provide guidance on how long divers can spend at a given depth and still ascend safely. They highlight a trade-off between depth and time: the deeper you go, the less productive time you can spend underwater. Someone may be able to spend an hour at 15 metres with no stop on ascent; at 40 metres that window shrinks to about eight minutes. Today, wrist-worn dive computers are used to simplify depth decisions in real time. Inside, a pressure transducer – often a piezoresistive strain gauge whose electrical resistance changes when squeezed – converts depth and pressure changes into an electrical signal. Coupled with a timer, a processor uses decompression models based on the same tables to display clear guidance on ascent rate, recommended pauses for safety stops and remaining no-stop time (the time you can remain at that depth without stopping on the way up). After surfacing, the computer remembers the dive profile of the previous dive and uses it to adjust safety guidance for later dives, accounting for any remaining nitrogen that may still be leaving the body – useful when planning several dives over a short period. Staying within depth–time limits and following a dive computer's real-time prompts keep the risk of decompression sickness (DCS) (see 'Why slow ascents matter') very low in recreational diving.

Accessing deeper parts of the ocean, or staying for longer, introduces new challenges. Submersibles that can reach greater depths are expensive, and remotely operated vehicles separate people from the water, limiting direct interaction with the environment. When hands-on work must be done in deeper parts of the ocean – such as in subsea construction, research, or salvage operations – saturation diving is used. Saturation diving is widely used to support deep-water offshore projects in the oil, gas and wind industries through building, maintaining and inspecting subsea infrastructure. In this specialised technique, divers live at the same pressure as their underwater work site until the job is complete, either in an underwater habitat, or in pressurised chambers on the surface, and shuttle to the work site in a pressurised capsule called a diving bell. Once the body has absorbed the maximum amount of gas at a given depth, it is 'saturated', and decompression time is fixed. Returning to the surface takes the same time whether the job lasts a day or two weeks. A mission at 200 metres requires roughly eight days to surface safely. Keeping the decompression to one event at the end of the mission increases the productivity of the time spent underwater and reduces the risk of DCS.

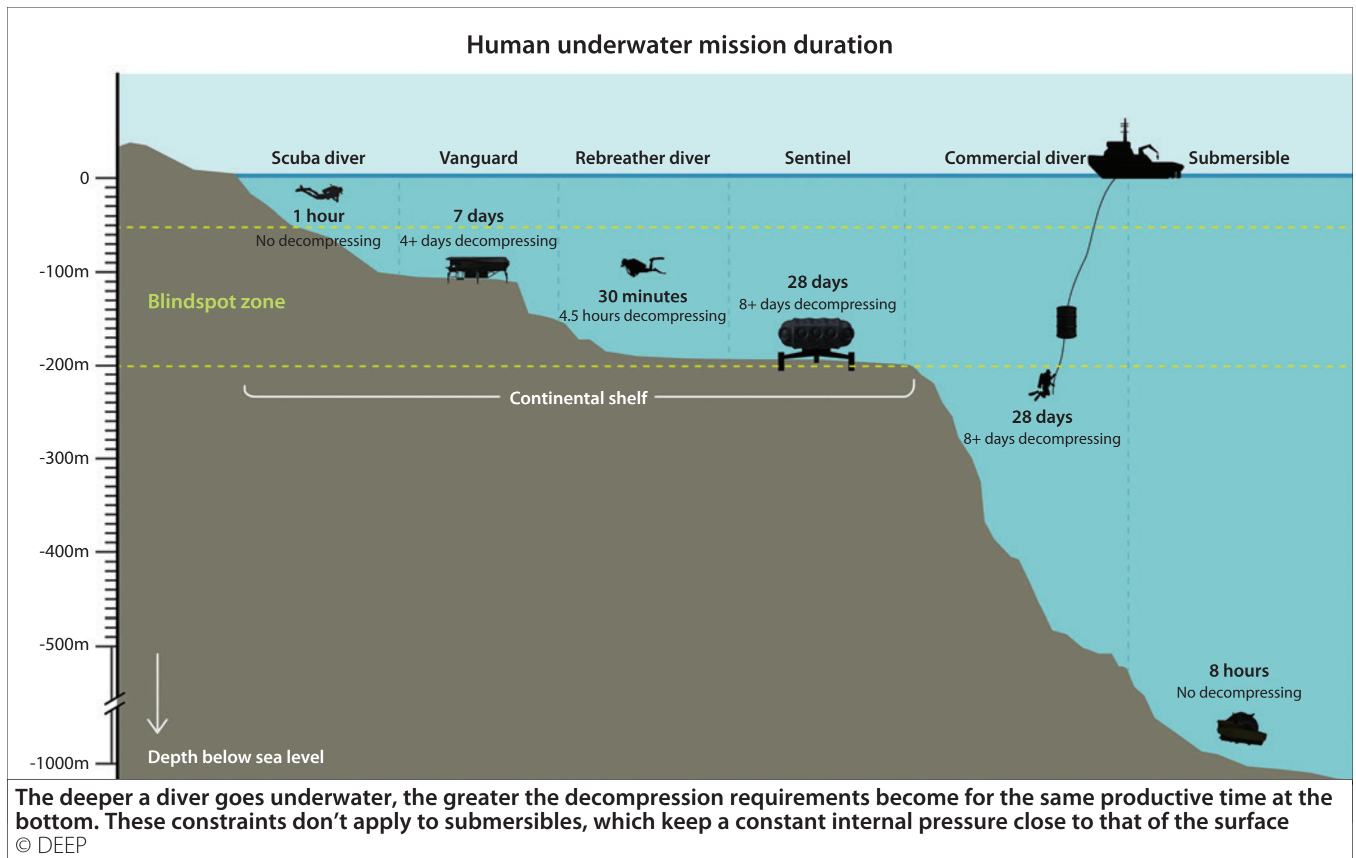
ACCESSING GREATER DEPTHS

Ocean technology company DEEP is developing underwater habitats to give scientists and researchers more time at depth – access once limited to specialist commercial saturation teams – in order to better understand the oceans. Safety is central to its work: the DNV, an independent maritime classing agency, verifies each stage of design, build and manufacturing operations. Phil Short, DEEP's Underwater Research and Training lead explains that DEEP's subsea habitats will be the first of their kind to be classified under DNV rules, adding that "we don't mark our own homework".

Vanguard, the company's pilot habitat, was unveiled in Miami in October 2025. It is designed to house four crew at a depth of about 15 metres for week-long missions. At this depth, the habitat can run on ordinary air mixtures and could boost the productivity of scientific missions such as coral restoration projects. DEEP repurposed a steel pressure vessel from a saturation system known as a surface decompression chamber, which would typically sit on the deck of a boat to keep saturation divers at pressure. A standard decompression chamber is an airtight vessel that provides a controlled, pressurised environment for divers to safely return to normal

