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In this issue

Cover photo: A bulk superconductor levitated by a permanent magnet

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Welcome

Professor David Cardwell takes over from Professor Dame Ann Dowling who led the Department for five years. Ann is now President of the RAEng, while continuing in the Department with her research and teaching.

"Ann Dowling is a hard act to follow. She has left the Department in excellent shape on all fronts. Our rankings, financial performance and growth have been outstanding," says David.

The Department now has over 180 academics and principal investigator status researchers, over 1200 undergraduates, over 800 graduate students, over 260 postdoctoral researchers and a turnover exceeding GBP70m. It is one of the world's top ranked engineering departments jockeying for leadership at the top of the board. Teaching has also stormed forward winning accolades from reviewers in the accreditation process.

David adds: "Engineering at Cambridge is an integrated department comprised of the best academics, staff and students from around the world. Not only do we top the academic rankings, but we deliver practical outcomes for society. I feel a great sense of both excitement and responsibility in leading this institution given the influence it has on pivotal issues such as energy, cities, transport, healthcare and manufacturing. My aim is to do everything I can to allow everyone here to perform at their best, engage with real issues and make a difference.

"It would be easy to get complacent given this success, but I see a tremendous opportunity to take the Department to a new level. Engineering in most universities is split into separate departments; but we are one department. This structural advantage means we can tackle the really big challenges facing society. But this strength is tempered by our old and scattered building stock. Uniting on one site with new purpose-built facilities and the right support will unlock the full potential of our brilliant people. This is the change I wish to bring."

David is assembling his team, consulting staff and making plans for this transformation. He notes: "I will not jump the gun by announcing plans ahead of consultation with all members of the Department, but I can promise that the plans will not only represent a leap forward for Engineering at Cambridge, but a leap forward for engineering globally. I look forward to sharing more news publicly in the Spring next year."

Professor David Cardwell FREng

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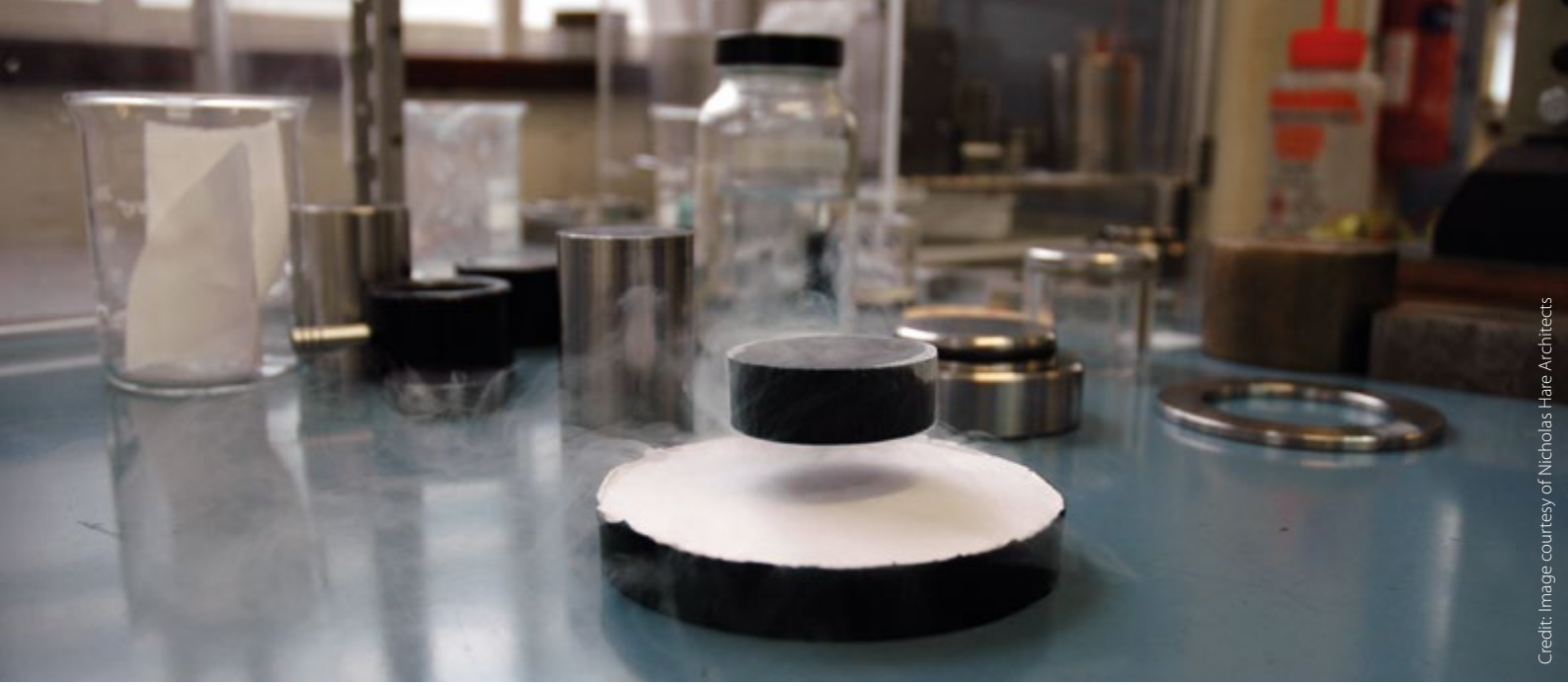


Credit: Image courtesy of Nicholas Hare Architects

↑ A bulk superconductor levitated by a permanent magnet

Cambridge engineers break superconductor world record

A new record for a trapped field in a superconductor, beating a record that has stood for more than a decade, could herald the arrival of materials in a broad range of fields.

A world record that has stood for more than a decade has been broken by a team of engineers led by Professor David Cardwell, our new Head of Department, harnessing the equivalent of three tonnes of force inside a golf ball-sized sample of material that is normally as brittle as fine china.

Professor Cardwell's team managed to 'trap' a magnetic field with a strength of 17.6 Tesla – roughly 100 times stronger than the field generated by a typical fridge magnet – in a high temperature gadolinium barium copper oxide (GdBCO) superconductor, beating the previous record by 0.4 Tesla. The results are published today in the journal *Superconductor Science and Technology*.

The research demonstrates the potential of high-temperature superconductors for applications in a range of fields, including flywheels for energy storage, 'magnetic separators', which can be used in mineral refinement and pollution control, and in high-speed levitating monorail trains.

Superconductors are materials that carry electrical current with little or no resistance when cooled below a certain temperature. While conventional superconductors need to be cooled close to absolute zero (zero degrees on the Kelvin scale, or –273 °C) before they superconduct, high temperature superconductors do so above the boiling point of liquid nitrogen (–196 °C), which makes them relatively easy to cool and cheaper to operate.

Superconductors are currently used in scientific and medical applications, such as MRI scanners, and in the future could be used to protect the national grid and increase energy efficiency, due to the amount of electrical current they can carry without losing energy.

The current carried by a superconductor also generates a magnetic field, and the more field strength that can be contained within the superconductor, the more current it can carry. State of the art, practical superconductors can carry currents that are typically 100 times greater than copper, which gives them considerable performance advantages over conventional conductors and permanent magnets.

The new record was achieved using 25 mm diameter samples of GdBCO high temperature superconductor fabricated in the form of a large, single grain using an established melt processing method and reinforced using a relatively simple technique. The previous record of 17.2 Tesla, set in 2003 by a team led by Professor Masato Murakami from the Shibaura Institute of Technology in Japan, used a highly specialised type of superconductor of a similar, but subtly different, composition and structure.

"The fact that this record has stood for so long shows just how demanding this field really is," said Professor Cardwell.

"This work could herald the arrival of superconductors in real-world applications. In order to see bulk superconductors applied for everyday use, we need large grains of superconducting material with the required properties that can be manufactured by relatively standard processes."

> "This work could herald the arrival of superconductors in real-world applications.
>
> Professor David Cardwell

A number of niche applications are currently being developed by the Cambridge team and its collaborators, and it is anticipated that widespread commercial applications for superconductors could be seen within the next five years.

The research was funded by The Boeing Company and by the UK Engineering and Physical Sciences Research Council (EPSRC). The National High Magnetic Field Laboratory, where the measurements were performed, is funded the National Science Foundation and the State of Florida.

Professor David Cardwell
www.eng.cam.ac.uk/profiles/dc135

↑ Compensation grouting at Bond Street Station

From Graduation to the Crossrail project

Alumnus Alan Skarda

Alumnus Alan Skarda is currently working as a Site Engineer for the Crossrail project. He has taken time out to tell us about his career path to date.

I studied at the Department of Engineering from 2007 to 2011, graduating with a BA MEng specialising in Civil, Structural and Environmental Engineering.

After working for Mott MacDonald on prestressed concrete bridge decks in my summer vacations, I joined Kier Construction — Engineering, the technical services division of Kier. We carry out civil, structural and geotechnical design for buildings, bridges and innovative or unusual temporary works to facilitate the construction process.

During my time there, I often benefited from the rigorous approach to design that I learned at Cambridge. For example, I was asked to assess the effect of building a 25m tall shotcrete batching plant on top of an underground Victorian masonry sewer. I was able to go back to first principles, calculate the strain induced in the sewer by hand and justify that it would not be damaged by the weight of the batching plant. I also benefited from certain academics' (e.g. Professor Ken Wallace) emphasis on drawing large clear diagrams, which are so useful in understanding a problem and communicating a solution to a client or checker.

In 2013, after two years in the design office, I was seconded to the Bam Ferrovial Kier (BFK) joint venture, which has won over £700M of work on Crossrail. My first post was in compensation grouting, a technique used to protect buildings and other sensitive assets located above and around the tunnels. I was part of the team responsible for managing the construction and operation of 13 grout shafts located at Bond Street Station, Tottenham Court Road Station and Fisher Street Shaft. BFK are constructing a series of Sprayed Concrete Lined (SCL) tunnels for Crossrail. SCL can create almost any shape of tunnel or shaft in the ground, but it tends to cause a lot more settlement than a Tunnel Boring Machine (TBM) because the ground is left unsupported between excavating and spraying.

Compensation grouting is a very interesting technique, introduced to me by Professor Robert Mair at Cambridge. It involves injecting a relatively weak cement and bentonite grout mix into the ground to create heave and so mitigate the settlement caused by tunnelling. The grout is injected from a network of pipes called tubes à manchettes (TAMs), drilled into the ground from shafts positioned around the stations. It relies on having very good systems in place for monitoring ground movement, which feed into the design of the grouting episodes. The tunnels are all located around some of the most expensive real estate in the country (Mayfair and Soho in central London), so compensation grouting plays an extremely important part in the project.

