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discovery and innovation

PIONEER

Engineering and Physical Sciences Research Council

16

**SPECIAL EDITION: SCIENCE FOR
A CONNECTED NATION**

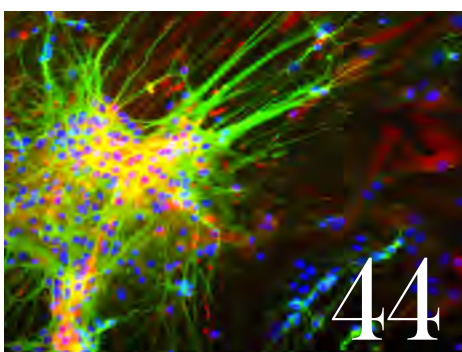
Super brain

Professor Steve Furber - building
a computer to think like a human



Greener trucking Cooler ice cream Safer water Smarter energy networks Faster supercomputers

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The Research Councils work collectively on issues of common concern via Research Councils UK.

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Linking thinking

EPSRC Chief Executive, **Professor Philip Nelson**, sets out the challenges and opportunities for research in the digital age.



Every year, EPSRC invests £800 million in research and postgraduate training in engineering and the physical sciences.

Indeed, we are the UK's largest investor in these two critical areas for science. But what does this mean in the real world?

To put things in perspective, we have identified four inter-linked outcomes from our investments which collectively underpin UK prosperity – Connectedness, Productivity, Resilience and Health.

These four outcomes provide a sense of focus for us as an organisation and inform our long-term investments – giving researchers the best environment for ideas and innovation to flourish; attracting significant leverage on public investment; and helping to create new jobs, products and services.

Taken as a whole, they facilitate growth, benefit society and improve the quality of people's lives – both in the UK and, by association, globally.

Of these four outcomes Connectedness is all pervading – spanning disciplines

and intertwining sectors in a rapidly changing digital world of smartphones, Artificial Intelligence and the Internet of Things.

Over the coming decades, the UK's prosperity will be driven by a host of new industries and services, some as yet unimagined. Our skill at connecting people, things and data together in safe, smart, secure, trustworthy, productive and efficient ways will be crucial to this process. But we can only achieve our goals through new discovery and innovation stemming from fundamental research – leading to transformational technologies from which the world will benefit.

This edition of *Pioneer* is all about exploring how we approach such challenges and opportunities now and in the future, in ways that will enable our economy and society not just to survive, but to thrive in a digital world as a truly connected nation.

“Over the coming decades, the UK's prosperity will be driven by a host of new industries and services”



£11 million autonomous vehicle programme

How can cars become fully independent of human direction? What is the best technology to incorporate into new vehicles and infrastructure? How will humans and vehicles interact with each other and their environment?

These are just a few of the questions facing academics and industrialists who will be working on a new £11 million research programme, jointly funded by EPSRC and Jaguar Land Rover, as part of their strategic partnership, to develop fully autonomous cars. The research will take place at 10 UK universities and the Transport Research Laboratory. The five projects will look into the use of radar and video sensing to interpret the external environment, road conditions and other road users; how drivers will react to new autonomous systems; and how systems can be designed to adapt to the personal characteristics of users. They'll also investigate how the transition between human control and automated systems can be designed to best effect; how distributed control systems and cloud computing can be integrated with vehicles; and how data from intelligent infrastructure, drivers and automated vehicles can be used to aid interaction.

£15 million for formulation manufacturing

EPSRC is investing £15 million in seven new research projects that aim to improve the complex formulation processes used to manufacture products such as toothpastes, inhalers and pharmaceuticals.

The projects involve researchers at 16 UK universities and over 40 industrial and academic partners.

Fellows on quantum quest

The UK's ability to lead the world in quantum science and technologies has been boosted by a £12 million investment in 10 EPSRC Quantum Technology Fellowships, which will support individuals and their teams to help realise the country's potential in this key area for science.

Part of the £270 million National Quantum Technology Programme (see pages 26-27), the Fellowships are aimed at early and established career stage academics whose research focuses on the exploitation

of quantum phenomena – leading to new technology and on to eventual application. Quantum technologies promise dramatic changes in key research areas such as secure communications, metrology, sensor technologies, simulation and computation. The Fellowships will help enhance capabilities in these areas and will complement other components of the national programme, including EPSRC's investments in Quantum Technology Hubs and Centres for Doctoral Training.