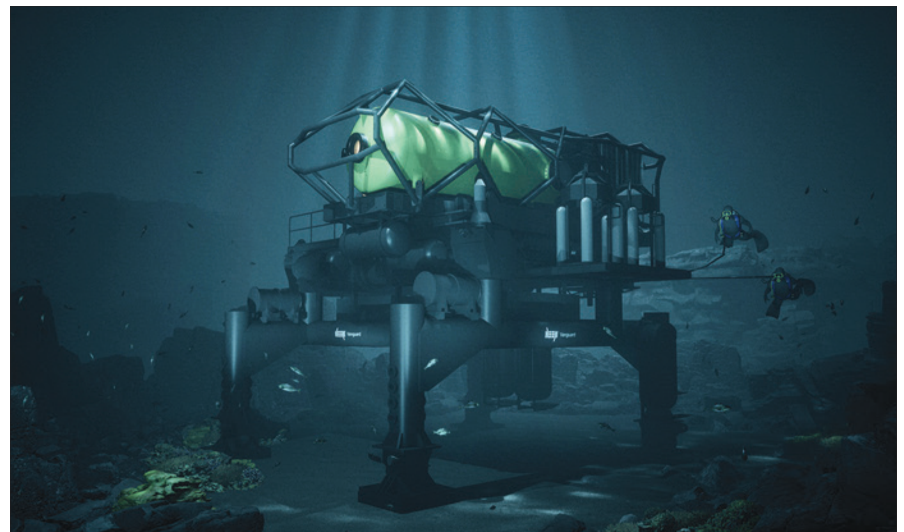
WHY SLOW ASCENTS MATTER

Divers breathe gas at the same pressure as the surrounding water. As depth increases, higher pressure causes more gas to dissolve into the body than at the surface. Nitrogen, which can't be metabolised, slowly accumulates in the blood and tissues during a dive. On the way back to the surface, divers ascend slowly to safely let the built-up gases leave their bodies – in the same way someone would ease open the lid of a fizzy drink that might have been shaken, rather than allow it to fizz over. Ascending too fast raises the risk of decompression sickness (DCS), also known as 'the bends', where bubbles of excess gas form in the body, causing symptoms ranging from joint pain and tingling, to more serious effects. The limited exposure to pressure on shallow, short dive times that are typical in recreational diving means that the risk of DCS is rare. Longer or deeper dives require slower ascents with planned pauses, like climbing a staircase, to allow the harmless release of the built-up gases through the breath. If, for some reason, this process is insufficient, or they need an emergency ascent, divers can be placed in a hyperbaric chamber to help extend the recovery process. This means they will stay in a sealed unit where they can breathe pure oxygen at a pressure two to three times higher than normal atmospheric pressure.



The deeper a diver goes underwater, the greater the decompression requirements become for the same productive time at the bottom. These constraints don't apply to submersibles, which keep a constant internal pressure close to that of the surface © DEEP

atmospheric pressure. It is used both as a preventative measure before or after a dive and as a treatment for DCS. The chamber gradually reduces pressure, allowing excess dissolved gases such as nitrogen to safely exit the body and preventing the formation of dangerous bubbles in the bloodstream. The engineers pressure tested the system to extreme internal and external depths and reengineered it into a comfortable living module classed by DNV. In-house engineers at DEEP designed a dive centre that is kept at the same pressure as the seabed to dock onto one end of the living vessel via a hatch, containing a moon pool – a floor opening to the ocean that allows entry and exit into the base. Extended time spent underwater in Vanguard will cause the crew to be saturated at the end of their mission.



A rendering of the Vanguard habitat shows how it will look once underwater. The yellow cylindrical pressure vessel houses the four-person living chamber. The surrounding exoskeleton acts as a protective cage with attachment points for external systems. Divers can enter and exit the habitat via a moon pool inside the dive centre to carry out experiments on the surrounding sea floor © DEEP

Vanguard sits on a foundation that anchors the habitat to the seabed. The habitat is connected to the surface via an umbilical that is attached to a large support buoy, which is roughly the size of two transit vans. The buoy houses compressors, generators with solar backups and systems that supply the habitat with breathing air, power and communications. If this buoy were to malfunction or become disconnected, Vanguard's dive centre is ringed with multiple 55-litre gas cylinders that act as onboard reserves and hold enough gas for the crew to complete a full decompression and return to the surface safely. Two other small independent habitats, known as refuges, are also fixed to the foundation and are accessible with their own moon pools to provide dry, safe environments for the crew to wait in if the main habitat cannot be used. Alongside supplies brought down in the umbilical from the surface support buoy, bladders – large, flexible containers that are commonly used within the commercial maritime industry – can be delivered to the habitat using submersibles or used for waste storage, which prevents anything from the habitat from being discharged into the ocean.

To return, the connecting hatch that isolates the living module from

The inside of the living chamber of Vanguard contains a multi-use space designed for work, relaxation and sleeping, where the crew will spend their time while they're not diving © DEEP/Getty Images

the other compartments is shut so it doubles as an underwater decompression chamber. Valves slowly bleed gas over the course of a day to reduce its internal pressure. This gradual depressurisation allows the extra gas absorbed over the mission to leave the crew's bodies until they are back at surface pressure. To leave, the living module is repressurised so the hatch to the dive centre can be opened. Because the crew are no longer saturated from the week spent at sea, they can exit through the moon pool and ascend the same way a diver would after a 15-metre dive. Short explains that this decompressing approach, in which decompression is completed inside a shallow underwater habitat before a simple diving ascent, has been in use for over three decades in previous underwater habitat programmes run by NASA, the US Navy and scientific diving teams, but is only applicable for habitats at shallow depths.

Future subsea habitats that DEEP is working on aim to enable human deployments up to depths of 200 metres, and will build on the technology tested during Vanguard's deployment. These habitats will be modular, self-contained systems carrying their own life support, like a submarine, without the need for a surface support buoy. Components will be built using wire-arc additive manufacturing, a metal 3D-printing method that melts metal wire with a controlled electric arc at the tip of a welding torch and lays the metal down in layers to form the part. HexBot, DEEP's six-arm robot, uses these torches to build curved pressure-rated segments up to 6.2 metres in diameter.

This process has DNV approval and Short points out that the approach lets them print, inspect and pressure-test individual components, rather than commit to a full hull upfront. In tackling unsolved problems, DEEP recognised the limiting factor was usually "[the lack of] enough budget to enable the engineering community to solve the problem", rather than if it was doable.

Short draws on 35 years of diving and teaching experiences across the globe to help lead the development of dive systems and training procedures for DEEP's future aquanauts who will live in its habitats. He says the goal is to "merge the safest bits of multiple dive communities" and create a programme that will prepare everyone from experienced commercial divers to non-diving scientists. Using astronaut training as a comparison he says "in the early space age, only elite military test pilots with thousands of flying hours went up. Now researchers [go] as they have an extreme scientific need to be there. We aim to do exactly the same [for the sea]." As Short puts it, "you can't bypass the limits" but DEEP is an example of using engineering to make "systems that safely work within them".

UNDERWATER AI

AI stands for air integration within the diving community: a feature that feeds pressure reading information from a diver's gas cylinder directly to their dive computer, either via a connecting hose or by a wireless transmitter. Using this extra information, the computer can provide estimates on remaining gas time at various depths, helping to track air consumption through the dive to inform safer in-dive decisions.

Application of the other AI – artificial intelligence – in diving is currently centred on research and post-dive analysis, for example in training image models to automatically identify marine species, or coral cover in underwater footage.

BIOGRAPHY

Phil Short, a Fellow of the Royal Geographical Society and The Explorers Club, is DEEP's Underwater Research Diving and Training Lead. He advises on the design, engineering, manufacture, and testing of its subsea habitats. His early experience exploring flooded caves sparked a 30-year career advancing diver safety and training. A member of the IANTD Board of Advisors, TDI Instructor Trainer and Full Cave Evaluator, and HSE Commercial Surface Supply Diver, he has led expeditions and trained scientific and public-safety teams worldwide, including Scientific Diving Teams from Woods Hole Oceanographic Institute, Lund University and the US National Parks Service.