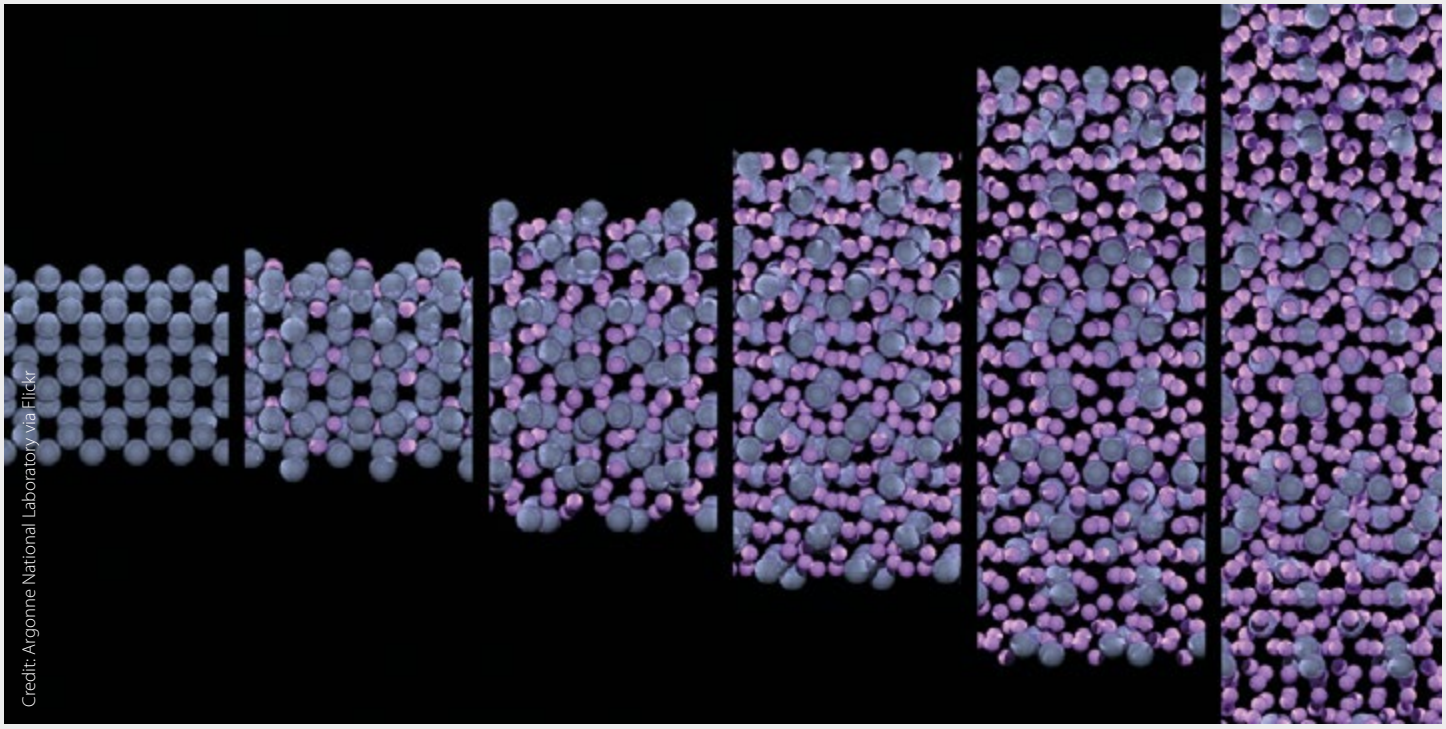
I am currently a Section Engineer and Temporary Works Co-ordinator in the SCL team at Bond Street, managing the construction of the permanent headwalls in the platform tunnels. I work with everyone from the Construction Manager to the operatives on site.

Working for a contractor has enabled me to spend time on site in addition to the design office. It is immensely beneficial for a designer to see how a massive construction project is built and managed; it helps you to understand the importance of proper workmanship and practical construction details in design. Cambridge naturally has a much more theoretical bent to the course, but the importance of the practicalities of construction was already recognised. In my third year I took part in the Constructionarium project at the National Construction College, Bircham Newton, in which our team of students built a 1:10 scale model of the Millau Viaduct in 5 days. In this project I successfully co-ordinated launching the steel deck of the bridge from the embankment to the piers. For me this was eye-opening and stands out as one of the highlights of my time in Cambridge.

I am working towards Chartership with the Institution of Civil Engineers (ICE) and hope to take my Professional Review next year.

Lifting the lid on silicon batteries

Resolving the mystery of what happens inside batteries when silicon comes into contact with lithium could accelerate the commercialisation of next-generation high capacity batteries, for use in mobile phones and other applications.



Credit: Argonne National Laboratory via Flickr

↑ Silicon (here shown in grey) is a promising next-generation anode material for lithium-ion batteries, capable of holding 10 times as many lithium ions (shown in pink) as currently-used anodes.

Next-generation batteries based on silicon have come one step closer to commercial reality, after the mystery surrounding what is happening inside batteries when silicon comes into contact with lithium has been understood in unprecedented detail. Silicon-based technology would greatly expand the capacity of the batteries used in mobile phones, electric vehicles and other applications.

Using a combination of nanotechnology and nuclear magnetic resonance (NMR) techniques, researchers have developed a new probing system that gives a view into what is happening inside the batteries at the atomic level, enabling greater control over the properties of the materials.

Silicon has been proposed as a replacement for carbon in battery anodes (negative electrodes) for the past 20 years, as it has roughly ten times more storage capacity than carbon. However, difficulty in managing silicon's properties has prevented the technology from being applied at scale.

The primary problem with using silicon in a lithium-ion battery is that silicon atoms absorb lithium atoms, and the silicon expands up to three times in volume, degrading the battery. Although controlling this expansion has become easier over the past decade, a lack of understanding about what is happening inside the batteries and what governs the reactions have continued to hold silicon batteries back.

Researchers at the University of Cambridge have developed a new method to probe silicon batteries and determined what causes the expansion to take place. The results are reported in the journal *Nature Communications*.

"The most basic challenge for delivering such high-capacity batteries is to understand the reactions going on inside them," said lead author Dr Ken Ogata of the Department of Engineering's Electrical Engineering division.

Using nanoscale wires made of silicon and NMR techniques, the researchers developed a robust model system able to accommodate the expansion of the silicon over multiple cycles, and integrated it with short-range probing techniques that reveal what is happening inside the battery at the atomic level. The team found that the reactions proceed with interactions of various sizes of silicon networks and clusters, energetics of which partly govern the path of the reaction.

Using these combined techniques, the researchers were able to develop a 'map' of how silicon transforms when it is put into contact with lithium in a battery. The insights opened up by the technology will boost further developments of silicon batteries, as it will be easier for engineers to control these properties.

> Using this technique will help make battery design more systematic, and less trial and error.
>
> Dr Ken Ogata

"Using this technique will help make battery design much more systematic, and less trial and error," said Dr Ogata. "The nanowire-based batteries coupled with the NMR system enabled us to follow the reaction kinetics over multiple cycles with various cycling strategies. Importantly, the insights achieved by the new technology are relevant to current state-of-the-art silicon-carbon composite anodes and will lead to further development of the anodes."


Credit: Sam Cocks

➜ Demonstrating the transplanter at an agricultural show

Alumni Jonathan Bassett and Sam Cocks are working on solar powered home-lighting systems in India

Over the past 20 years SELCO India, a social enterprise in Bangalore, has worked to provide solar powered home-lighting systems for people in unelectrified or under-electrified regions in India. To date, they have reached over 200,000 households through their unique model, with a heavy focus on providing servicing and maintenance, and working closely with banks to help their clients access loans. Alumni Jonathan Bassett and Sam Cocks are working for SELCO, each in a different part of India.

Sam and Jonathan are both part of the research and development arm of the organisation, set up around three years ago to investigate new approaches and opportunities to help the underserved poor. This includes looking at technologies, such as different solar technologies, small-scale wind turbines and agricultural machines. The other large part of the Foundation's work includes experimenting with different business models.

The Foundation is split into two labs in two locations. Sam was based in the 'rural lab' in Ujire, a town in the Western Ghats, a mountain range near India's South-Western coast. Jonathan is in Bangalore at the 'urban lab', a large city in the south of the country. Last autumn they took some time out to tell us about their projects to date.

Sam

samueljcocks@gmail.com

I've been working for SELCO for almost two years now and have spent most of that time as the only Westerner in this small town. My work has largely been surrounding agriculture but I've found myself involved in a diverse range of other projects during the time, as the rural lab has been investigating how it can have the deepest impact.

Even with its huge and rapidly growing population, India is currently facing a dire labour shortage in rural areas as more and more people migrate to the cities in search of better paid work. Small-scale farmers are finding it harder and more expensive to find the labour they require to perform certain tasks and, while large-scale farmers are beginning to take advantage of new machinery on the market, there are very few labour-saving machines available which are suitable for these small-scale farmers. We have been trying to identify (and design where necessary) machinery which can fill this gap and explore how it can be made accessible to farmers, building on SELCO's extensive experience of marketing to people at the 'bottom of the pyramid'.

I'm also currently leading two other projects which are aiming to put solar water pumps and solar-wind hybrid systems on the SELCO product list. They've both been very interesting and provided ample opportunities to put my mechanical degree into practice.

Jonathan

jon@selcofoundation.org

I spent the third year of my degree on an exchange programme with the National University of Singapore, where I got more interested in power electronics and the applications in energy. After a short trip to India and Nepal, witnessing the real problems of power shortage in that area, I decided to concentrate on energy during my final year. Through Engineers Without Borders at Cambridge I heard about SELCO and found Sam's blog on what he was doing in India. The company stuck in my mind and during a post-graduation trip across Europe, I decided to scrap my previous plans of moving back to Singapore and instead try to work for a company like SELCO. Eventually a volunteer contract was settled on and I moved over in January 2013.

Most of the Foundation's electrical and electronic work is done in Bangalore. The electrical team is being developed at the moment, with only myself and two other dedicated engineers. So most of the work we do is new to us and there is a lot of learning! However the projects I'm involved with at the moment are very exciting. I'll highlight one: our investigation into mini-grids.

A mini-grid is a village wide power-grid, separate from the normal AC national grid. The idea is to have a central power supply (solar, wind, micro-hydro) and send that power to each house in a village. This is different to SELCO's normal model of having individual solar-systems in each home. The potential advantages are increased scalability and security and reduced costs. SELCO has not done any work on mini-grids before, but with the current interest from government and non-government bodies has encouraged some investigation. We are trying to set up some pilot projects, with the aim of testing out technology and finance models.

Myself and a colleague have been mainly responsible for the technical design, including the grid layout and solar system design. This is quite a jump in responsibility, and certainly feels like the deep-end of projects! But I'm personally very excited to see where the project will go.

➜

www.selcofoundation.org
www.selco-india.com

Royal Academy backing for Department research

Dr Sithamparanathan Sabesan, a Research Fellow in the Department of Engineering, has been awarded a Royal Academy of Engineering (RAE) Enterprise Fellowship. He has been awarded funding of up to £85,000 and will receive money-can't-buy mentoring as part of the Academy's Enterprise Fellowships scheme to help turn his technology into a viable business.

In collaboration with Dr Michael Crisp, Professor Richard Penty and Professor Ian White of The Department of Engineering, Sabesan has developed a battery-less radio frequency identification (RFID) system that will allow airlines, retailers and other businesses to inexpensively track the locations of merchandise and passenger luggage over a wider area with greater reliability than conventional systems. A company, PervasID Ltd, has been formed to exploit this technology.

The PervasID system can successfully detect items with near 100% accuracy, and a single reader can cover an area up to 400 square metres. It can also scale up to accommodate much larger deployments and has already been used successfully in several field trials. The system has the potential to save airlines millions of pounds annually through allowing frequent fliers access to fully automated self-check-in, and to enable high-value goods retailers to benefit from secure self-service checkouts.

Sabesan and his colleague Michael Crisp also won the Royal Academy of Engineering's ERA Foundation Entrepreneurship Award for the system in 2011.

Arnoud Jullens, head of Enterprise at the Royal Academy of Engineering, said: "UK universities produce some of the greatest innovations in the world, but getting them out of the lab and into the marketplace remains a huge challenge.