New autonomous manufacturing projects

EPSRC is investing £6.2 million in three projects that will aid the development of autonomous systems in UK manufacturing in sectors such as aerospace, construction and automotive. Researchers at the University of Birmingham, Imperial College London and the University of Strathclyde will be supported by companies including Caterpillar, Kuka Robotics, Skanska Ltd,

Dyson Ltd, SPIRIT AeroSystems and Autocraft Drivetrain Solutions. Together they will investigate areas such as automating the complex disassembly of returned products; developing the world's first aerial additive manufacturing systems for use on-site, and creating automated non-destructive evaluation systems for use in high value manufacturing.

£20 million for new energy systems centre

EPSRC has invested £20 million in a new centre at Newcastle University that will allow experts to test the entire energy system in real time. The EPSRC National Centre for Energy Systems Integration will bring together energy experts from around the world to help unravel the energy network and understand future supply and demand.

Focused on understanding how we can optimise the energy network and inform future government policy, the centre will play a leading role in the drive towards a fully integrated, smart energy network, and will help improve energy efficiency, drive down customer bills and reduce carbon emissions.

Fellowships for the future of manufacturing

EPSRC has created four new fellowships, based at the universities of Nottingham, Manchester and Kent, to support senior researchers in manufacturing at the frontiers of technological change. The grants will allow senior researchers to spend time responding to the challenges set out in the government's 2014 Manufacturing Foresight report; and will focus on key technologies likely to change how products are designed, made, offered and used by consumers, including additive manufacturing, biomaterials for personalised healthcare, analytical technologies in continuous manufacturing, and passive bio-sensing wireless tag technologies.

£204 million for science

Forty UK universities will share a total of £167 million in support for doctoral training thanks to a new two-year investment by EPSRC in its Doctoral Training Partnerships (DTPs).

In addition, £37 million will be invested in developing the graduate skills, specialist equipment and facilities that will put UK quantum technologies research at the forefront of its field.

These strategic investments will help science push at the boundaries and make discoveries that are taken through into innovations.

£3.9 million urban regeneration partnerships

People in Birmingham, Bristol, Leeds, Newcastle and Gateshead and York will benefit from a new research and innovation initiative that puts them in the driving seat to help improve their cities' health, wellbeing and prosperity as they face up to the challenges of modern urban living. Phase one of the Urban Living Partnership (ULP) (see page 20), a first-of-its-kind investment by the seven UK Research Councils and Innovate UK, brings citizens together with university researchers, local authorities and over 70 partners from business and the third sector, including IBM UK Ltd, Atkins Global, The Environment Agency and the Future Cities Catapult, in five multidisciplinary pilot initiatives. Taking a 'whole city' approach, the partnership combines a unique body of expertise cutting across over 20 disciplines including civil engineering, computer science, planning, psychology, management, arts and humanities, the creative industries and health sciences.

£20 million for manufacturing hubs

EPSRC is investing in two £10 million manufacturing research hubs, led by the University of Southampton and Brunel University in London, that will address major, long-term challenges facing the UK's manufacturing industries, and capture opportunities from emerging research. Impact from the EPSRC Manufacturing Hub in Future Liquid Metal Engineering will initially be in the UK automotive industry and its supply chain and then the wider transportation industry.

The EPSRC National Hub in High Value Photonic Manufacturing, in partnership with the National Centre for III-V Technologies at the University of Sheffield, will provide national leadership in manufacturing for the next-generation of photonics technologies. The hubs will feature multidisciplinary research with strong engagement with manufacturing industries. EPSRC's £20 million investment will be enhanced by £14 million from the universities and a further £58 million from industry.

Maths centres tackle life-threatening diseases

EPSRC is investing £10 million in five new research centres that will explore how mathematics and statistics can help clinicians tackle serious health challenges such as cancer, heart disease and antibiotic resistant bacteria. The centres, based at Liverpool, Glasgow, London, Cambridge

and Exeter universities, will enable mathematicians and statisticians to work closely with healthcare planners, clinicians, policymakers and industry partners across the UK to conduct multidisciplinary research to help overcome some of the biggest challenges facing the NHS (see page 20).

UK-China low carbon cities initiative

Researchers from UK and Chinese universities are collaborating on four new projects to work towards achieving low carbon cities in the UK and China. The projects will receive over £3 million in funding from EPSRC. This will be matched by equivalent resources from the National Science Foundation of China. Funded under the RCUK Low Carbon Cities programme, the projects will encourage collaboration between leading UK and Chinese academics, combining research to reduce the carbon emissions of existing technologies. The projects will also carry out fundamental research into alternative energy sources and ways to reduce energy demand, all with a focus on future urban environments (see page 20).