FILM ENGINEERING: GETTING THE PERFECT SHOT

In 2024 and 2025, vintage film format VistaVision has enjoyed a resurgence, with directors such as Paul Thomas Anderson (shown here filming *One Battle After Another* with Leonardo DiCaprio) choosing to shoot primarily in this richly detailed large format film. With its massive cameras, weighing over 20 kilograms, new camera stabilisation technologies are playing a role in allowing camera operators greater flexibility with the format © Alamy/Landmark Media

Film and documentary makers are unveiling stunning cinematic shots and scenes from the natural world that audiences have never seen before. From *The Favourite* and *One Battle After Another* to *The Green Planet*, these incredible visuals are thanks to advanced stabilisation systems and custom robotics, writes Leonie Mercedes.

Did you know?

- Your eyes are the ultimate Steadicam: while cameras wobble with every step, your brain runs an advanced stabilisation system that smooths out the world in real time. The Steadicam was the first to replicate that effortless continuity in the 1970s
- Robots make plants look savage: the jaw-dropping timelapse battles in *The Green Planet* were filmed by custom-built robotic rigs that tracked unpredictable plant movements for weeks, turning slow growth into cinematic drama
- Elastic can tame a 1950s beast: directors chasing vintage aesthetics use stabilisers such as the Mantis, which relies on latex elastic and pulleys to suspend vintage VistaVision cameras weighing as much as a small child, while keeping shots smooth

You may not be aware of it, but inside your brain is an advanced film production studio.

As our bipedal bodies plod their way through space, sending tremors through our eyeballs with every footstep, this studio ensures our visual experience of the world is smooth and continuous.

Cameras do not have it so good. Sitting upon our shoulders, or held in space by our unsteady human arms, they're subject to all the movements in our bodies, which they obediently capture in their shots.

The first decades of filmmaking smoothed out a lot of the bumps by putting cameras on tracks or cranes, and while these kept things gliding along nicely, they did limit where you can shoot – tracks can't go up stairs, and they're impractical on bumpy ground. That was until the Brown Stabilizer, later to be known as the Steadicam.

HOW THE STEADICAM CHANGED CINEMA

The invention of the Steadicam in the mid-1970s meant that for the first time, cameras could go off-road. The Steadicam hugely extended the range of where cameras, and therefore

The Steadicam, invented by camera operator Garrett Brown in the 1970s, allowed effortless continuity in cinema for the first time. It both isolates the operator's movements from the camera and distributes the camera's weight through the operator's vest © Shutterstock

Rizwan Wadan, for the first time in history, operating successfully in a production environment with a 24.5-kilogram film camera system, the heaviest camera system to ever be stabilised on a gimbal © Pixeleyed Pictures

viewers, could go, marking a watershed in visual storytelling.

Its inventor, cameraman Garrett Brown, described moving camera shots before the Steadicam as now appearing "primitive". He said: "What was missing, and it took me years to understand this, is the glorious continuity of movement that we have as humans."

The Steadicam provided that visual continuity. It let viewers drop smoothly from over nine metres in the air to follow Woody Guthrie through a crowd (*Bound for Glory*, the first film to use Steadicam), and follow Jack Torrance's son Danny on his tricycle round the corridors of Overlook Hotel (*The Shining*). Most memorably, it let us bound triumphantly up the steps of the Philadelphia Museum of Art alongside Rocky Balboa (*Rocky*).

The Steadicam isolates the operator's movements from the camera, so that all the viewer sees is smooth motion, like that provided by our eyes. It's made of three main parts: the vest, worn by the operator; the arm, which attaches to the vest; and a sled, an upright post attached to the arm via a gimbal.

The arm holds the camera and other equipment, including a monitor and battery. The gimbal lets the operator move the camera smoothly on all three axes. It can pan (side-to-side, also known as yaw), tilt (angling up and down, also known as pitch), and roll (rotation). Gimbals trace their history back to the ships of ancient Greece, where they were used to keep compasses steady on rolling seas.

Mounting the camera at the top of the sled and adding the counterweights of the battery and monitor to the bottom both increases the camera's moment of inertia, that is, makes it harder to move, and moves the camera's centre of gravity to the sled, where the operator can control it.

The arm does a lot of the heavy lifting, figuratively and literally, by absorbing the operator's movements with a system of springs, hinges and links, and taking the weight of the camera, which is distributed comfortably through the operator's vest.

Learning to operate a Steadicam with sensitivity and artistry takes years to master. Using one can also be physically demanding. "You have to have really good stamina," says Ilana Garrard, a Steadicam operator who has worked on productions including *Sex Education*, *Anatomy of a Scandal* and *Black Mirror*.

Each Steadicam setup is fitted closely to the operator via the vest, and finely balanced before every shoot. Any misalignment could pull the operator off-balance and compromise their control. "Every single element is interlinked into how you understand your own body and how it's balanced onto your body," Garrard continues. "It's a very personal and physical thing."

After almost a half-century in Hollywood, the Steadicam is still a crucial piece of kit for many filmmakers. But in 2013, a technology debuted in the cinematography world that could provide the fluidity of a Steadicam shot without the years of training – the three-axis gimbal.

ENTER THE GIMBALS

Gimbals stabilise shots electronically by sensing their position in space. They do this with devices called inertial measurement units (IMU), and correct any undesirable wobbles or shakes with a system of motors. Camera operators simply load their camera onto the gimbal and shoot.

Gimbal IMUs incorporate accelerometers and gyroscopes, each a type of tiny device called a micro-electromechanical system (MEMS), to detect their motion relative to a starting position. (As well as keeping camera shots smooth, IMUs also hold drones steady and let you rapidly switch your smartphone from portrait to landscape mode.)

Gimbals' versatility and accessibility – no years of Steadicam training required – has made them popular

Wadan came to filmmaking with a mission: to improve relationships between the Muslim and non-Muslim world through storytelling. Having worked as a mechanic, he became fascinated by the technical aspects of the filmmaking process.

not only with influencers looking to eliminate footsteps from their TikToks, but also among Hollywood filmmakers seeking an intimate feel in their dramatic scenes. When paired with a load-bearing vest, or "exoskeleton", they can let camera operators move hefty film cameras with the ease and sensitivity of entirely handheld cameras.

Director of photography for *The Favourite*, Robbie Ryan, used the Helix gimbal and exoskeleton system in order to manoeuvre a 24.5-kilogram Panavision film camera. He told Kodak that the Helix system "gives a visual language that is different to Steadicam, and allowed us to capture shots … in a fluid and floating way that you can't achieve with any other piece of kit 35mm-wise".

Filmmaker Rizwan Wadan was a major contributor to the research and development of Helix in direct partnership with camera technology company Letus. He founded the UK-based Mr Helix in 2016 to continue development of the system. Seeking to create a gimbal that could bear the weight of an entire cinema camera package, as a camera operator, he spent years studying how mass, inertia and balance interact.

A breakthrough came when, developing the first prototype with Letus, they decided to place the optical centre of the lens precisely at the pivot point – that is, where the operator is holding the camera.

"That single engineering decision changed everything, because it meant the sensor stayed as still as possible while the frame absorbed the unwanted motion," Wadan says. "Movement looks organic, the horizon stays level, composition stays intentional, and the image doesn't have the artificial float common to drone-style gimbals."

Wadan came to filmmaking with a mission: to improve relationships between the Muslim and non-Muslim world through storytelling. Having worked as a mechanic, he became fascinated by the technical aspects of the filmmaking process. He taught himself photography and filmmaking by taking on 44 LinkedIn courses in two and a half years.