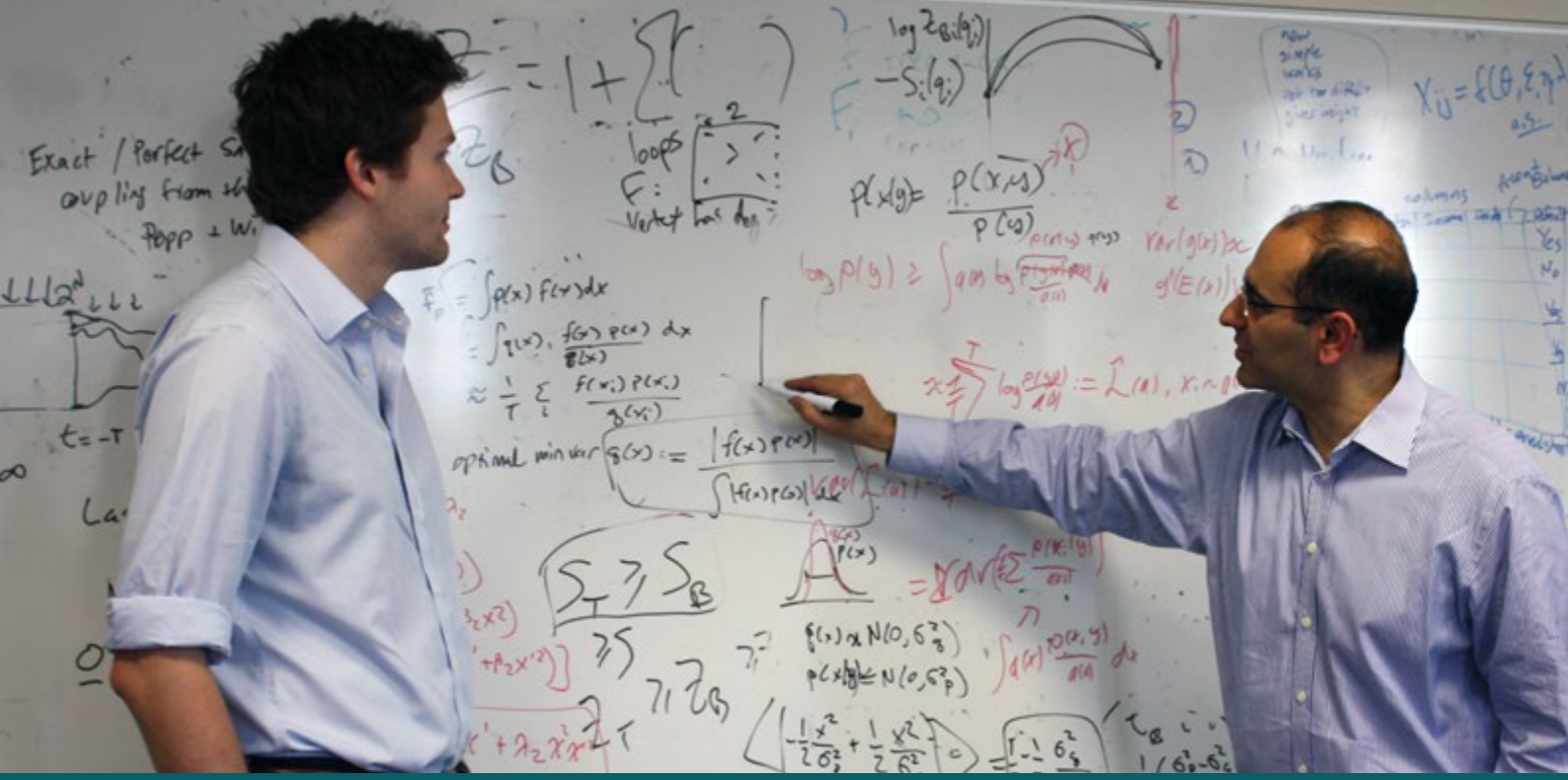
"Business-minded academics need investment and support from experienced industry practitioners to exploit their research, which could become the commercial success stories of tomorrow, and this is exactly what the Academy's Enterprise Hub provides."

Volunteer mentors supporting the Enterprise Hub include Sir Robin Saxby FREng, former Chief Executive and Chairman of ARM, and Professor Neville Jackson FREng, Chief Technology and Innovation Officer at Ricardo.

This is the third year of the Enterprise Fellowships scheme and is the largest cohort to date. President of the Royal Academy of Engineering, Sir John Parker GBE FREng, said, "Engineering already contributes at least £480 billion to the UK economy each year, and the ability to create wealth from innovation is essential in building a stronger and more competitive economy. By bridging the gap between industry and academia and enabling entrepreneurship to thrive, the Academy's Enterprise Hub aims to ensure that the country's brightest entrepreneurial minds are given the best possible chance to succeed, whilst helping to bring new technologies and services to market for the benefit of society."

Dr Sithamparanathan Sabesan
www.eng.cam.ac.uk/profiles/ss740

> By bridging the gap between industry and academia and enabling entrepreneurship to thrive, the Academy's Enterprise Hub aims to ensure that the country's brightest entrepreneurial minds are given the best possible chance to succeed.
>
> Sir John Parker



↑ Professor Zoubin Ghahramani (right) with PhD student James Lloyd

Google Award for the Automatic Statistician

The Automatic Statistician, a project led by Zoubin Ghahramani, Professor of Information Engineering, has won a US$750,000 Google Focused Research Award.

This Award consists of a no-strings attached donation to support research in the Cambridge Machine Learning Group on this topic.

Automating the process of statistical modelling would have a tremendous impact on fields that currently rely on expert statisticians, machine learning researchers, and data scientists. Such expertise in the data sciences is increasingly in demand, especially with the growth in Big Data problems in the sciences and in industry. The Automatic Statistician is a system which explores an open-ended space of possible statistical models to discover a good explanation of the data, and then produces a detailed report with figures and natural-language text. The Cambridge group, including PhD students James Lloyd and David Duvenaud working with Roger Grosse and Joshua Tenenbaum at MIT, has developed an early version of this system which not only automatically produces a 10-15 page report describing patterns discovered in the data, but returns a statistical model with state-of-the-art extrapolation performance evaluated over real time series data sets from various domains. The system is based on reasoning over an open-ended language of nonparametric models using Bayesian inference.

As Zoubin says: "Making sense of data is one of the great challenges of the Information Age we live in. While it's becoming easier to collect and store all kinds of data, from personal medical data, to scientific data, to public data, and commercial data, there are very few people trained in the statistical and machine learning methods required to test hypotheses, make predictions, and otherwise create interpretable knowledge from this data. Our Automatic Statistician project aims to build an artificial intelligence system for Data Science, helping people make sense of their data."

Kevin P. Murphy, Senior Research Scientist at Google, says: "In recent years, Machine Learning has made tremendous progress in developing models that can accurately predict future data. However, there are still several obstacles in the way of its more widespread use in the data sciences. The first problem is that current Machine Learning (ML) methods still require considerable human expertise in devising appropriate features and models. The second problem is that the output of current methods, while accurate, is often hard to understand, which makes it hard to trust. The "Automatic Statistician" project from Cambridge aims to address both problems, by using Bayesian model selection strategies to automatically choose good models/ features, and to interpret the resulting fit in easy-to-understand ways, in terms of human readable, automatically generated reports. This is a very promising direction for ML research, which is likely to find many applications at Google and beyond."

The ultimate aim of the Automatic Statistician is to produce an artificially intelligent (AI) system for statistics and the data sciences.

Professor Zoubin Ghahramani
www.eng.cam.ac.uk/profiles/zg201

> While it's becoming easier to collect and store all kinds of data, there are very few people trained in the statistical and machine learning methods required to test hypotheses, make predictions, and otherwise create interpretable knowledge from this data.
>
> Professor Zoubin Ghahramani

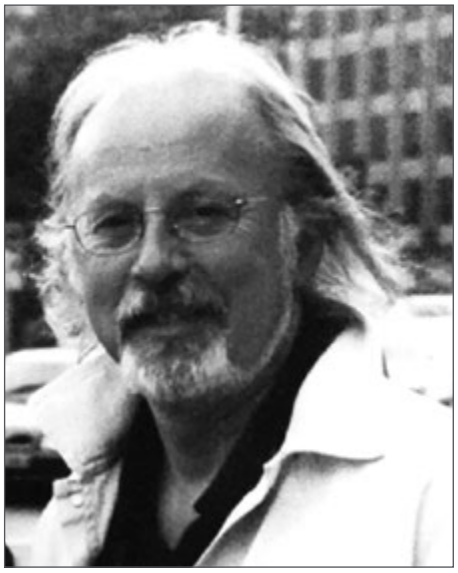
Robogals

Robogals Cambridge held their first outreach robotics workshop at the Department of Engineering.

Cambridge Robogals, a new chapter of the global non-profit outreach group Robogals, is dedicated to introducing young girls in the Cambridgeshire region to science, engineering, technology, and mathematics careers through robotics workshops and competitions. Earlier this year, in collaboration with the Department of Engineering's outreach officer, Maria Kettle, they hosted 50 year nine girls from five schools in the Cambridgeshire region for a day of robot building, programming, and competition.

Not only did the event introduce girls to the field of robotics and programming, but also allowed them to interact with female engineers at levels ranging from undergraduate to senior fellow. This exposure to female role models in the engineering field coupled with the fun, accessible way in which Robogals Cambridge presents engineering and technology projects makes Robogals a unique and effective outreach tool for encouraging girls to consider science based careers. Robogals also benefits its volunteers, both male and female, by allowing them to develop their leadership and presentation skills, confidence, and professional networks.

If you are interested in becoming involved with Robogals Cambridge as a volunteer, sponsor, or school participant, please contact Jenni Sidey (jams4@cam.ac.uk).



Professor William (Bill) Fitzgerald

It is with great sadness that we report that Professor William (Bill) Fitzgerald died on 2nd April 2014.

Bill joined the Department of Engineering in August 1990, having previously worked for Marconi. He was a Fellow of Christ's College and became Professor of Applied Statistics and Signal Processing in 2002. Bill held a BSc, MSc and PhD in Physics from the University of Birmingham. He had also held academic positions at the Institut Laue Langevin in Grenoble, France, and the ETH in Zurich.

He worked on Bayesian inference applied to signal and data modelling in addition to nonlinear signal processing, image restoration and medical imaging, extreme value statistics, bio-informatics, data mining and data classification. His particular interest was in the applications of Sequential Monte Carlo (particle filtering) methods to signal processing and communication problems.

Bill made many contributions in the applications of Bayesian theory in signal processing and this was recognised by the award of the EURASIP Technical Achievement Award.

Credit: Jenny Downing

Just made coffee while chatting to a friend? Time to thank your 'visuomotor binding' mechanism…

Experts have identified a dedicated information highway that combines visual cues with body motion. This mechanism triggers responses to cues before the conscious brain has become aware of them.

We talk about being 'on autopilot' when we're describing carrying out a familiar series of actions without being aware of what we're doing – now researchers have for the first time found evidence that a dedicated information highway or 'visuomotor binding' mechanism connects what we see with what we do. This mechanism helps us to coordinate our movements in order to carry out all kinds of tasks from dunking a biscuit in your coffee, while maintaining eye contact with someone else, to playing basketball on a crowded court.

The research (published in the journal *Current Biology*) was a collaboration between Dr David Franklin, of the Computational and Biological Learning Lab at the Department of Engineering, and Dr Alexandra Reichenbach, of the UCL Institute of Cognitive Neuroscience.