£2.5 million for autonomous systems

EPSRC and the Natural Environment Research Council (NERC) are co-investing £2.5 million in a new Centre for Doctoral Training in the use of Smart and Autonomous Observation Systems (SAOS) for the environmental sciences. The NEXUSS centre will provide specialised training in this increasingly vital area, creating a community of highly-skilled people whose expertise will contribute both to scientific breakthroughs and to economic growth. The consortium behind NEXUSS is led by the University of Southampton, in partnership with the British Antarctic Survey, Heriot-Watt University, the National Oceanography Centre, the Scottish Association for Marine Science and the University of East Anglia.

THINGS WE'VE LEARNED

To find out more, type the keywords into your favourite search engine.

Air today...

EPSRC-supported researchers at The University of Nottingham, led by Dr Ed Cooper, have developed an easy-to-use test for measuring the airtightness of buildings in order to help eliminate draughts, improve energy efficiency, prevent poor indoor air quality and reduce heating bills.

The PULSE test is quick and easy to operate and can be conducted by anyone with minimal training. It has been extensively researched and developed over 14 years since an EPSRC First Grant helped secure proof of concept, and is now being commercialised with industry partners, supported by funding from Innovate UK.

Search engine: Pulse Ed Cooper



Soothing shuteye

Discoveries made by a multidisciplinary team at the University of Bristol's Centre for Synaptic Plasticity have provided further evidence of the benefits of a good night's sleep.

The findings show that patterns of brain activity that occur during the day are replayed at fast-forward speed during sleep. This replayed activity happens in part of the brain called the hippocampus, which is our central filing system for memories.

The key new finding is that sleep replay strengthens the microscopic connections between nerve cells that are active – a process deemed critical for consolidating memories. Therefore, by selecting which daytime activity patterns are replayed, sleep can sort and retain important information.

The research team was supported by EPSRC, the Medical Research Council, Wellcome Trust and Eli Lilly & Co.

Search engine: Bristol Sleep EPSRC

Battery power

A lithium-oxide-powered 'super battery' 90 per cent more efficient than its lithium-ion counterparts has been developed by researchers from the University of Cambridge.

Supported by EPSRC, Johnson Matthey and the EU, the team have not only been able to increase capacity 10-fold they have also been able to increase the battery's stability.

In time, batteries like this could be used to power electric cars – at a fifth of the cost of a gasoline-powered vehicle.

Search engine: Lithium-oxide super battery EPSRC



Mini mote

A low cost energy harvester developed by the EPSRC-supported Cambridge Centre for Smart Infrastructure and Construction

(see page 21), has been successfully tested on the Forth Road Bridge in Scotland where, powered only by traffic and wind-induced bridge vibrations, it powered a minuscule wireless 'mote' which transmitted data to a miniature receiver.

The wireless, battery-free energy harvesting technology has the potential to enable maintenance free, autonomous measurement of the behaviour of key structural elements of infrastructure, even in the most difficult-to-reach areas, giving the owner a far greater understanding of the actual capacity and level of safety of an asset.

A spin-out company, 8Power, is being formed to commercialise the technology.

Search engine: CISC Forth Road Bridge





Data download

A tracking system based on eye-safe lasers, developed with EPSRC support at the University of Oxford, could enable aircraft, unmanned aerial vehicles and even orbiting satellites to transmit vital data to ground stations more securely, quickly and efficiently.

The proof-of-concept HYPERION system, developed through Innovate UK's HITEA programme and with Airbus Group Innovations, has a range of 1km and has been successfully tested in flight. Work is under way to extend this range.

HYPERION could also enable airliners of the future to offload huge amounts of technical and performance data gathered by on-board sensors to ground crews during final approach to an airport, speeding maintenance procedures and cutting aircraft turnaround times.

Search engine: EPSRC Hyperion

Mind control

EPSRC-supported research led by Newcastle University has resulted in technology that enables amputees to 'feel' using their prosthetic limbs.

Project leader Dr Kianoush Nazarpour (pictured) says the bionic arm contains a new generation of sensors which detect pressure, enabling the user to carry out complex tasks such as picking up a glass by 'sensing' the shape and feel of the object.

Search engine: Nazarpour



Nuclear waste filter

A team led by Sir Andre Geim at The University of Manchester have shown that 'wonder material' graphene can simplify production of heavy water and help clean nuclear waste by filtering different isotopes of hydrogen.

The EPSRC-supported team demonstrated that using membranes made from graphene can act as a sieve, separating protons – nuclei of hydrogen – from heavier nuclei of the hydrogen isotope deuterium.