He adds: "Anything relating to the camera such as drones, cranes, gimbals, and exoskeleton technologies captivated my imagination as I could envision how they could be used to capture not just shots but stories entirely."

Wadan works closely with filmmakers to ensure the technology supports their creative vision. The gimbal and the exoskeleton "were designed from a perspective of capturing drama," he says. When working out how to develop the technology, "it was always with a script in mind".

Despite its deployment on high-profile productions, the Helix system is still – strictly speaking – a minimum viable product that Wadan is continuing to develop and test in the field.

FRICTION IS YOUR FRIEND

In a busy town square, Chris Herr is jumping up and down on the spot. Just in front of him, a film camera, suspended from a thin cord attached to his back via an arm, hangs in midair. Despite Herr's hopping, the camera remains almost motionless, suspended in space. It should be impossible. Passersby stop what they're doing for a better look.

Herr is demonstrating the Mantis, a camera stabilisation system that uses a length of elastic to dramatically reduce

Robbie Ryan BSC ISC shooting *The Favourite* with the Helix and exoskeleton arms customised to attach to a dolly. This was a first time such technologies were used and combined in this way, with a Panavision XL2 35mm film camera attached to the exoskeleton and to the dolly where the operator has freedom of movement in a unique way © Pixeleyed Pictures

One of Field's robots, named Gomez, captures the flowers of an orange tree blooming in his Colorado studio in November. Fields uses an 86-inch TV that works with video game engine Unreal Engine to provide the backdrop for his plants. "I use the same technique they use with *The Mandalorian*," he says © Chris Field

camera wobble. The elastic, up to nearly two and a half metres in length, runs back and forth along a series of pulleys that the operator wears on their back. Pulleys dampen the operator's movements, while the elastic both takes the weight of the camera and allows them to move it freely in space.

"It's a culmination of a lot of little hacks that I created on the rigs I've used over the last 10, 12, years on film sets," explains Brett Harrison of BLKBRD, who developed the Mantis with Herr. "I realised that the more elastic the better. And so over the last eight years, I've added more and more pulleys to extend the amount of elastic that's in place."

The quality of the elastic, made of latex, is important. The pair tested different types for durability, stiffness and strength, and currently source it from a specialist supplier in Mexico. "It smells very aromatic when it arrives," says Harrison.

These strong lengths of elastic can take a lot of weight, meaning today's directors can get the aesthetic they're seeking with heavy vintage movie cameras while enjoying the stabilisation modern tech provides. For his latest feature *One Battle After Another*, director Paul Thomas Anderson suspended a roughly 23-kilogram 1950s VistaVision camera – which offers rich detail in an analogue format, but without the graininess – from two Mantises.

While dramatic scenes at human timescales call for human camera operators, when capturing the drama unfolding imperceptibly slowly in the plant world, you need to call in the robots.

AGE OF THE ROBOTS

"It's a monster," David Attenborough tells viewers.

A spiked fist of a plant slowly rises from the depths, before swinging around at the water's surface like a mace wielded by a medieval knight. After clearing enough space, it starts to open, revealing more of its teeth-like barbs every second. As it opens and flattens on the surface, it shoves other plants out of the way, skewering any that happen to be too close. They shrink and retreat. Who knew a plant could be so savage?

Now, we do – all thanks to timelapse photography, which squeezes hours, days, months, even years of action, into seconds. The terrifying actions of this particular plant were captured on *The Green Planet* by a robotically controlled camera, one of a group that came to be known as the Triffids, built by visual engineer Chris Field.

The Green Planet producer Paul Williams brought Field on board after seeing his timelapse footage that followed a pitcher plant's unpredictable movement as it grew. "I was able to tailor and adjust my motion with the robot over the course of six weeks, to capture it, keep it in frame and keep it looking good," Field says.

Field taught himself how to create timelapses, starting out building the rigs that capture footage of the night sky. Wanting to get the camera to move while he was filming, but finding the systems on the market too expensive, he started building his own. "Robotics seems really complex, but most of this stuff kind of goes together like Lego," he says. "You don't really need formal engineering training."

He uses a software package called Dragonframe to control the cameras,

Cinema is a fertile ground for technological innovation, as filmmakers strive to push the boundaries to create things we've never seen before. "It's absolutely phenomenal," says Wadan. "The sets are designed to allow you to do what you could not do in the real world."

adjust the lighting and bring the shots together into a film. Being able to change how often you take shots of a plant on the fly is important. "Plants march to the beat of their own drum," he says. "Filming plants is kind of like trying to take pictures of kids when they've had coffee and [are playing with] a puppy – like, very rambunctious."

Like all of the other tech we've seen so far, Field's systems are the result of a lot of trial and error. "You don't start it knowing everything," he says. "Everything that I have done, every success that I have, is a small little cap on top of a mountain of failure."

BALANCING TECHNOLOGY WITH HUMANITY

Cinema is a fertile ground for technological innovation, as filmmakers strive to push the boundaries to create things we've never seen before. "It's absolutely phenomenal," says Wadan. "The sets are designed to allow you to do what you could not do in the real world."

Outside the studio, Harrison is developing software that aims to make film look more natural and organic by integrating models that mimic how our brains handle images. "We think that our eye is a window to the world," he says. Actually, a lot of computation is happening in our brains to make what we see comprehensible to us. "Cameras just aren't that way."

Meanwhile, new technologies let filmmakers digitally eliminate any shaky camera work. Could this signal the end of physical camera stabilisation technology? According to Harrison, this new tech hasn't dampened interest in the Mantis. "There was a concern that … people would lose interest in hands-on creation of shots, but that hasn't proven out at all; people seem just as intent as ever to craft the shot and be involved with the scene directly," he says. "Filmmakers just want to hold a camera very specifically."

Herr adds: "The analogue methods of operating a traditional Steadicam put a lot of finesse into the hands of an operator, much like a pen on paper."

This is fundamental: filmmakers want the stability that these systems can provide, though never at the expense of their creative expression. Technology that creates a barrier between the action and capturing it will always be a nonstarter.

Physical stabilisation technologies, like the Steadicam, Helix and Mantis, let the filmmaker enmesh themselves in the scene at the moment of capture, offering different ways to bring the audience as close to the action as possible. And at a time when high-end film formats such as VistaVision are regaining popularity, the stabilisation technologies allow operators to wield those whopping cameras more easily.

"When I'm operating [filming a scene], I'm thinking less about the technology and more about what the audience should feel," Wadan says. "Every movement, every slight tilt or pause, changes how a scene breathes … The camera shouldn't draw attention to itself; it should move as naturally as emotion does."

During a particularly emotionally heightened scene, the cast and crew can enter an almost meditative state, says Garrard. "The thing that I love most about my job it that when you are so into the performance, you're feeling what the actor is feeling," she says. "You have to let go of your own thoughts."

In these situations, the Steadicam, a virtual extension of her body, helps her respond instinctively. "With a Steadicam you are just one person operating that camera, and so you are able to follow your feeling and react. That is the best kind of operating – where you combine photography, technology and emotion."

DON'T OVERDO IT

"Over-correction is absolutely a thing," says Chris Herr. "It's usually seen during the tuning of stabilisation systems. PID (proportional, integral, derivative) tuning can be overdone to the point where the motors apply too much counter torque and in turn induce vibration and oscillation. It's an art form to toe that line of tuning, enough for a stable image but not too much that the whole head begins to shake."