Their research suggests that a specialised mechanism for spatial self-awareness links visual cues with body motion. The finding could help us understand the feeling of disconnection reported by schizophrenia patients and could also explain why people with even the most advanced prosthetic limbs find it hard to coordinate their movements.

Standard visual processing relies on us being able to ignore distractions and pay attention to objects of interest while filtering out others. "The study shows that our brains also have separate hard-wired systems to track our own bodies visually even when we are not paying attention to them," explained David. "This allows visual attention to focus on objects in the world around us rather than on our own movements.

"The newly-discovered mechanism was identified when three experiments were carried out on 52 healthy adults. In all three experiments, participants used robotic interfaces to control cursors on two-dimensional displays, where cursor motion was directly linked to hand movement.

"The robotic virtual reality system allowed us to instantaneously manipulate visual feedback independently of the physical movement of the body," said David.

In the first experiment, participants controlled two separate cursors with their right and left hands. Their goal was to guide each cursor to a corresponding target at the top of the screen. Occasionally the cursor or target on each side would jump left or right, requiring participants to take corrective action. Each jump was cued by a flash on one side, but this was random and did not always correspond to the side about to change.

Not surprisingly, people reacted faster to cursor jumps when their attention was drawn to the correct side by the cue. However, reactions to jumps were fast regardless of cueing, suggesting that a separate mechanism independent of attention is responsible for tracking our movements.

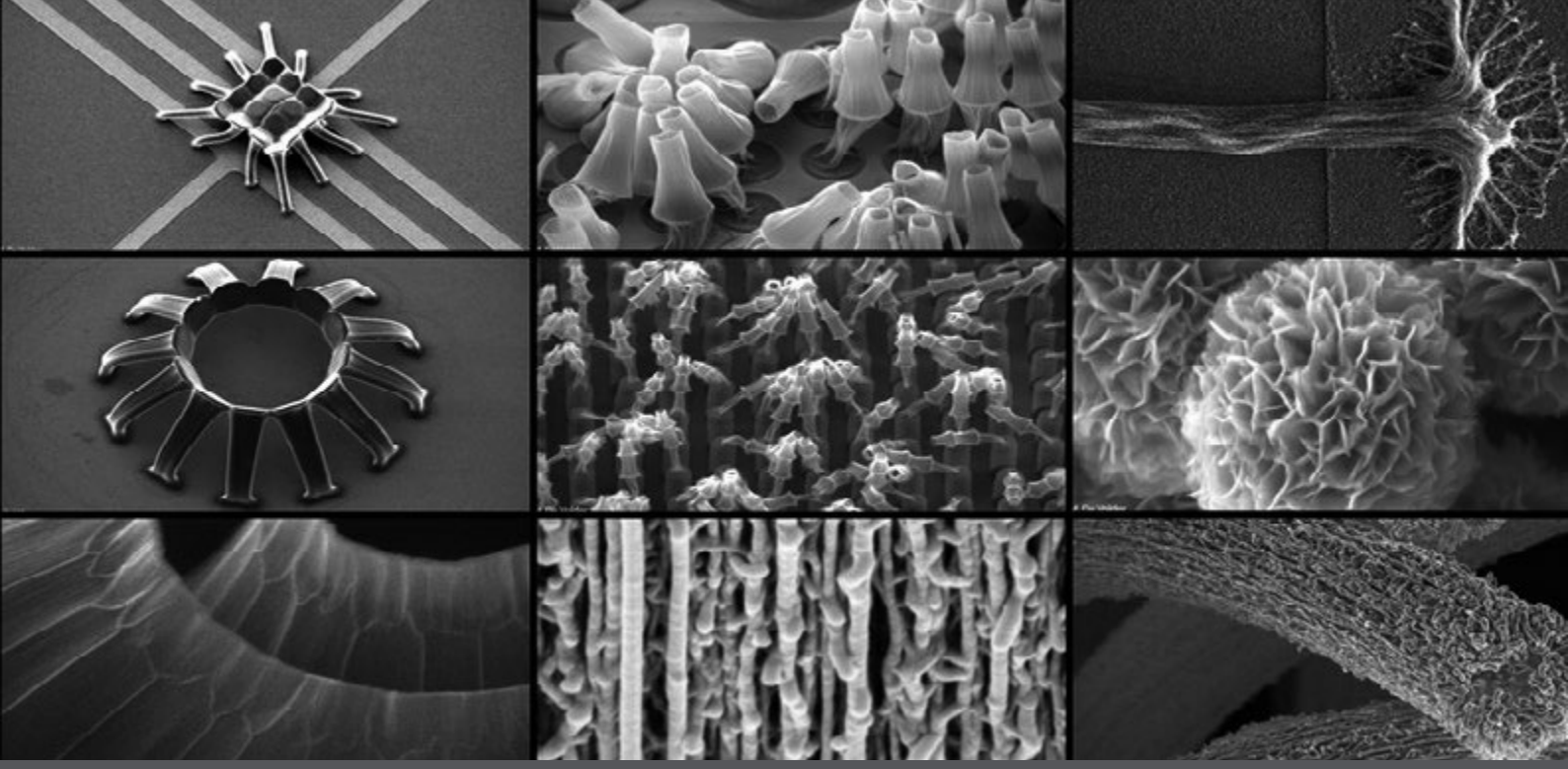
"The first experiment showed us that we react very quickly to changes relating to objects directly under our own control, even when we are not paying attention to them," explained Alexandra.

"The second experiment introduced changes in brightness to demonstrate the attention effect on the visual perception system. In the third experiment, participants were asked to guide one cursor to its target in the presence of up to four dummy targets or cursors, acting as distractors alongside the real ones. In this experiment, responses to cursor jumps were less affected by distractors than responses to target jumps.

"These results provide further evidence of a dedicated visuomotor binding mechanism that is less prone to distractions than standard visual processing," said Alexandra.

Dr David Franklin
www.eng.cam.ac.uk/profiles/dwf25

> The study shows that our brains also have separate hard-wired systems to track our own bodies visually even when we are not paying attention to them.
>
> Dr David Franklin



↑ Carbon nanotubes

Carbon nanotubes find real world applications

No one disputes that carbon nanotubes have the potential to be a wonder technology: their properties include a thermal conductivity higher than diamond, greater mechanical strength than steel and better electrical conductivity than copper.

But, like other 'great technologies of the future', are we over-hyping nanotubes? Are they near passing the real test – that of widespread practical use? The answer is a qualified yes. The success of carbon nanotubes (CNTs) is proved by a surprising statistic: worldwide commercial production capacity presently exceeds several thousand tons per year, according to Dr Michael De Volder, lecturer at the Department of Engineering's Institute for Manufacturing. But it's a level of production that has taken around 20 years to achieve.

"The beginning of widespread carbon nanotube research was preceded in the 1990s by the first scientific report of CNTs, although hollow carbon nanofilaments were reported as early as the 1950s," Dr De Volder says. "However, carbon nanotube related commercial activity has grown most substantially during the past decade. Since 2006, worldwide carbon nanotube production capacity has increased at least tenfold."

Dr De Volder's science review paper of commercially available carbon nanotube applications gives a flavour of just how widespread a real impact the technology is starting to make [M. De Volder et al, Science 339, 2013]. Take water purifiers, for example: the size, surface area and adsorption properties of carbon nanotubes make them an ideal membrane for filtering toxic chemicals, dissolved salts and biological contaminants from water.

The huge surface area of carbon nanotubes is also being exploited when they are used as the electrodes in batteries and capacitors to provide more current and better electrical and mechanical stability than other materials. The properties of carbon nanotubes make them ideal for enhancing different kinds of structures – for example, sports equipment, body armour, vehicles, etc., where they are being widely used.

But while carbon nanotubes are being used in practical applications, it doesn't imply their more widespread use will not be problem free.

"There are a number of obstacles which we haven't solved yet," Dr De Volder says. "Particularly in high end targets, like the search for better transistors, the exact morphology of the nanotube and the orientation of the graphene lattice with respect to the tube axis – referred to as its chirality – is really important. At this moment, we have little ability to synthesise carbon nanotubes with specific types of chirality and it is this that determines the semiconducting versus conducting properties of the carbon nanotubes.

> "Since 2006, worldwide carbon nanotube production capacity has increased at least tenfold.
>
> Dr Michael De Volder

"One of the interesting things happening is the improvement in computer simulations of how carbon nanotubes are synthesised, which will hopefully enable us to tweak the fabrication process. And electron microscopy is making it possible to look at the carbon nanotubes while they are being formed, which is helping improved understanding of the process."

Dr De Volder concluded: "I am trying to develop techniques for bringing particles together in more efficient ways, or looking at new emerging properties of the materials depending on how you bring the carbon nanotubes together."

Adapted from an interview by D. Boothroyd for New Electronics.

Dr Michael De Volder
www.eng.cam.ac.uk/profiles/mfld2

Institute for Manufacturing
Design Show 2014

The Design Show is held each year by the Institute for Manufacturing (IfM) for an invited audience of local industrialists and designers. Students create displays to explain the technical and business ideas behind the products, together with design details and prototype models of the products themselves.

The show is the culmination of team-based projects in which the Manufacturing Engineering Tripos (MET IIA) students find a design-based solution to a problem, create a marketing plan and present their ideas to their peers. The ten projects this year covered social entrepreneurship, safety, health, sport and more.

Infinity Bakery

A solar bakery for equatorial countries which autonomously tracks the sun and ventilates to provide a constant baking temperature

Infinity Bakery plans to work with charities to provide ovens that allow existing bakeries to switch from firewood to solar power, and partner with micro-financiers to empower groups of entrepreneurs trained at these bakeries to set up satellite bakeries. The oven mimics the baking times of a fire and requires no additional input, as a self-tracking and temperature regulating solution.

Team: Leyla Sudbury, Daniel Cox, William Hatcher and Keno Marie-Ghae

FlexiWRIST

A low-cost prosthetic wrist joint

FlexiWRIST Prosthetics aims to revolutionise wrist technology. By adding a small technological improvement to the design, large improvements in functionality can be achieved, resulting in more natural movement for certain tasks. The FlexiWRIST is unique in that it uses silicone rubber to provide certain motions passively and offers a simple return mechanism.

Team: Chris Goodfellow, Daniel Brackenbury, Stephen Hall and Emma Clement

Hive Aid

A shelter for refugees and those who have lost their homes in disaster areas

It has the unique ability to tessellate with other shelters to build communities. The Hive Aid shelter centres on the provision of uniquely designed poles as a framework onto which panels are slotted. Each plastic pole comes from the same extrusion, and has three flexible slots to connect the panels at a range of angles. They are extruded in the UK then transported to the site alongside other emergency supplies such as food, medication and clothing.

Team: Jack Bews, Charles Holland, Sam Blackett and Sasha Nagarajah

The Low Cost Bed

A solution to ultra-low cost sleeping to ensure that everyone has access to a bed

The bed is designed for use in homeless shelters in the UK, particularly during winter when bed shortages occur, as many can be stored by day and placed on the floor at night. It is also designed for disaster relief situations where the immediate needs of people have been met, providing an additional level of comfort and tackling problems caused by sleeping on damp or hard ground. The bed will fold flat for transport and storage, and is water resistant for damp or humid conditions.