The process means producing heavy water for nuclear power plants could be 10 times less energy intensive, as well as simpler and cheaper, using graphene.

Search engine: Geim heavy water



Cool for cats

EPSRC-funded engineers at Lancaster University have drawn inspiration from the eyes of cats to create a new camera that can see radiation coming from nuclear reactors – boosting safety and efficiency and helping during nuclear disaster emergencies.

Developed with Createc Ltd, the technology can see high-intensity 'fast-neutron' and 'gamma-ray' fields simultaneously – enabling monitoring of the state of nuclear reactors, as found in nuclear power stations, in near real time, giving vital information on the state of the nuclear core.

Search engine: EPSRC cat's eyes



Book learning

Heritage scientists at UCL have developed demographic models of decay and loss to predict when a large library or archival collection might age beyond repair.

Lead author, Professor Matija Strlic, says: "Although some library materials might easily survive thousands of years, some have internal clocks triggering faster decay. Using the demographic models from this research we can now easily predict how much more degradation will be induced by a hotter and more humid climate in the future, and perhaps more importantly, how this can be mitigated."

The research was co-funded by EPSRC and the Arts and Humanities Research Council through the Science and Heritage Programme.

Search engine: Strlic decay

Flight plans



Cella Energy, a company formed to commercialise EPSRC-supported research into hydrogen storage materials, and Arcola Energy have combined to successfully develop and test fly a prototype unmanned autonomous aircraft (pictured) that uses a new solid-state hydrogen power system

with the potential to outperform lithium-ion batteries. The maiden flight was conducted by the Scottish Association for Marine Science using Cella's hydrogen-powered gas generator married with a fuel cell supplied and integrated by Arcola. The work was funded by a grant from Innovate UK.

Cella specialises in advanced hydrogen storage material capable of storing up to one litre of hydrogen per gram – giving three times the specific energy compared to lithium-ion batteries.

US organisation, Space Florida, has invested in Cella's unique pelleted hydrogen system for an Unmanned Aircraft System platform, paving the way for a second Cella facility at NASA's Kennedy Space Center in Florida.

Search engine: Cella Arcola



Palm power

Palm oil, commonly used in foods such as cakes and biscuits, is in high demand, causing environmental issues such as deforestation, water and air pollution due to the increased number of global palm plantations.

Researchers from the universities of Bath and York have integrated cutting-edge bio- and chemical technologies to develop a 'synthetic' yeast-derived alternative to palm oil with near-identical qualities.

This four-year project was jointly funded by EPSRC, the Biotechnology and Biological Sciences Research Council and Innovate UK as part of the IB Catalyst Programme, aimed at supporting the development and commercialisation of innovative industrial biotechnology processes.

Working with industry partners Croda, C-TECH and AB Agri, the researchers are confident their work will lead to a palm oil alternative that can be produced on an industrial scale.

Search engine: EPSRC palm oil

Super software

EPSRC-supported researchers from Queen's University Belfast and The University of Manchester are creating ground-breaking computer software that will increase the ability of future supercomputers to model and simulate incredibly complex systems. Simulations that would take thousands of years on a desktop PC will be completed in minutes.

Now being tested, evaluated and optimised for use by computational scientists at the Science and Technology Facilities Council's Daresbury Laboratory, the software is said to be critical to drive Exascale supercomputers that would be capable of performing one billion, billion calculations per second. This is a thousand times more powerful than the Chinese Tianhe1A – the fastest supercomputer in operation today.

Search engine: EPSRC Tianhe1A

MRI marvel



Scientists at The University of Manchester and The Institute of Cancer Research, London have developed a new imaging test using magnetic resonance imaging (MRI) that could enable doctors to identify more dangerous tumours before they spread around the body – and tailor treatment accordingly.

The technology maps areas of oxygen deprivation within tumours. Lack of oxygen, or hypoxia, is often a sign that a cancer is growing aggressively. Hypoxia also stimulates the growth of blood vessels within tumours, which in turn can fuel the spread of cancer cells to other parts of the body.

The new study could also lead to more effective radiotherapy planning to boost the doses of X-rays delivered to dangerous, hypoxic areas within tumours, and new ways of monitoring whether radiotherapy or some drugs are working.

The research was funded by a range of organisations including EPSRC, Cancer Research UK, and Wellcome Trust.

Search engine: Manchester MRI EPSRC hypoxia



London driverless car trials

Oxbotica, a company formed to bring to market EPSRC-funded research into autonomous vehicles led by Professor Paul Newman at the University of Oxford, is collaborating with Westfield Sportscars and Heathrow Enterprises on a project that will see Ultra POD autonomous vehicles operating on the streets of London this summer.