Leonie Mercedes would like to thank Chris Field, Ilana Garrard, Brett Harrison, Chris Herr, and Rizwan Wadan for their help in producing this article.

A REVOLUTION IN ORGAN TRANSPLANTATION

Professor Constantin Coussios OBE FREng FMedSci

After testing out a few fields of engineering, Professor Constantin Coussios OBE FREng FMedSci settled on biomedical, following his instinct to help others. He speaks to Beverley D'Silva about his journey from astronomy to co-creating an award-winning innovation that is transforming how liver and kidney transplants are done.

Coussios concluded that civil engineering wasn't for him, but he loved fluid mechanics and control engineering, "both of which I hadn't even been aware of when starting my degree".

Imagine an engineering career where every working day involves a life-or-death situation and decisions. That has been the chosen path of Professor Constantin Coussios OBE FREng – one that he describes as being "fun and a huge privilege".

Coussios was born in Greece and, aged six, moved to Belgium with his parents. His father was a civil engineer, and he would often accompany him on work projects. "I was seeing the practical side of construction," he says. "What struck me, from a young age, was the idea of building things from the ground up where there was nothing before."

A family friend introduced him to astronomy and another introduced him to his areas of expertise: astrophysics and chaos theory. "I was inspired and fascinated by the idea of, say, exploring Mars, but I couldn't see where I could achieve an impact [in these fields] over my lifetime." He felt they were too removed from day-to-day practical application and that idea of "building things from the ground up".

So, at 16, Coussios decided to study aeronautical engineering. A geography teacher at his international school suggested he could apply to study engineering at the University of Cambridge. "I would never have considered applying to the university or moving to the UK." He applied, "and was accepted, to my surprise, even to this day".

He entered Cambridge young, at 17. "It was a life-changing experience". First, although he had felt he was a "pretty good student in school", at the university he felt "distinctly below average in a cohort of extremely bright people". He turned that into a positive; feeling "lifted" by their brilliance encouraged him to "find another gear to be able to exist in that environment".

He is also very glad he chose to study general engineering: "At 17, I knew very little about what engineering really was, and a general course allowed me just long enough to figure out what my true passion is." Work experience was instrumental in figuring that out. He spent a summer at Balfour Beatty Civil Engineering, working on concrete castings for the A13 – "I would advise avoiding this road, designed by a very inexperienced engineer, with excellent supervision!" – then at French Aerospace, and the Greek Air Force (as part of compulsory military service in his native country).

Coussios concluded that civil engineering wasn't for him, but he loved fluid mechanics and control engineering, "both of which I hadn't even been aware of when starting my degree". However, he still felt that something was missing, "something more soul than mind". From a young age he had felt "empowerment and joy" whenever he was helping others. He ascribes it to being an only child, "and having your friends be your family". His chosen field had to serve people in some way.

A FLUID CHANGE

Searching for a final-year project, one title – 'study of blood as a non-Newtonian fluid' – jumped out. Non-Newtonian fluids are materials that don't flow like regular fluids (flowing freely when gentle force is applied but becoming solid under shear stress), and he'd found these unpredictable materials one of the most exciting aspects of fluid mechanics. The project stemmed from a call by eminent transplant surgeon Professor Peter Friend FMedSci. He needed engineering help in the field of perfusion – the passage of fluid through the circulatory or lymphatic system to an organ or a tissue. Friend was looking for an efficient way to make blood flow through an organ to be able to use and make that organ function outside the body. "I really wanted that project," says Coussios. He was so enthused that, when he found out the project's supervisor, the late Dr Jeffrey Lewins, was on sabbatical in Fiji, he used a "significant amount" of his monthly income to call him. "I think he was sufficiently impressed by my tenacity that he took me on."

QUICK Q&A

What inspired you to become an engineer?
My 'can-do-anything' father and my brilliantly inspiring PhD supervisor.

What are you are most proud of?
Helping bring life-saving technology to life and widespread clinical adoption for patient benefit.

What is the best part of your job now?
Being challenged by far brighter younger engineers daily and having only experience to counter with.

What's your most admired historical example of an engineer?
Archimedes, for simultaneously conquering the conceptual (buoyancy) and the practical, embodied in the mechanical complexity of the Antikythera mechanism with which he is credited.

Which engineering achievement couldn't you do without?
Closed-loop feedback control systems, which encompass engineers' entire way of thinking.

Most impressive engineering to look at?
Thomas Heatherwick's Rolling Bridge at Paddington Basin in London: simple, brilliant, functional, timelessly elegant, and biomimetic – everything great engineering should be!

Preparation of a liver before connection to the OrganOx metra®, which is pre-filled with blood-based perfusate (seen in the background)

A few weeks into his fourth year, he was sitting in an operating room with Friend, and two medical research fellows, attempting to keep a pig liver alive outside the body by flowing non-Newtonian blood through it. "I remember holding this liver connected to a machine, and it was making bile. I thought: 'this is incredible! This is what I want to do for the rest of my life'." He couldn't then see the practical implications of the research, but it did have the strong connection to people he sought: "we needed to be four of us around this machine to make it work". This "life-changing" moment sealed his path in biomedical engineering.

At the time of his first experiments with Friend, in 1997 and 1998, the technology was "the size of two upright pianos. It had about 1,600 control variables … it was completely unusable by anyone other than Peter, me and the other two research fellows involved in the project." He was "educated very rapidly" by his medical colleagues and besides quick thinking, he needed stamina – and sheer staying power. He recalls often going into the lab on a Friday "and not sleeping until Monday, when my first lecture was, in order to get an experiment done". This was his choice; he was driven by "fire in the belly … something exciting was happening – much more exciting than going home to watch *The Simpsons*."

Some of those nights he spent sleeping with the pigs being used in pre-clinical research to make sure they were OK. "We had to look after the donor and the recipient. On a skeleton crew, you do what you need to." He believes all engineers need to follow their invention, to understand the reality. "As a technologist, as an inventor, you live and breathe your invention. Understand how it interacts with its natural environment."

BUILDING A LIFE-CHANGING INNOVATION

His thesis would form a significant part of what would become OrganOx ('Keeping transplant livers alive', *Ingenia* 81), the world's first normothermic machine perfusion (NMP) device for liver transplantation. During its development, Coussios faced many challenges. He recalls: "I remember sitting there thinking: 'it's wonderful what they're doing by twiddling knobs, but I'm a half-decent engineer. I can model this away in about six months, build a predictive controller that is going to anticipate every little thing the liver is going to do. Building a control system is going to be child's play.' Twenty-eight years on, I'm still trying."

Biomedical engineering taught him "a lesson in humility" as "everything in biology is interconnected in ways we cannot yet hope to begin to understand".

Having a great sense of humour helped, though. During his PhD in acoustics under the supervision of Professor Shôn Ffowcs Williams, one of the designers of Concorde, he recalls conducting experiments using ultrasound to detect whether red blood cells had been damaged when flowing around the artificial circuit keeping the organ alive. These required latex: "and the most widely available commercial form of latex is condoms," he grins. A legislation change meant the non-lubricated condoms needed were going to be withdrawn from sale. "I needed a thousand [condoms] to complete my experiments. So I went to my local Sainsbury's and filled a trolley with their entire stock. I'll never forget the person at the till, scanning these condoms robotically – click, click – and when they had finished, leaning over to me and saying: 'Got a big weekend planned, sir?'."