Team: Richard Cadman, Jonathan Godden, Tayo Moore and Stephanie Brown

MyPod

A platform to control the physical environment which acts as a portable sensory room to calm children with Autism Spectrum Disorder (ASD)

MyPod's main function is to offer relaxation techniques in the form of rocking and pressure application, both of which are techniques that have been validated by psychologists. The sensory pod can be rocked externally by a teacher or parent, which makes for easy interaction during the calming period. Rocking can also be generated internally, by the users themselves so they can feel independent if they want to. To facilitate its use in the classroom, MyPod aims to offer sensory reduction, mainly in the form of sound cancelling and light channelling to reduce distractions.

Team: Joseph Mambwe, Sarah Tong and Bruno Sussat

Piste Pilot

Making skiing more accessible for the blind and partially sighted through use of tactile feedback in the ski poles

The Piste Pilot is designed to be picked up by a blind skier on holiday with a sighted friend using an interface that can be mastered quickly. The product will be provided as four integrated ski poles – two for the guide and two for the skier with sight loss. The skier will receive vibrations in their ski poles, triggered by a series of button presses from the guide on their own poles. The information given will include direction, how hard to turn and when to start/stop. This will be achieved wirelessly using radio communications.

Team: Christopher Owers, Elizabeth Tyler and David Elliott

PyroCut

Aiming to save lives by reducing fire service response times

PyroCut automatically isolates the power supply in the event of a fire. Once a fire has been detected, there is a three-minute time delay before the power is isolated, ensuring sufficient time for the occupants of a dwelling to exit, as well as allowing them sufficient time to address a false alarm. Once these three minutes have elapsed, the power is isolated and a signalling device is activated. This device demonstrates to the fire service that the power is off and water can be used to tackle the fire.

Team: James Popper, Leonidas Aristodemou, Kamran Tajbakhsh and Jessica Manning

Rota-Pill

A pill dispenser for those starting to encounter cognitive or physical difficulties with their self-administration of medication

The Rota-Pill dispenses medication directly from personalised blister packs filled for patients at the pharmacist. The user must simply turn the dial to the current time and pills intended

← TOP LEFT: Infinity Bakery team
TOP TIGHT: Piste Pilot team
BOTTOM LEFT: FlexiWRIST team
BOTTOM RIGHT: Rota-Pill Team

to be taken then will be dispensed into a cup for easy consumption. The simple mechanical system combined with smart use of ergonomic principles makes the Rota-Pill easy to use and will prolong the independence of users.

Team: Jack Beattie, Tim Palmer and Ciara Wheeler

Snowriski

A ski lock which is directly integrated into the ski brakes

Snowriski has designed an innovative locking mechanism for a pair of skis. This new design is built within the skis themselves, relieving the skier of carrying the lock around or forgetting to take it along in the first place. With ski theft becoming an increasing problem in ski resorts across the world, this lock is more than a deterrent. Its robust and compact design locks the brakes on one ski to the other around a uniquely compatible Snowriski rack. In addition to these features, this lock is designed to be waterproof and iceproof, unlike those on the market today.

Team: Renate McKenzie-Onah, Anahita Pradhan, Guy Peters and Thomas Nesch

True Blue Markets

A rapidly deployable market stall for Cambridge's historic outdoor market

It can be set up in less than 15 minutes, is aesthetically pleasing and made using material and labour sourced as locally to Cambridge as possible. It collapses into a bench, providing storage space for stallholders, seating for the public and turning the square into mostly open space. The benches can be fork-lifted away to free the square completely. The spacing between the stalls can be modified to facilitate van access.

Team: Shakti Kumpavat, Thomas Cole, Nicholas Schulman and Stephanie MacAulay

Visit the IfM YouTube channel at the link below or scan this code to view videos by each team describing their project.

www.youtube.com/ifmcambridge/playlists

Alumnus Ben Whitaker discusses international mobile ticketing success

First Capital Connect have a queue-busting mobile ticketing app, allowing passengers to use their mobile phone or tablet as a train ticket for trips to Cambridge, so that they don't have to wait in line for a ticket ever again.

> The engineering department was hugely supportive of students finding out more about turning ideas into business, and helped me to follow some of the department's fellows into starting my own business.
>
> Alumnus Ben Whitaker CEO of Masabi

Masabi, a company founded by Engineering alumnus Ben Whitaker and Computer Science alumnus Tom Godber, develops transport mobile ticketing that allows customers to download an app to their phone and instantly purchase tickets for immediate use. After success in the UK and ground breaking deployments in the US, their company was recently selected by New York's Metropolitan Transportation Authority (MTA) to provide mobile ticketing for its commuter railways.

Mobile tickets appear on the phone screen in the form of an electronic ticket that can be validated visually by conductors, or as an encrypted barcode that can be scanned by a conductor's handheld device to verify that the barcode is valid. This turns the phone into a personalised ticket machine. The apps also provide real-time information on trains and timetables, saving frequent journeys and securely storing payment information. Users therefore can make repeat purchases with just a few taps, removing the need to enter log-in details each time.

Ben, the company's product evangelist and a classic visionary, was pivotal in the definition of the UK rail mobile ticketing standard and moving the weight of industry opinion behind it. Masabi's mobile ticketing technology is now in use by over half of the UK's rail operators such as Virgin, Cross Country, Chiltern Railways, First Group, as well as river bus service Thames Clippers, with more cities in Europe also in the pipeline.

In late 2012, the company launched its first mobile ticketing service in the US with Boston's MBTA. The solution was deployed on the commuter rail, saving more than $70m of capital expenditure that would have been required to extend the existing smartcard system. The company is also working with San Diego's MTS and NICE bus in Long Island. Information on all of Masabi's customer deployments can be found here: www.masabi.com/about/customer-deployments

Alumnus Ben Whitaker, CEO of Masabi said:

"Mobile ticketing is all about making life easier for transport passengers. By transforming smartphones into vending machines, we are making waiting in line a thing of the past. We are excited to be bringing our award-winning and UK deployment-proven technology to New York's commuters."

Talking about his time at the Department of Engineering Ben added, "The Department of Engineering is hugely supportive of students finding out more about turning ideas into business, and helped me to follow some of the Department's fellows into starting my own business. They provided me with my own office for a period while spinning out a course project into a business, as well as providing lecture rooms for CUE (the Cambridge University Entrepreneurs society) to provide support for other students."

www.masabi.com

3D printing

The shape of things to come?

In the Institute for Manufacturing (IfM) Review, Dr Simon Ford, from the IfM's Centre for Technology Management, explains why we need to take a clear-eyed view of this much hyped technology if it is to realise its potential.

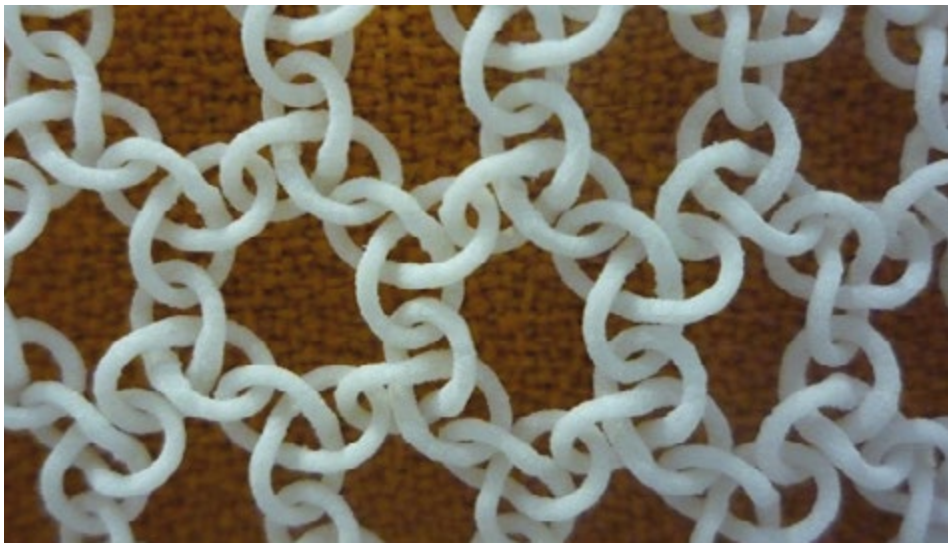
If you ask the proverbial man or woman in the street what they understand by the terms 'stereolithography', 'selective laser sintering' and 'fused deposition modelling', you're likely to be met with a blank expression. Say the words '3D printing', though, and you're likely to be met with an entirely different response.

Over the last couple of years, 3D printing has attracted significant media attention. Stories about 3D printed Stradivariuses, undetectable plastic guns, novel building designs, personal miniatures, medical devices and a variety of other 3D printing objects, have become an almost daily occurrence in the mainstream press. 3D printing has been heralded as a technology that will transform the world, with commentators claiming that it could be "bigger than [the] internet" (Financial Times) and "the PC all over again" (The Economist). Even Barack Obama has added his voice to the clamour, stating in his 2013 State of the Union Address that 3D printing "has the potential to revolutionise the way we make almost anything".

While 3D printing is now attracting significant attention and generating high expectations, the process of 'additive layer manufacturing' (the academic term for 3D printing) can be traced back to technologies that were first developed and commercialised in the 1980s. Two of the leading 3D printing companies, 3D Systems and Stratasys, were founded in that decade based on innovative stereolithography (SLA) and fused deposition modelling (FDM) technologies.

Historically, the UK has been good at such experimental research and development, and novel technologies are expected to emerge from research institutions. However, where the UK has often been less successful is in the commercialisation of technologies from these institutions. It is here that research at the Department of Engineering's Institute for Manufacturing comes in.

Led by Dr Tim Minshall of the Centre for Technology Management, Bit by Bit: Capturing the Value from the *Digital Fabrication Revolution* is a project that seeks to understand how value is being created and captured in the 3D printing industry, and how UK firms will



be affected by 3D printing technologies. The project is jointly funded by the Engineering and Physical Sciences Research Council (EPSRC) and the Economic and Social Research Council (ESRC). The need for cross-disciplinary approaches is reflected in the make-up of the investigating team, with Professor Ian Hutchings from the IfM's Inkjet Research Centre, Dr Chander Velu, Lecturer in Economics of Industrial Systems at the IfM and Dr Finbarr Livesey, from the University's Department of Politics and International Relations, bringing their knowledge of digital fabrication science, business models, and economic policy respectively to bear on the project.

Under their leadership, the research team of Dr Letizia Mortara and Dr Simon Ford are currently engaged in the first part of the project: investigating the industrial emergence of the 3D printing industry. It is only through an understanding of historical patterns and processes that we can hope to gain insights into how current events are unfolding and how they will shape the future.

This historical study involves analysis of supply and demand in the industry; supply in the form of equipment manufacturers, and demand in terms of the early users of 3D applications such as prototyping, in the aerospace and automotive sectors, and in the development of hearing aids and orthodontics. Later in the project the researchers will explore the different business models companies are using to capture value from 3D printing, and how 3D printing enables new business models to be adopted in the digital economy.