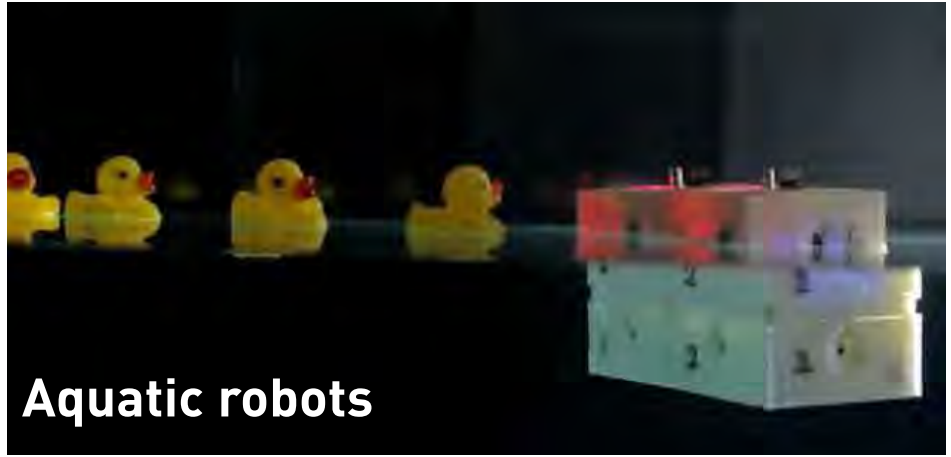
Since 2005, Ultra PODs, the concept for which is based on EPSRC-supported research at the University of Bristol in the 1990s, have carried 1.5 million passengers and completed three million kilometres of fully automated operation at Heathrow Airport's Terminal 5.

The project is part of the GATEway driverless car initiative, funded by Innovate UK and industry, which is taking place in the London borough of Greenwich.

If the trials prove successful, these iconic vehicles could become a familiar sight in many cities around the world.

The technology available in Oxbotica's IP portfolio underpins the Oxford RobotCar – the UK's first autonomous car approved for public trials.

Search engine: Ultra POD Oxbotica



Aquatic robots

Researchers at the University of Sheffield have created an aquatic robot which could be used during underwater search and rescue operations.

The researchers developed a set of robotic modules (pictured above) that, similar to Lego, can be assembled into robots of arbitrary shape. This allows robots to be customised to meet the changing demands of their task.

Each module is a cube and has four micro pumps which allow it to move around independently in the water. When modules are joined together, they can draw in fluid from each other as well as the environment.

The routing of the fluid through the network of modules causes the robot to move. Six prototype modules of an MHP robot were constructed, which float on the surface of water. In search and rescue operations the modules could split up and search for survivors more quickly and recombine to lift a heavy object and open up a passageway.

This type of robot could also be used by utility companies wanting to deal with blockages or faults in pipes that are difficult and expensive to access from the surface.

Search engine: Sheffield aquatic robots

Magnetic motors

More efficient and less polluting marine vessels could result from a UK collaboration to build a new type of motor based on magnetic gears.

The compact, low maintenance motor is being developed by award-winning magnetic gear developer Magnomatics, a company formed in 2006 to commercialise EPSRC-supported research at the University of Sheffield, together with Rolls-Royce and motor specialist ATB Laurence Scott.

Innovate UK, the government's innovation agency, is co-funding the £1.7 million project.

The magnetic gear developed by Magnomatics, known as the Pseudo Direct Drive (PDD), uses magnetic fields generated by powerful permanent magnets to transmit mechanical power, and is an important advance over conventional permanent magnet motor and generator technology.

Magnomatics employs 30 people in a variety of disciplines – from electromagnetic design to manufacturing engineering – creating bespoke solutions to customers in hybrid/electric vehicles, renewable energy, rail, marine propulsion, oil and gas and aerospace.

Search engine: Magnomatics Laurence Scott



Cool news



As our thoughts turn to barbecues, Pimm's and the occasional sunbeam peeking through the clouds, there's good news to report from the University of Edinburgh where scientists have unlocked the secret of slower melting ice cream, thanks to a new food ingredient.

Professor Cait MacPhee CBE, from the University of Edinburgh, working with colleagues from the University of Dundee, has discovered a naturally occurring protein, known as BslA, that can be used to create ice cream that is more resistant to melting than conventional products.

The protein binds together the air, fat and water in ice cream, creating a super-smooth consistency.