He then moved to the US for two years and trained in therapeutic ultrasound, returning to Oxford in 2004, when he restarted work with Friend and colleagues in NMP for liver preservation before transplantation. One of his greatest concerns was that his algorithms would one day fail (thankfully that hasn't happened). But in his work, he can never forget that "someone's life is ending and someone's life is being prolonged".

Raising capital and building belief in the project were other ongoing challenges. But by 2004, he was fully engaged in making OrganOx happen. "I gave it my time and passion, I really believed in it." There were many landmarks on the way: in 2008, the key method patent that underpinned the metra® was granted, and OrganOx was spun out independently from the University of Oxford;

Usability is a key feature of any biomedical device, embodied in the design of the OrganOx metra so that it self-fills from the bottom up while effortlessly expelling air at the top of the device

Coussios (fifth from right) with the OrganOx team accepting the 2025 MacRobert Award from Minister for Science Lord Vallance of Balham KCB HonFREng FRS and his OrganOx co-founder Professor Peter Friend FMedSci (sixth from right)

in 2009 product development began on metra® for liver; in 2016 it received its CE mark; and in 2021 it gained FDA approval for liver transplants in the US.

What the team created was a world-first technology that mimics conditions as if the liver is already in the donor, keeping an organ alive and functioning outside the body for at least twice as long as conventional cold preservation techniques. It has dramatically increased the number of transplants for patients and reduced the need for nighttime and weekend operations. It allows medics to make better use of donor pools. A second device from the team is being developed to do the same for kidneys; a third, patient-connected device to provide 'liver dialysis' is under development and has entered clinical trials.

SAVING LIVERS AND LIVES

The OrganOx metra® can enable safe transplantation of more than 70% of organs that are currently being discarded. In 2024 it was being used in four transplants a day, rising to more than 10 per day in 2025. Today there are "over seven and a half thousand lives saved and accelerating". His teams have counters on display, notching up the lives saved: "That's what drives us as a company."

The device is in use in more than 15% of NHS transplants in the UK, and across 12 countries. Adoption was always a key driver, as was an egalitarian ethos: to this end the company leases the devices free, for a commitment it will be used a certain number of times in a year.

Today its success is such "you can't walk into a transplant conference without it being dominated by these technologies," says Coussios. He credits his "extraordinary" research team, and fundamental to that was Friend, OrganOx Co-Founder and Chief Medical Officer, with whom he felt "an incredible connection" from day one and "without whom none of this would have happened." Whatever else was happening, be it marriage, children, or examining work, their loyalty and friendship was never in question.

OrganOx's groundbreaking achievements were crowned when it won the Royal Academy of Engineering's MacRobert Award in 2025 – "a pinnacle of my career" he beams. At the Academy's *Innovation incoming: adventures in organ preservation* event, its President Sir John Lazar CBE FREng praised it as "a breakthrough that exemplifies the power of engineering to change lives". Judge Dr Loubna Bouarfa saluted its "serious science, AI, fluid dynamics, gas analysis, all designed to keep the organ healthy for longer. It's medical brilliance powered by engineering magic." During the accompanying interview, when asked about the use of AI in organ preservation, Coussios described the challenge of finding one set of control algorithms that would work for every organ, coupled with surgeons working in different ways. "Using AI to make tech adaptive

is a challenge," he said, adding that AI "can't describe what isn't described in the original data set".

ROUTES TO EXPANSION

The dust hadn't settled on the MacRobert Award before another big announcement, in August 2025: OrganOx was to be bought by Terumo, a Japanese multinational biomedical company. "It felt right," says Coussios. "We had already managed to get the technology out to 12 countries on four continents. [This] was a unique opportunity to go to the next level up, a company that has the capability to bring it to almost every single country on the globe." OrganOx being acquired, not sold, allowed it great opportunities he notes, including keeping most of its R&D in the UK for the foreseeable future, and attracting greater investment.

Other projects are OxSonics, launched in 2014, a clinical-stage therapeutics company that has discovered a new way to enhance the delivery of anti-cancer drugs into tumours, using ultrasound and tiny gas bubbles: and OrthoSon, launched in 2016, which has "developed an extraordinary material to repair the intervertebral disc in the spine", with lower back pain the biggest most and expensive cause of missed work days and disability worldwide, he points out.

OrganOx has grown from "three people for the first three years to almost 300 today". With it, he has fulfilled his vocation: to make a real difference to people. "When you find something that feels like your calling – and you inspire others to find theirs – you get the best out of yourself, individuals and teams." There's still so much to be done, he believes; OrganOx can be "the foundation for transforming the entire field of organ technology". Did it at times almost feel as if he was going through medical training? "I tease my medical mentors – not just Peter, but those in radiology, oncology and orthopaedics – and say I get to experience the exciting bits of medicine without the boring bits." Running or co-running "really exciting clinical trials" and seeing major advances has been a huge privilege. "It's also very ironic, because there was a small part of 16-year-old me who wanted to be a doctor. I decided not to do it because I thought I couldn't stand the sight of blood or rapid decision-making under pressure. And 20 years on, I have spent more of my life elbows deep in blood than most surgeons I know."

When Coussios recently handed over as director at the Institute of Biomedical Engineering in Oxford, after a decade, a colleague noted he had achieved a lot, but what he was really about was people and helping them feel equally important, whatever their role. "That was very touching, and if it's true, I'm sure it has a lot to do with my parents." To his father, he owes his dynamism and ability to make things happen; his mother has "an incredible maturity and inner peace" and he feels "had the biggest influence on me emotionally". "And my wife," Niki Trigoni FREng, with whom he shares a common passion for bringing transformative technologies to life, which led them to become one of several married couples to both be Fellows of the Academy.

Although work has "never stopped being 24/7 for me" he does strive for balance. His passion for sport is part of that and fed into the January 2024 official launch of Podium Institute for Sports Medicine and Technology at the University of Oxford. It aims to improve sport safety with particular focus on youth, community and women's sport. His wife, who he met at Cambridge, was "very understanding" when his birthday weekend plans for her were railroaded as he had to rush off to save a "major bit of data acquisition" concerning a rugby match. Their three sons share his interest in "creating something out of nothing", he feels; one is studying architecture; one is considering medicine; one may become an engineer but is also an extraordinary cook. He doesn't mind what they want to do, but he'd like them to have "the privilege I have of going to work for fun and working with your best friends".

He reflects on his career: "When I came to the UK alone at 17, my main language was French. But I was never made to feel like a foreigner. I was embraced … Being on that journey has been so important and so empowering. And to have had the recognition and support from organisations such as the Royal Academy of Engineering and the Academy of Medical Sciences … I feel very fortunate to have had it in spades."

CAREER TIMELINE AND DISTINCTIONS

Studied engineering at the University of Cambridge, **1994–1998**. Engineering intern, Balfour Beatty Civil Engineering and French Aerospace, **1995**. Supersonic Aircraft Engineer, Hellenic Air Force, **1996 and 1997**. PhD in engineering, University of Cambridge, and Engineering Research Associate, Department of Surgery, University of Cambridge and Nuffield Department of Surgery, University of Oxford, **1998–2001**. Postdoctoral Research Fellow, University of Cincinnati, **2001–2002**. Postdoctoral Fellow, Boston University, **2002–2003**. Lecturer in biomedical engineering then Reader in biomedical engineering, University of Oxford, **2004–2010**. Statutory Chair of Biomedical Engineering, University of Oxford, **2011–present day**. Chief Technology Officer and Co-Founder, OrganOx, **2008–present day**. Director, Institute of Biomedical Engineering, University of Oxford, **2016–2025**. Fellow, Royal Academy of Engineering, **2020**. Director, The Podium Institute for Sports Medicine and Technology, **2021–present day**. Awarded an OBE for services to biomedical engineering, **2022**.