So, while 3D printing is certainly big news, there is still a long way to go. As with all disruptive technologies, uncertainties abound. Bit by Bit will help both industry and government better understand and benefit from the undoubted opportunities to create and capture value that 3D printing will provide.

www.ifm.eng.cam.ac.uk

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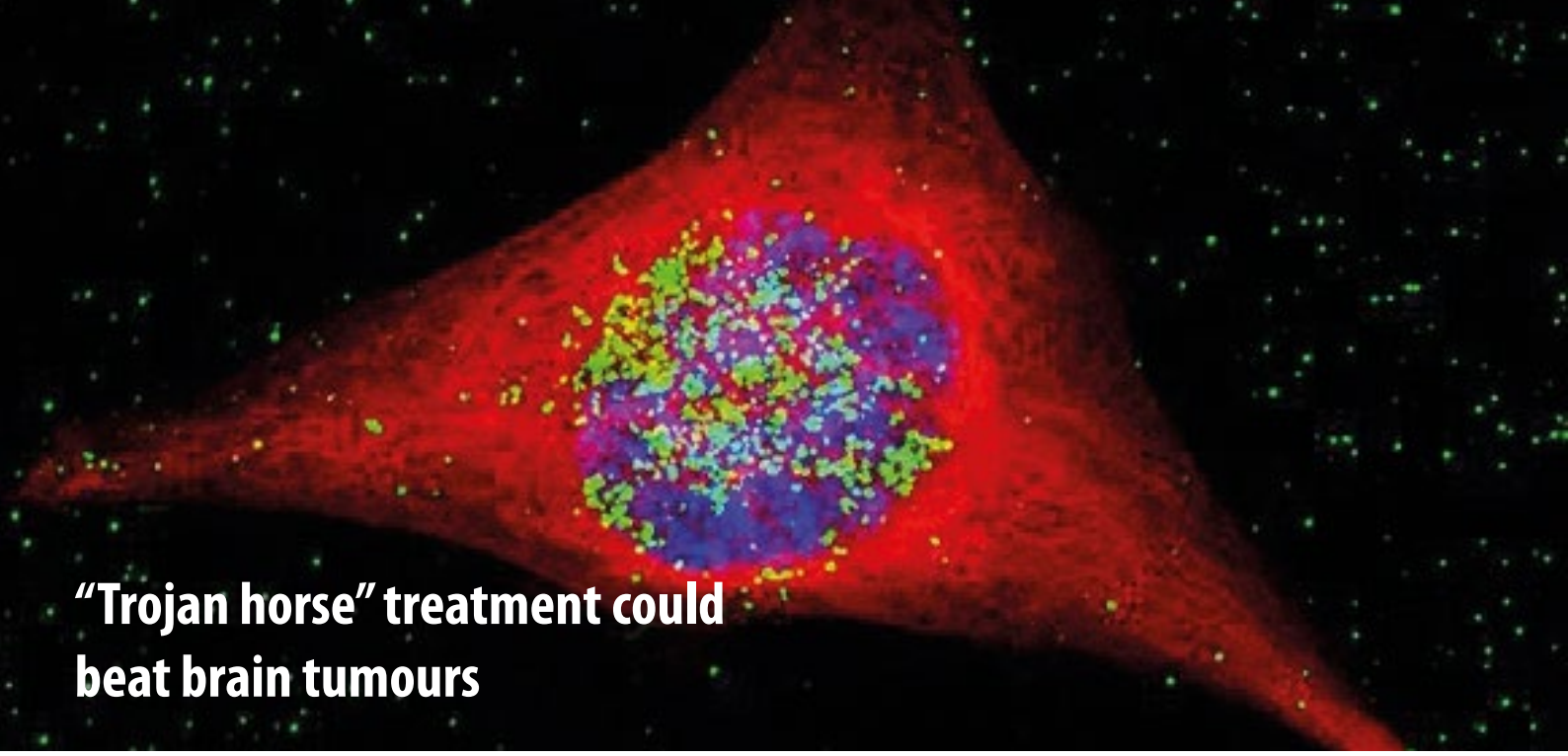
>
> Dr Simon Ford



"Trojan horse" treatment could beat brain tumours

A smart technology which involves smuggling gold nanoparticles into brain cancer cells has proven highly effective in lab-based tests.

A "Trojan horse" treatment for an aggressive form of brain cancer, which involves using tiny nanoparticles of gold to kill tumour cells, has been successfully tested by scientists.

The ground-breaking technique could eventually be used to treat glioblastoma multiforme, which is the most common and aggressive brain tumour in adults, and notoriously difficult to treat. Many sufferers die within a few months of diagnosis, and just six in every 100 patients with the condition are alive after five years.

The research involved engineering nanostructures containing both gold and cisplatin, a conventional chemotherapy drug. These were released into tumour cells that had been taken from glioblastoma patients and grown in the lab.

Once inside, these "nanospheres" were exposed to radiotherapy. This caused the gold to release electrons which damaged the cancer cell's DNA and its overall structure, thereby enhancing the impact of the chemotherapy drug.

The process was so effective that 20 days later, the cell culture showed no evidence of any revival, suggesting that the tumour cells had been destroyed.

While further work needs to be done before the same technology can be used to treat people with glioblastoma, the results offer a highly promising foundation for future therapies.

Importantly, the research was carried out on cell lines derived directly from glioblastoma patients, enabling the team to test the approach on evolving, drug-resistant tumours.

The study was led by Professor Sir Mark Welland, Professor of Nanotechnology at the Department of Engineering and a Fellow of St John's College, University of Cambridge, and Dr Colin Watts, a clinician scientist and honorary consultant neurosurgeon at the Department of Clinical Neurosciences. Their work is reported in the Royal Society of Chemistry journal, Nanoscale.

"The combined therapy that we have devised appears to be incredibly effective in the live cell culture," Professor Welland said. "This is not a cure, but it does demonstrate what nanotechnology can achieve in fighting these aggressive cancers. By combining this strategy with cancer cell-targeting materials, we should be able to develop a therapy for glioblastoma and other challenging cancers in the future.

"To date, glioblastoma multiforme (GBM) has proven very resistant to treatments. One reason for this is that the tumour cells invade surrounding, healthy brain tissue, which makes the surgical removal of the tumour virtually impossible."

Used on their own, chemotherapy drugs can cause a dip in the rate at which the tumour spreads. In many cases, however, this is temporary, as the cell population then recovers.

"We need to be able to hit the cancer cells directly with more than one treatment at the same time" Dr Watts said. "This is important because some cancer cells are more resistant to one type of treatment than another. Nanotechnology provides the opportunity to give the cancer cells this 'double whammy' and open up new treatment options in the future."

In an effort to beat tumours more comprehensively, scientists have been researching ways in which gold nanoparticles might be used in treatments for some time. Gold is a benign material which in itself poses no threat to the patient, and the size and shape of the particles can be controlled very accurately.

When exposed to radiotherapy, the particles emit a type of low energy electron, known as Auger electrons, capable of damaging the diseased cell's DNA and other intracellular molecules. This low energy emission means that they only have an impact at short range, so they do not cause any serious damage to healthy cells that are nearby.

In the new study, the researchers first wrapped gold nanoparticles inside a positively charged polymer, polyethylenimine. This interacted with proteins on the cell surface called proteoglycans which led to the nanoparticles being ingested by the cell.

Once there, it was possible to excite it using standard radiotherapy, which many GBM patients undergo as a matter of course. This released the electrons to attack the cell's DNA.

While gold nanospheres, without any accompanying drug, were found to cause significant cell damage, treatment-resistant cell populations did eventually recover several days after the radiotherapy. As a result, the researchers then engineered a second nanostructure which was suffused with cisplatin.

The chemotherapeutic effect of cisplatin combined with the radiosensitizing effect of gold nanoparticles resulted in enhanced synergy enabling a more effective cellular damage.

Professor Mark Welland
www.eng.cam.ac.uk/profiles/mew10

New Centres for Doctoral Studies

The Department of Engineering is proud to announce that there are now eight Engineering and Physical Sciences Research Council (EPSRC) Centres for Doctoral Training (CDTs) associated with the Department.

CDTs are a bold new approach to training PhD students and are widely supported by business and industry. Students follow a four year course – 1 foundation year and 3 years of research towards the PhD degree. During the first year, students follow a course of lectures and undertake a number of mini projects. At the end of the first year, students are awarded an MRes degree. Successful students are permitted to continue to the PhD degree with a number of Research topics available in the Department of Engineering, other Departments in the University of Cambridge and, in some cases, in other institutions.

The aim of each centre is to create a community of researchers working on current and future challenges. The multidisciplinary centres bring together diverse areas of expertise to train engineers and scientists with the skills, knowledge and confidence to tackle today's evolving issues. They also create new working cultures, build relationships between teams in universities and forge lasting links with industry at a range of levels, from small and medium-sized enterprises to large, multinational corporations.

The eight centres are:

CDT in Ultra Precision is a collaboration with Cranfield University.

CDT in Integrated Photonic and Electronic Systems (IPES) a joint course with University College London (UCL). Students from UCL and Cambridge can choose modules from both institutions in the first year.

CDT in Future Infrastructure and the Built Environment.

CDT in Gas Turbine Aerodynamics – in partnership with Universities of Oxford and Loughborough.

CDT in Graphene Technology.

Nano Science & Technology Doctoral Training Centre Cambridge (NanoDTC) is an interdisciplinary PhD program involving several departments, including Engineering, Chemistry, Materials Science and Physics.

CDT in Computational Methods for Material Science – Department of Physics led cross-disciplinary CDT, including Chemistry, Physics, Materials and Engineering

CDT for Sensor Technologies and Applications – is an interdisciplinary programme lead by the Department of Chemical Engineering and Biotechnology, involving Departments from the Schools of Physical Sciences, Technology, Biological Sciences and Clinical Medicine.

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

Graphene and related materials promise cheap, flexible printed cameras

Dr Felice Torrisi, University Lecturer in Graphene Technology, has been awarded a Young International Researchers' Fellowship from the National Science Foundation of China to look at how graphene and two-dimensional materials could enable printed and flexible eyes.

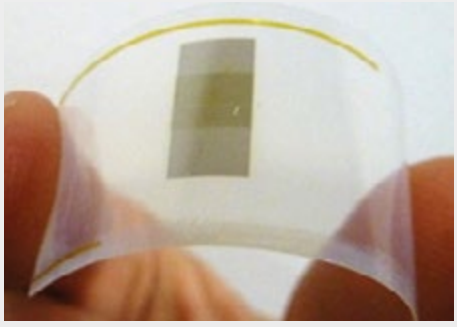
The vision is to create a technology for cheap flexible cameras that can be printed or stamped on plastic or paper. "For example it might eventually be possible to embed these printed, flexible optoelectronic devices into clothes, packaging, wall papers, posters, touch screens or even buildings. Everybody with a printer at home will be able to print their own "artificial eye" and physically stick it to a flexible mobile phone" Felice said.

The goal of the project is to design, develop and characterize inkjet printed 2D crystal-based flexible photodetectors and study their integration with commercial electronics.

"Photodetectors are needed in cameras, automotive applications, sensing and telecommunications, medical devices and security" he says. "If these could be made flexible they could be integrated in clothes, rolled up or printed over any irregular surface, substantially increasing the quality of printed and flexible electronics."

The current generation of flexible photoactive materials, based on organic polymers have a slow response time (few milliseconds), which is too slow for photodetection. This represents a strong limitation for flexible electronics in a wide range of applications, from active matrix displays to ultrafast light detectors and gas sensors. Moreover organic polymers suffer from chemical instability at room conditions (temperature and pressure), thus requiring extra protective layers or special handling of the printed devices, leading to an increase in cost.

Felice and the team at the Cambridge Graphene Centre have been looking to formulate a set of inks based on various 2D crystals. He said: "This will create an entirely new set of tools for printable electronics,



enabling printed, flexible photodetectors and possibly paving the way for printed flexible photo-cameras".