The new ingredient could enable ice creams to keep frozen for longer in hot weather. It could also prevent gritty ice crystals from forming, ensuring a fine, smooth texture like those of luxury ice creams.

The development could allow products to be manufactured with lower levels of saturated fat – and fewer calories – than at present.

The team have developed a method of producing BslA, which occurs naturally in some foods, in friendly bacteria. They estimate that ice cream made with the ingredient could be available within five years.

The protein works by adhering to fat droplets and air bubbles, making them more stable in a mixture. Using the ingredient could offer significant advantages for ice cream makers. It can be processed without loss of performance, and can be produced from sustainable raw materials.

Manufacturers could also benefit from a reduced need to deep freeze their product, as the ingredient would keep ice cream frozen for longer. The supply chain would also be eased by a reduced need to keep the product very cold throughout delivery and merchandising.

BslA was developed with support from EPSRC and the Biotechnology and Biological Sciences Research Council (BBSRC), and the team are working directly with industry partners across various sectors interested in applying this technology commercially.

The protein could soon be used not just in ice cream but for home and personal products. Professor MacPhee (pictured above) says: "BslA came about through my research into the behaviour of proteins – biomolecules responsible for the vast majority of functions in living organisms. I'm investigating their role in health and disease, and their possible use in industry.

"The controlled self-assembly of proteins into well-defined structures and functional assemblies is essential to our wellbeing. However, occasionally protein self-assembly takes place inappropriately. When this happens in the body it typically causes disease, including diseases of ageing, such as Alzheimer's.

"Protein self-assembly can also cause havoc in industrial processes including the production of biopharmaceuticals such as insulin. When this occurs, the pharmaceutical is often lost as an irretrievably tangled mass of gelled protein.

"All is not lost, as the self-assembly of proteins also underpins the texture of foodstuffs including egg, meat and milk products.

"My research seeks to understand this process of self-assembly – both to prevent or reverse disease, and to drive the development of new materials and foodstuffs."

Search engine: MacPhee ice cream



Opposites attract

EPSRC-supported scientists at the University of Leeds have demonstrated for the first time how to generate magnetism in metals that aren't naturally magnetic, which could end our reliance on some rare and toxic elements currently used.

In their study, the researchers detailed a way of altering the quantum interactions of matter in order to 'fiddle the numbers' in a mathematical equation that determines whether elements are magnetic, called the Stoner Criterion.

Co-lead author, Fatma Al Ma'Mari, from Oman, says: "Being able to generate magnetism in materials that are not naturally magnetic opens new paths to devices that use abundant and

hazardless elements, such as carbon and copper."

Magnets are used in many industrial and technological applications, including power generation in wind turbines, memory storage in hard disks and in medical imaging.

"Future technologies, such as quantum computers, will require a new breed of magnet with additional properties to increase storage and processing capabilities," says Fatma (pictured above), who made the breakthrough with colleagues Dr Oscar Cespedes (above centre) and Tim Moorsom (above right).

"Our research is a step towards creating such 'magnetic metamaterials' that can fulfil this need."

Search engine: Fatma magnet

Liquid asset

EPSRC-supported research led by Professor Wayne Hayes, from the University of Reading's School of Chemistry, Food and Pharmacy, has led to the development of a new kind of plastic that can repair itself at body temperature. Experts not involved in the study have hailed the discovery as 'beautiful'.

The new material, a supramolecular polyurethane, 'flows' like a liquid when cut or scraped, filling in the damage in a couple of hours before its molecules bind together to become solid again.

Professor Hayes says: "While self-healing plastics have been developed before, the new material is remarkable because it is safe to humans and works at temperatures as low as 37 degrees Celsius, making it ideal for use in healthcare, and opens the door to new self-healing wound dressings."

Other potential applications include self-healing vehicle paint, or as a coating for mobile phones, which could repair scratches or scuffs automatically with only mild heat.

Search engine: Wayne Hayes plastic

Serial innovator and technology investor, Dr Hermann Hauser, has been awarded an honorary Knighthood for his extraordinary contribution to entrepreneurship in the UK. Born in Vienna, Dr Hauser has played a vital role in the growth of Cambridge's cluster of high-tech companies for over 30 years.

A founding director of many companies, including Acorn Computers and ARM Holdings, one of the UK's leading listed technology companies, he gave a first job to Steve Furber, who features on the cover of this edition of *Pioneer* (see pages 28-33).

Search engine: Hauser KBE

Professor Winfried Hensinger, and a team of physicists at the University of Sussex, have frozen single charged atoms to within a millionth of a degree of absolute zero with the help of microwave radiation. The team used equipment found in everyday technology such as kitchen microwaves.