HOW PRECISION MAPPING IS MAKING MINEFIELD CLEARANCE FASTER AND EASIER

Clearing minefields can include days of painstaking mapping. Taking its cues from precision agriculture, Manchester-based startup MiFi Maps' technology promises faster and easier work for humanitarian teams in conflict zones.

A deminer escorting children across a minefield in Iraq © Patrick Truong/MiFi Maps

Patrick Truong's six years clearing landmines for humanitarian organisations was still the best job he's ever had. It took him to Syria, where he led teams of local nationals clearing minefields so that farmers could work on their land again, and Iraq, where he and his colleagues cleared children's paths to school. "With every item we found and disposed of, you could sense there was an immediate impact, that we were helping protect people's lives and limbs," Truong says.

While working in Syria, Truong met his now-partner Jacqui Brownhill, at the time a programme manager in the sector. When the pandemic broke out the couple, who had moved to the UK, had some time to think and spotted an opportunity to help mine clearance organisations spend less time mapping and more time clearing mines.

Mapping is one of the trickiest aspects of mine clearance. It entails knowing precisely where the boundaries of minefields are, which areas have been cleared and which areas remain uncleared. With Truong's knowledge of the limitations of mine clearance, the couple decided to try and make this painstaking part of the process easier, and founded Manchester-based startup MiFi Maps.

FROM TRACTOR AUTOSTEER TO PRECISION MINE MAPPING

Landmines may be banned by international law, but they're still a huge threat to life in current and former conflict zones. According to UK-based landmine clearance charity (and one of Truong's former employers), the HALO Trust, over 5,700 civilians were killed or injured by landmines or explosives in 2023.

EYES ON THE INNOVATORS

Ingenia **is keeping a close eye on the engineering breakthroughs making a difference around the world.**

Scientists at the **University of Glasgow** have used the first bioengineered bone marrow model to advance cancer research and reveal new therapy insights

The **City of Bogotá** is among the Earthshot Prize winners, for its work to cut air pollution in the city by 24% since 2018

Before a minefield can be cleared, the team on the ground must first find out where exactly it is. That often means speaking to the local community, as in some cases, a person, vehicle or animal may accidentally have triggered a mine. Then, they draw a rough map and survey the area in detail, either by finding the mines themselves with metal detectors, or by spotting evidence of mines, such as blast craters.

Only then can clearance start. You might picture people with metal detectors, excavating metallic signals to determine if it's a piece of scrap or a mine. There are also mine detection dogs, which sniff out explosives and sit down by the trace, ready for their handler to mark the spot; and armoured clearing vehicles, which plough the earth to push buried objects to the surface.

After disposing of any mines unearthed in the process, the team has to record the area that's been cleared. More often than not, this involves old school tools: a compass, tape measure and a hand-drawn map, which "takes forever, and it's a real pain," says Truong. Some teams use a smartphone or tablet, but it's not ideal, as GPS can be off by three metres or more.

Truong's solution was inspired by tractor autosteer, itself underpinned by a well-established technology called real-time kinematics. Real-time kinematics corrects GPS errors caused by interference from atmospheric conditions, and increases positional accuracy from over three metres to within a few centimetres.

Setting up real-time kinematics involves first setting up a lightweight, portable base station with a known position, explains Truong. The base station receives satellite signals, calculates errors, and then transmits this error correction to 'roving' (movable) devices. For MiFi Maps, the roving devices are attached to a metal detector, or to a dog or mine clearing vehicle, mapping clearance as it happens.

MiFi Maps' roving tracking device being tested during a field trial in Sarajevo, in this case attached to a metal detector © MiFi Maps

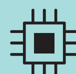
"It saves everybody a lot of time and effort, so that they're not having to go in after the fact and then draw their map by hand or save GPS coordinates on their phone," explains Truong. "And it will be done to centimetre accuracy, rather than maybe being off by three metres or more, which, depending on where the minefield is, can be quite crucial." Aside from knowing the data is more accurate, it ultimately saves mine clearance professionals time and resources. Rather than taking a day or two to map a minefield, that time can go towards further clearance in the area.

Truong and Brownhill are now focused on making the roving devices even smaller and lighter. They have also developed a version that operates without the need for a base station. By using precise point positioning, which receives GPS corrections directly from a satellite or the mobile phone network, the system can achieve accuracy of less than 20 centimetres without the need for extra equipment. This makes the system more versatile and portable, important when operating in challenging environments.

As an engineer with a background in explosive ordnance disposal, developing the technology behind MiFi Maps has been a new experience for Truong. Nevertheless, the company has already attracted attention from humanitarian mine action groups. It has signed a memorandum of understanding with Norwegian People's Aid, an Oslo-based charity that works internationally, and conducted a field demo for the organisation in Bosnia in May 2025. The team has also secured grant funding from Innovate UK, the Business Growth Hub and the Royal Academy of Engineering's Regional Talent Engines programme. It aims to conduct further field testing in different countries in the coming months.

As MiFi Maps' technology continues field testing, the hope is that the technology will be embraced by mine action organisations worldwide, transforming the way mapping is carried out in the sector. By making the process more accurate and far less resource- and time-intensive, it allows greater focus on the most critical task of all: clearing landmines and explosive ordnance.

Researchers at the **University of Birmingham** are developing a quantum brain scanner to measure the effects of blast exposure on military personnel



The Royal Academy of Engineering's report on the State of UK Deep Tech found that the UK is the **world's third largest deep tech hub**, raising $43.7 billion since 2019

Cambridge Photon Technology has raised £1.6 million to commercialise technology that converts wasted sunlight into usable light in silicon solar panels

EYE SCANS LAY OUT A PATH TO SPOTTING CHRONIC HEALTH CONDITIONS

An award-winning handheld glaucoma detection device is the first step towards detecting a wide range of chronic conditions, from diabetes to Alzheimer's. All it takes is a quick scan of the eye.

When you go for an eye check-up, you probably expect to squint at some tiny letters, compare some red and green lights ("One or two? Three or four?") and find out whether you're at risk of conditions such as glaucoma or cataracts.

What you might not expect is for your eyes to reveal if you're at risk of diabetes or Alzheimer's – or other chronic health conditions that at first seem unrelated to the eye. But far more than even a window to the soul, the eyes can indeed tell us about these conditions, in an approach known as oculomics.

When Dr Dan Daly and Dr Robin Taylor founded Occuity in 2019, the pair had a vision to develop oculomics devices that would make detecting chronic health conditions as easy as tests at your high street opticians.

With oculomics being a relatively new area, the founders, who are now CEO (Daly) and CTO (Taylor), first focused their energies on developing a handheld device that supports glaucoma detection, the PM1, to demonstrate that its core technologies were sound. But the PM1 turned out to be much more than just a proof of concept, winning the engineering team the Royal Academy of Engineering's 2025 Colin Campbell Mitchell Award.