Dr Felice Torrisi
www.eng.cam.ac.uk/profiles/ft242

↑ James Dyson with a student during a visit to the Department of Engineering

Backing Britain

The James Dyson Foundation donates £8m to University of Cambridge to fuel invention powerhouse

The James Dyson Foundation has donated £8m to create a technology hub at the heart of Cambridge, providing the University of Cambridge's brightest engineers with some of the world's most advanced engineering laboratories. The donation is the largest gift ever received by Cambridge's Engineering faculty, which has long been the most successful in Europe.

> I'm hopeful that this new space for Britain's best engineers at the University of Cambridge will catalyse great technological breakthroughs that transform how we live.
>
> James Dyson

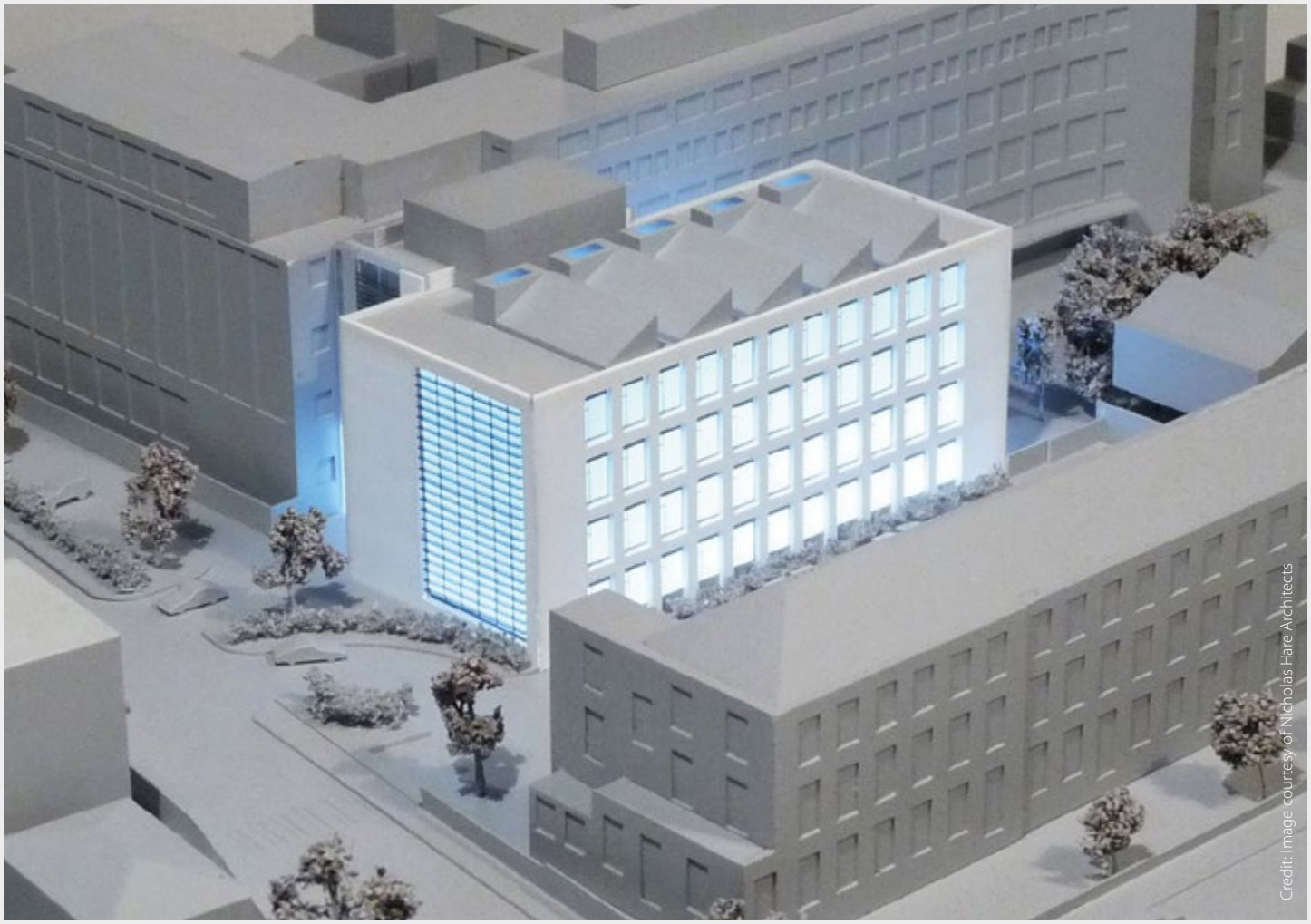
The James Dyson Foundation supports design, technology and engineering education from primary school to postgraduate level. To date it has donated £35m to good causes, the most recent of which is the £8m to the University of Cambridge. The donation will fund the James Dyson Building for Engineering, providing space for Cambridge postgraduate research. It also funds a new Dyson Engineering Design Centre within the Department of Engineering. The donation expands on the existing partnership between the James Dyson Foundation and the University, which includes funding a PhD student and a number of undergraduate engineering projects.

The new four storey building, the James Dyson Building for Engineering, due to open in 2015, will house postgraduates and support world-leading research in areas including advanced materials, smart infrastructure, electric vehicles, and efficient internal combustion systems for cars. Bridge links across buildings will allow easy access to testing laboratories housing world-class fluid dynamics machinery, aerodynamics equipment and areas for aeroacoustics analysis. Specialist knowledge on research strategies and funding advice will be available on site, supported by Philip Guildford, Director of Research at the Department of Engineering.

Philip said: "The new James Dyson Building for Engineering will go a long way to solving the space crunch we are currently experiencing. This space crunch is the result of a huge surge in research grants. Last year was our most successful year ever for winning grant applications."

James Dyson said: "Developing the intellectual property that will help Britain succeed in the global technology race depends on applying our brightest minds to ambitious and exciting research projects. I'm hopeful that this new space for Britain's best engineers at the University of Cambridge will catalyse great technological breakthroughs that transform how we live."

The Dyson Engineering Design Centre, due to open in 2015, will be created through the re-modelling of an existing workshop. The Centre will include a Bio-inspired Robotics laboratory as well as flexible, open plan space that will encourage the sharing of ideas and create a collaborative research environment whilst accommodating a variety of practical design and workshop-based undergraduate activities. The re-modelled workshop will provide the space for over 1,200 engineers to conduct their research.



↑ Architects' impression of the new four storey James Dyson Building for Engineering

New James Dyson Building for Engineering to be a live laboratory

As construction gets underway on the new James Dyson Building for Engineering, the Cambridge Centre for Smart Infrastructure and Construction (CSIC) is preparing to create a live laboratory on site at the Department of Engineering.

Pioneering sensing technologies will be installed in the infrastructure of the new four-storey James Dyson Building for Engineering, due to open in 2015.

Dr Mohammed Elshafie, a member of the CSIC team involved, said: "We have been developing and installing fibre optic sensing all over London and the UK, throughout Europe and in the US, but rarely had the opportunity to showcase our work in Cambridge. This is a chance to populate a new building in our own back yard with a range of sensing technologies so, when CSIC is working with students and industry, we can demonstrate our sensing devices operating in real time. Installing CSIC sensing technologies transforms the building from a passive block of material into a living creature. We will be able to ask the building how it is feeling and the building will be able to reply."

The extension project is already underway and the CSIC team will be on site from autumn this year. Dr Elshafie said: "It's very exciting and certainly has numerous benefits. This will be the first time the team has been able to install our technology without having to deploy a group of people at 4am in the morning. As the project is happening at our own university we can work during office hours."

CSIC website
www-smartinfrastructure.eng.cam.ac.uk

> "Installing CSIC sensing technologies transforms the building from a passive block of material into a living creature. We will be able to ask the building how it is feeling and the building will be able to reply.
>
> Dr Mohammed Elshafie, CSIC

Young Consultant of the Year by New Civil Engineer

Alumnus Gavin White

Ramboll associate structural engineer Gavin White, New Civil Engineer's (NCE) Young Consultant of the Year, is currently designing the tallest timber building in the world – a ten-storey residential tower in London.

It is the most recent of more than 40 timber buildings White has designed, and his passion for the material is evident. He sees the use of timber in construction as one of the most simple and effective ways that structural engineers can lead the fight to combat climate change, and is on a crusade to educate the wider design and construction industry about its possibilities as a mainstream structural material.

"I do a lot of talks with architects, contractors and clients to explain what it is and to change perceptions," says White. "A lot of people think it's more expensive, or it can only be used in small buildings.

"White's interest in timber stems from an enthusiasm for sustainable design. He has been working for Ramboll (and its predecessor Whitby Bird) for 12 years, starting in London, and then moving to to the firm's Cambridge office in order to focus on educational buildings. This in turn led to the progression towards timber, as education is one sector that has embraced the material. Since then, he has developed his expertise to the extent that in 2011 he became Ramboll's worldwide expert on timber design. But as a structural engineer, responsible for managing a team of ten people, White is aware that his job is not simply to promote one material if it is not the best solution.

"Although I like to push timber, I don't push it blindly. You have to have a reason for it," he says. "As engineers we need to be working on our client's behalf and not pushing things just because we think it's right."

Given an opportunity, however, he can be very persuasive. The new City Academy in Norwich, which opened in 2012, was going to be built in concrete, which was comparable in price to the alternative timber option. White went back to the supply chain and found ways to make savings in the cost of the timber design that eventually convinced the contractor that it would be the most cost effective solution. The success of this project led to Ramboll designing another timber school in Greenford, West London, for the same contractor.

An alumnus of the Department, White says he is concerned that the next generation of engineers is emerging from university with no real timber engineering knowledge and is working with both Bath and Cambridge Universities to address this by seeking out and supporting areas of timber research.

"If the industry is not aware of the advantages timber can present over traditional construction – fast erection, lightweight, carbon negative, clean sites, less waste – professionals will continue to turn to traditional alternatives with which they are familiar," he says.

While White's passion for timber is undisputed, the judges were impressed by his knowledge of the wider industry, and the articulate way in which he could discuss a wide range of topics, from the technical issues surrounding material choice to the future of the consultancy sector and the role of the structural engineer.

"Structural engineers aren't the people who make the building stand up once the architect's designs are ready," he says. "I want to be in there with the architect, shaping the design.

"White's role models are pioneering engineers who are "visionary in terms of their thinking and design focus" – and in choosing him as Young Consultant of the Year, the judges acknowledged that he has definitely inherited something of that spirit.

This article originally appeared in New Civil Engineer.

Better building through design

The construction industry could slash its carbon emissions by as much as 50% by optimising the design of new buildings, which currently use double the amount of steel and concrete required by safety codes.

The construction industry, which uses half of the 1.5 billion tonnes of steel produced each year, could drastically reduce its carbon footprint by optimising the design of new buildings. Smart design could slash the sector's carbon emissions by around 50%, without any impact on safety. If buildings are also maintained for their full design life and not replaced early, the sector's emissions could in total be cut by around 80% – the target set in the UK's 2008 Climate Change Act.

New research from the University of Cambridge has found that the amount of steel used by the construction industry, and the resulting carbon emissions, could be significantly lowered by optimising the design of new buildings in order to use less material.

At present, in order to keep labour costs down, the construction industry regularly uses double the material required by safety codes. Analysis of more than 10,000 structural steel beams in 23 buildings from across the UK found that on average, the beams were only carrying half the load they were designed for. The results are published in the journal Proceedings of the Royal Society A.