The technique, developed with EPSRC support, will simplify the construction of 'quantum technology devices' including powerful quantum sensors, ultra-fast quantum computers, and ultra-stable quantum clocks.

Search engine: Hensinger zero

Dr Melanie Despeisse, from the EPSRC Centre for Innovative Manufacturing in Industrial Sustainability, and Ian Bamford, the centre's commercial director, have devised an eco-efficiency tool based around a card game format. Trialled with employees from partner organisation Airbus SAS at its factory in Broughton, the game helps staff understand the opportunities that exist to make energy saving improvements in a factory environment.

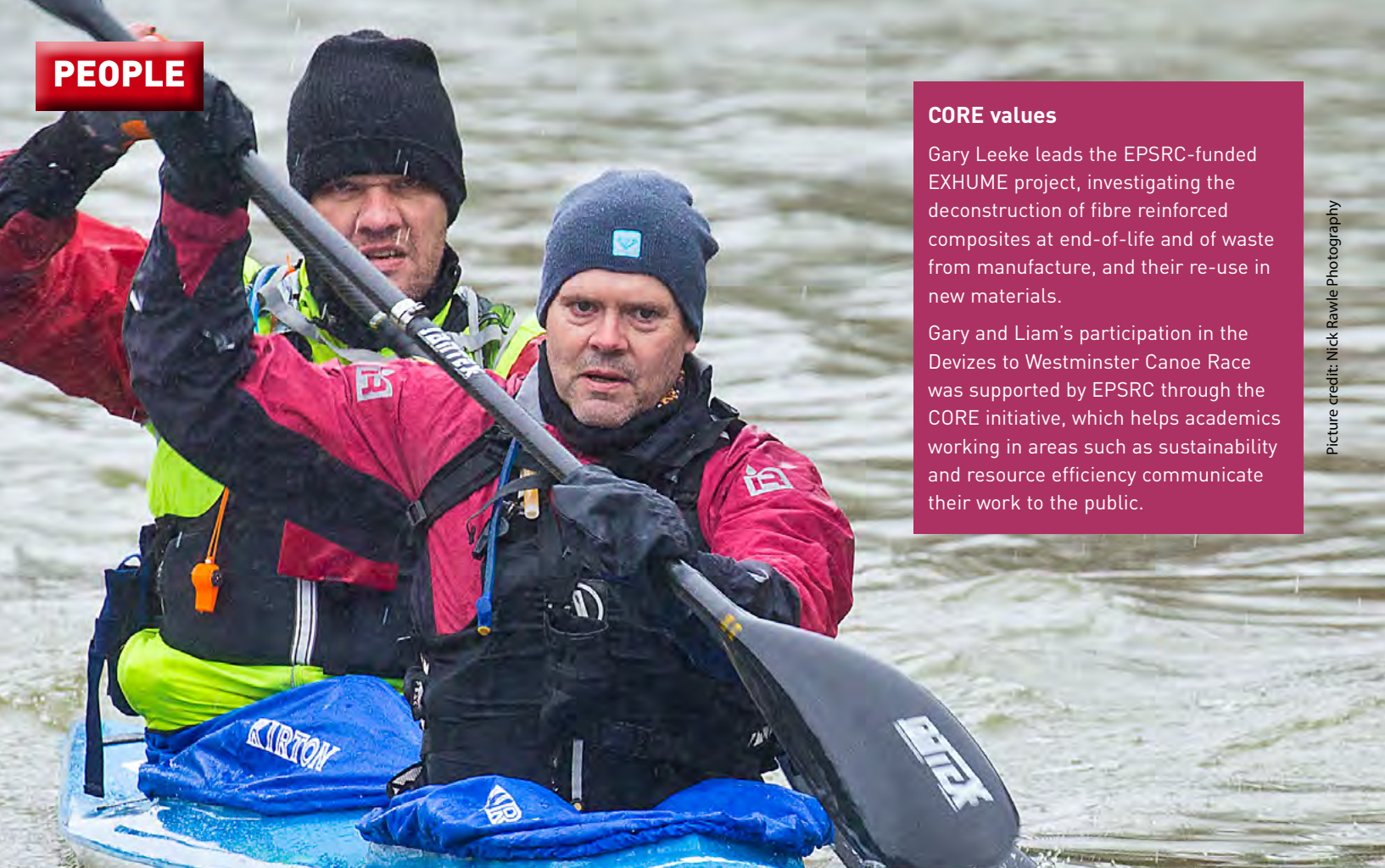
Search engine: Despeisse card

An EPSRC Knowledge Transfer

Account at the University of Bath was instrumental in founding CiteAb: an antibody search engine that provides a simple way for scientists to find antibodies that work.