Occuity's handheld PM1 device supports glaucoma detection, and takes just a few seconds to scan the eye. The company is also developing oculomics devices that will share many of its design features, but will instead allow clinicians to test for chronic health conditions such as diabetes and Alzheimer's © Occuity

Glaucoma is most accurately detected by adjusting eye pressure readings with corneal thickness measurements taken with an ultrasound pachymeter. This is an uncomfortable and time-consuming process, typically requiring anaesthetic eye drops and a trained practitioner. The PM1 requires neither and its measurements take just a few seconds. In practice, an optometrist can simply hold it a couple of inches from a person's eye, and it begins to scan, before displaying the results on its screen.

"What we're trying to do is eliminate a lot of the barriers to care that these

existing devices have seen," explains Jamie Serjeant, Occuity's Lead Engineer, "whether that's requiring training and practitioners, or [tests] being quite intimidating and not very nice for the patient experience."

GUINEA PIGS IN THE GARAGE

The PM1 applies the principles of a confocal microscope, the kind with which biologists might peer at fluorescently labelled cells, in miniature. Confocal microscopes have an exceptionally tight focus and high spatial resolution, with the ability to reconstruct 3D images by scanning micrometre-thick slices of the sample. Relying on complex optics and a pinhole system to limit depth of field, they are also "very large, very expensive, very high power", explains Taylor.

Getting the same effect with a handheld device called for an entirely different setup. The team ingeniously repurposed low-cost optical devices common in the telecoms industry. Optical fibres replicated the effect of the much more expensive pinhole systems, to block out-of-focus light. Another key component is a small module called a bi-directional (bi-di) transceiver, comprising a low-power laser source and optics that both transmit and receive returned laser light.

The final piece of the puzzle was a scanning system developed entirely in-house by Taylor – the part of the device that would enable it to produce 200 high-resolution scans of the eye per second.

With the pandemic looming not long after the company's beginnings, Occuity's early prototyping was forced into Taylor's garage over lockdown, with off-the-shelf components resembling "optical Meccano". He and his dog were the first guinea pigs to test the first prototype, an integrated, handheld device for which Taylor machined all the components, hand-assembled the electronic boards and 3D printed the enclosures.

Not long after, Daly and Taylor hired a team and a proper office space, to take the early hand-built prototypes into a viable, scalable product. This involved taking a tactical approach to sourcing components. Off-the-shelf parts might do just fine in some places. Others had to be custom-made, for example where Occuity's core IP was, to ensure greater precision than industry standards.

"There is a tiny screw that is custom inside PM1," laughs Serjeant. "But that's a funny example because we got close to sourcing most parts off the shelf. It just made me laugh, that at the end of the day, that's what we had to do to get it to market."

The proof of concept device, which connected to a computer rather than having an inbuilt display. Right: Garage 'prototype', fully integrated with a camera and touch screen display on the back, with all processing embedded in the electronics
© Occuity

THE PATH TO OCULOMICS

Serjeant describes the PM1 as establishing a "design language". It prioritises patient comfort, usability and simplicity. "We relish trying to get rid of as many buttons as possible," says Serjeant.

This philosophy will underpin Occuity's move towards bringing oculomics devices to market. They will incorporate many of the PM1's design elements and core technologies, such as the bi-di and the scanning system, but combine them in new ways.

Oculomics hinges on the optical transparency of the eye and its makeup of fluids. These resemble "blood without the blood cells", according to Taylor, carrying many of the same proteins and biomarkers found in the bloodstream. Among these are compounds associated with diabetes, known as advanced glycation end-products (AGEs), along with amyloid plaques, which are a hallmark of Alzheimer's disease.

But first, the company will release the AX1, which measures the eye's axial length – the distance between the retina and cornea. Excessive growth in axial length during childhood is the most common cause of myopia (shortsightedness). With the ability to measure this, clinicians will be able to identify myopia earlier and more accurately, rather than relying on people (especially children) to notice changes in their vision and refer themselves.

The AX1 looks identical to its PM1 cousin, opening up the possibility of screening in schools or in high street shops. Yet it is a "far more complex device", Taylor says, with greater precision requirements. "If PM1 is what got our name out, AX1 is the moment we grew up," says Serjeant.

With Occuity in touching distance of beginning the final clinical trial for the AX1, and the PM1 already being sold globally through 19 regional distributors, the foundations are laid for its oculomics work. Catching disease progression early could be just around the corner – through a simple eye scan at your high street optician.

HOW DOES THAT WORK?

HOW TO ENGINEER A PERFECT MATCHA

Matcha, a powdered, vibrant green tea that's traditional to Japanese tea ceremonies, has become a ubiquitous drink across the UK and the West. Chau-Jean Lin gets to the bottom of the perfect matcha.

Matcha is a phenomenon. Such a phenomenon, in fact, that it's been prone to shortages due to its sudden propulsion into the limelight. Matcha fans seek a deep green colour and smooth flavour with little bitterness. As it turns out, bringing this to life is quite an involved process.

Making matcha involves frothing a few grams of the tea in a ceramic bowl with warm water and a bamboo whisk. It sounds simpler than it is: the mechanical action is the difference between making a matcha and simply pouring a green tea.

"You make sure first that the entire whisk goes to the very bottom of the bowl, and then, you whisk it very fast. The movement is all in the wrist, and it's not in a circular motion, but up and down. Then you slow down, and whisk the top surface," says Dr Voltaire Cang, a senior researcher of culture at RINRI Institute of Ethics and a tea master in Japan.

During whisking, a liquid film forms to cover the air, creating tiny bubbles. These bubbles move toward the edge of the matcha bowl and sometimes break. Whisking the surface of the matcha removes the bigger bubbles, creating a glossy surface with a slight microfoam. "You need to disturb the liquid surface as much as possible with waves and random motion," says Dr Yutaka Kita, a lecturer of engineering at King's College London.

Matcha-makers have settled on about 80 to 90°C as the optimal temperature, as boiling, or very hot, water would cause the bubbles to disappear. This is because increasing the temperature lowers the surface tension of water, which reduces its viscosity. "If the matcha has a higher viscosity, then it'll be more difficult to break the bubbles," explains Kita.

Creating the perfect texture for matcha is all in the wrist: the mechanical action must create a glossy, subtle microfoam
© Sentindos Humanos/Unsplash

The way matcha is grown and processed impacts flavour and texture. Tea bushes are covered for about three weeks before harvesting. With the sunlight blocked, the leaves overproduce chlorophyll, turning a deep green colour. The plant also makes more polyphenols, which promote foaming through intermolecular bonds and interactions, and amino acids, which stabilise the foam.

Even if a matcha isn't shaded, it can still be possible to produce a light foam under certain conditions. It's arguably why matcha lattes are so popular. "Milk proteins can improve foaming, as [they] are known to foam very well, and they help stabilise the bubbles," says Anniina Salonen, a professor at ESPCI Paris. Given recent matcha shortages, this means those making matcha lattes could try lower 'grades' without affecting the quality of the foam.

After the tea has been plucked, matcha producers steam the leaves to prevent oxidation, which causes the leaves to brown. The heat from the steam keeps the matcha a bright green colour and ensures that the leaves retain their amino acid profile. Then the tea leaves are dried in an oven, and the stems removed. After the dried tea is cut, it's known as tencha.

Tencha is kept in cold rooms until it is ground into matcha by stone mills. Controlling the mills' speed is essential in retaining matcha's colour and taste. The faster the mills grind, the hotter the leaves get, causing chemical changes that create a more bitter taste.

Exposing matcha to air causes it to oxidise, so it's often packed under nitrogen to extend its shelf-life. The tea's catechins, a type of polyphenol, will brown, so how the tea is stored is as important as how it's manufactured.

Words by Chau-Jean Lin

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