Over one-quarter of the steel produced each year is used in the construction of buildings. Demand for steel is increasing rapidly, especially in the developing world, and is expected to double in the coming decades.

The iron and steel industry contributes nearly 10% of total global carbon emissions, which climate change experts recommend be halved by 2050. Coupled with skyrocketing demand from the developing world, drastic action is required if a reduction in the sector's carbon footprint is to be achieved.

One option to achieve this reduction is by designing and building more efficiently, delivering the same performance from buildings but with less steel, but this is not common practice at present.

"Structural engineers do not usually design optimised structures because it would take too much time; instead they use repetition to decrease the cost of construction," said Dr Julian Allwood of the Department of Engineering, who led the research, which was funded by the UK's Engineering and Physical Science Research Council (EPSRC). "This leads to the specification of larger steel components than are required."

The researchers found that building designs are exceeding Eurocode Safety Standards by a factor of two and so are unnecessarily using double the amount of steel and concrete needed. "As materials are cheap and structural design time is expensive, it is currently cheaper to complete a design by using safe but considerably over-specified materials," said Dr Allwood.

Additionally, many buildings are being designed to last for 100 years but on average are replaced after just 40.

By designing for minimum material rather than minimum cost, steel use in buildings could be drastically reduced, leading to an equivalent reduction in carbon emissions, at relatively low cost. The net result of avoiding over-design and early replacement is that the UK could provide the same amount of built space with just 20% of the materials – and therefore 20% of the carbon emissions – used at present.

> "We need to see a more sensible use of materials in the construction sector if we are to meet carbon reduction targets.
>
> Dr Julian Allwood

"We need to see a more sensible use of materials in the construction sector if we are to meet carbon reduction targets, regardless of the energy mix used in manufacturing the materials," said Dr Allwood.

Dr Julian Allwood
www.eng.cam.ac.uk/profiles/jma42

Designing our Tomorrow

Resources to inspire the next generation of engineers

New resources designed to inspire the next generation of engineers by bringing authentic engineering challenges into the classroom have been launched by the University of Cambridge.

Designing our Tomorrow (DOT) is a joint project of the Department of Engineering and the Faculty of Education at the University of Cambridge.Working in partnership with leading engineering companies and local schools, DOT has developed a distinctive teaching approach and a unique set of resources, 'DOT in a Box', for teachers to use in Key Stage 3 Design and Technology classes. The three boxes being launched currently are: Inclusive Design, Sensor Circuits and Picture Holders. Each box includes a complete set of teaching resources, which would normally cover 12 design and technology lessons. "Inclusive Design" sets the challenge of designing more inclusive cutlery. The box includes a set of gloves and glasses that mimic the effects of human ageing – the gloves restrict dexterity in a similar way to arthritis; while the glasses mimic common effects of visual decline with ageing. Immersion in these and other creative/analytical tools contained in the box become the starting point to authentic engineering design challenges.

To help ensure that the case studies and challenges are authentic, leading engineering companies helped to develop the teaching resources:

- Cambridge Design Partnership contributed real-world industry case studies to inspire the students, including the design of Dulux PaintPod, a self-cleaning powered painter; and the Waterpebble, a small device with complex electronics to measure water usage in the shower. "We enjoyed the opportunity to demonstrate how interesting product development and engineering work can be, and share this in the classroom," a spokesman said.
- Heba Bevan, PhD Researcher in Low-power Wireless Sensor Networks at the University of Cambridge's Centre for Smart Infrastructure and Construction, said: "Engaging with students in a creative and relevant way at the age of 13 and 14 is critically important to develop analytical skills and a lifelong love of problem solving. These workshops create a different atmosphere for learning, encouraging teamwork, innovation, and thinking about problems in a multi-dimensional way rather than in a linear input-output manner. I believe that widespread implementation of DOT will lead to an significant increase in the number of students that pursue careers in science and engineering."

BT, Marshalls and Chesapeake also supported the development of DOT in a Box. The project has been piloted in a range of schools, including a number from Cambridgeshire, to make sure that the resources work for teachers and pupils. The most recent pilot was funded by the Royal Academy of Engineering through its Ingenious grant scheme. The project is actively seeking additional sponsors for the next phase.

Ian Hosking, Senior Research Associate at the University of Cambridge's Engineering Design Centre, said: "Everything is designed. It is how we shape the world around us. Designing Our Tomorrow is about equipping students to design their futures and in particular address the global challenges of population ageing and environmental sustainability."

Bill Nichol, Lecturer in Design Education at the University of Cambridge's Faculty of Education, said "Although 71% of 13 and 14 year olds interviewed for the project said that engineering was 'cool', less than half felt challenged by their lessons and only 38% said they were considering a career in design and technology.

"By developing and delivering inspirational resources for teaching design and technology at secondary level, DOT hopes that all Key Stage three students will enjoy challenging lessons and be inspired to consider design as a real and rewarding career path."

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> Heba Bevan, PhD Researcher in Low-power Wireless Sensor Networks

For further information email:
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Credit: Andy Reid via Flickr

Engineering the Kelpies

Scotland saw the opening of the Kelpies, two thirty metre high horse head sculptures either side of a lock in a new canal extension in Falkirk.

The sculptures are the figurehead of a major redevelopment project called the Helix, changing an industrial wasteland into parkland and reuniting communities in Falkirk and Grangemouth. The finished article is visually stunning, but behind the artwork is eight years of work to take the Kelpies from a concept, to an artist's vision, to an engineered reality. Alumna, Felicity Starr, works as a senior engineer at Atkins. Here she discusses some of the key challenges in leading the development of the engineered solution:

"The form of the structure is based on tenth scale maquettes, two three metre high miniature models built from 9,115 individually cut flat steel plates welded together over a wire frame by the sculptor, Andy Scott. The mosaic effect created by the flow of the plates and the view through the openings capture the horses as if in motion. The challenge was to take these scale models and translate them into an engineered solution, which had the structural strength required, whilst being suitably detailed for manufacture and transportation, and would stand as a monument for years to come, and yet retain the sculptor's vision.

Working closely with the artist at every stage of the design was key. The internal structure design began with discussions on the muscle groups of a horse's head. The final form, with columns creating two stiff triangular-based structures at the front and back of the horse's head interconnected by braced flat frames, provides an efficient, strong structure, but also maintains a clear cathedral-like space internally and keeps the structural density low in key areas. This approach led to the creation of an internal structure which was a sculpture in itself.

The result was 928 unique stainless steel panels, each one based on scanned data of the artist's maquettes and then optimised using finite element analysis, first to create flattened panels for the laser cutter, and then to ensure that the panel could be pulled back from a flat plate to the required shape using the discrete support positions. Each panel has been carefully designed to reduce pull forces, reduce error in final positioning and to ensure the panel had the strength to withstand high and fluctuating wind loads, as well as to maintain the original visual impact. The majority of the resulting panels were site fixed onto the erected frame, the ease of assembly is a testimony to the engineered solution.

Engineering the Kelpies was a real privilege. The team created something which not only we can be proud of, but is a source of pride for the community and a symbol of regeneration for the area."

A time-lapse short film of the Kelpies and their construction can be viewed at vimeo.com/90747645

Honours, Awards and Prizes

Professor Dame Ann Dowling, former Head of the Department of Engineering, has been honoured by the American Society of Mechanical Engineers (ASME).

She has been awarded the Kate Gleason Award for 'significant contributions to advance gas turbine engine technology and the engineering science of combustion and acoustics; and for outstanding leadership in industry-university co-operative research and international engineering education.'

Professor Robert Mair CBE, Sir Kirby Laing Professor of Civil Engineering, has been appointed Chairman of the Department for Transport's Science Advisory Council.

Professor Mair is also one of two new Vice Presidents to be elected to the Institution of Civil Engineers (ICE). As a world-leading expert on civil and environmental engineering, Professor Mair's appointment will bring a combination of academic excellence and professional expertise to the role.

Professor Kenichi Soga, Professor of Civil Engineering at the Department of Engineering, was invited by the Council of the Italian Geotechnical Association (AGI) to deliver the twelfth Croce Lecture at the Italian National Research Council in Rome, Italy.

Professor Soga's lecture was entitled: 'Understanding the real performance of geotechnical structures using innovative sensor technologies.'

Professor Norman Fleck, Professor of Mechanics of Materials in the Department of Engineering, and Founder/Director of the Cambridge Centre for Micromechanics, received an honorary degree from the Eindhoven University of Technology (TU/e).

Dr Stephan Hofmann, Reader in Nanotechnology, has been awarded the 2014 Journal of Physical Chemistry C Lectureship by the American Chemical Society (ACS).

Dr Hofmann was recognised for his outstanding contributions to the understanding of the growth and device integration of novel nanomaterials, including carbon nanotubes, graphene and semiconductor nanowires.

New use for an old 'trouble maker'

↑ Fans of devitrite crystals

A 'trouble maker' from a bygone method of glass production could find a new use as an optical diffuser in medical laser treatments, communications systems and household lighting.

A form of crystal that was long considered an unwanted and unloved 'stone' in glass making could find practical use as a cheap and efficient optical diffuser, which is used to scatter and soften light for a range of industrial and household applications.

Devitrite is a form of crystal which is produced when commercial soda-lime-silica glass is heat treated for extended periods. As it degrades the performance of glass by making it opaque, it was considered a 'trouble maker' in early 20th century glass manufacture and, once identified, its functional properties were never studied. Improvements in commercial glass manufacturing have enabled it to be removed from the final product altogether.

However, researchers from the University of Cambridge have discovered that far from being fit for the bin, devitrite actually possesses many useful characteristics which could make it suitable for a range of practical applications.

Writing in the journal ACS Nano, the researchers found that the very optical characteristics which help to make devitrite unwanted in commercial glass can make it extremely useful as an inexpensive and efficient optical diffuser.

Devitrite grown in glass consists of needle-like crystals, formed into fan-like shapes. The tiny spacings between the needles are similar to that of the wavelength of visible light, so when light passes through the devitrite, it scatters the light at wide angles of up to 120 degrees.

Optical diffusers are typically either mass produced by sandblasting glass, resulting in low cost devices which diffuse light in a relatively uniform manner, or more expensive engineered holographic diffusers, which can control the shape of the beam of light.

The devitrite-based diffusers developed by researchers from the Department of Engineering and the Department of Materials Science and Metallurgy diffuse light more broadly than the sandblasted devices, while giving some control over the shape of the beam, at lower cost than the engineered holographic devices.

Devitrite can be produced on a large scale, simply by treating ordinary window glass with heat. The devitrite crystals grow into the glass itself, making the diffusers robust and resistant to damage. In addition, the high melting point of the glass means that the diffusers can withstand temperatures in excess of 500°C.

These diffusers could be used in a range of practical applications, from medical laser treatments, to optical imaging, or even in everyday household use. For instance, the adoption of high-efficiency LED lighting has been slowed somewhat by the harsh light which LEDs produce. A reproducible, low-cost diffuser on an ordinary LED bulb would help address this issue, resulting in softer, warmer light.

"For years, the properties of this material were not studied because it was considered as just a trouble maker in the glass making process which needed to be eliminated," says Dr Kevin Knowles of the Department of Materials Science and Metallurgy. He developed the diffusers with Dr Haider Butt, formerly of the Department of Engineering's Photonics Department, and now of the University of Birmingham. "But by taking a closer look at it, we found that it could have a new lease of life with real practical applications."

The inventors are currently developing the technology for commercial use with the assistance of Cambridge Enterprise, the University's commercialisation arm.

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