Now the largest antibody search engine in a US\$2 billion industry, and ranked number one by Google, CiteAb is helping save time and money across research into the life sciences.

Search engine: CiteAb \$2 billion



Picture credit: Nick Rawle Photography

CORE values

Gary Leeke leads the EPSRC-funded EXHUME project, investigating the deconstruction of fibre reinforced composites at end-of-life and of waste from manufacture, and their re-use in new materials.

Gary and Liam's participation in the Devizes to Westminster Canoe Race was supported by EPSRC through the CORE initiative, which helps academics working in areas such as sustainability and resource efficiency communicate their work to the public.

Paddle power

Professor Gary Leeke, from Cranfield University, recalls his experiences in the 125-mile Devizes to Westminster Canoe Race – in a kayak built from recycled aerospace waste.

Gary (pictured front) says: "I lead a multi-centre EPSRC-funded research project that's developing processes to recycle fibre-reinforced composite waste. Composites are increasingly used in modern aircraft because of their light weight and high strength; currently the majority of waste goes to landfill.

Recycled composites are set to play a huge role in future manufacturing industries such as automotive, renewable energy and construction, and I was very keen to create a demonstrator product to show that they can be put to good use. I turned to one of my hobbies – kayaking – for inspiration.

We set about creating a racing kayak from these materials – and then racing it in the international Devizes to

Westminster Canoe Race, a 125-mile endurance test that's as hard on the boat as it is on its pilots.

I have completed the race twice before, with my Birmingham colleague, Professor Liam Grover, so we were confident we could handle 22 hours of non-stop paddling. But racing down a river in an untested boat made from bits of old aircraft was another matter.

In previous attempts we've lost five rudders, cracked the hull of one boat, broken a footrest in another and had to constantly repair the kayaks as we went along.

To make our racing kayak, we worked closely with British manufacturer Kirton Kayaks. The Kirton team were excited to be using an experimental material, which we created in the lab by treating waste aerospace composites using a process called solvolysis, which results in a product that we believe can be as strong as the original, unmodified material.

Building the kayak took longer than expected, and in the end the boat was ready just three days before the race. We were, however, delighted with the vessel, which is just 2mm thick throughout. But how would it fare in the ordeal ahead? We had trained hard to prepare ourselves physically. What we couldn't have factored into our equations was typical British bank holiday weather. Storm Katie was on its way...

After 85 gruelling miles and over 16 hours paddling through the night in the wind and rain, and up against constantly churning waves, Liam sustained a back injury. We were forced to withdraw.

The good news is the kayak had performed impeccably. In fact, it was as good as new. It will now be used as a demonstrator at events and exhibitions. We are already making plans to complete the race next year. In the same boat, naturally."

Search engine: Solvolysis kayak



Picture courtesy: Yu Ji/University of Cambridge

Swirl in motion: Expanding polymer-coated gold nanoparticles.

World's tiniest engine

A University of Cambridge research team, co-funded by EPSRC and the European Research Council and led by Professor Jeremy Baumberg, have developed the world's tiniest engine – just a few billionths of a metre in size – which uses light to power itself.

The nanoscale engine could form the basis of future nano-machines that can navigate in water, sense the environment around them, or even enter living cells to fight disease. The prototype device is made of tiny charged particles of gold, bound together with temperature-responsive polymers in the form of a gel.

When the 'nano-engine' is heated with a laser to a certain temperature, it stores large amounts of elastic energy in a fraction of a second, as the polymer

coatings expel all the water from the gel and collapse. This has the effect of forcing the gold nanoparticles to bind together into tight clusters. But when the device is cooled, the polymers take on water and expand, and the nanoparticles are strongly and quickly pushed apart, like a spring.

Professor Baumberg says: "Our method is incredibly simple, but can be extremely fast and exert large forces, with a force per unit weight nearly a hundred times better than any motor or muscle. The devices are also bio-compatible, cost-effective to manufacture, fast to respond and energy efficient. The challenge now is how to harness this technology for nano-machinery applications."

Search engine: EPSRC nano-engine

FeedFinder



Dr Madeline Balaam, from Newcastle University, has developed a highly successful free mobile phone app, FeedFinder, that supports women in finding, reviewing and

sharing places for public breastfeeding.

Madeline and her team worked with mothers in the Newcastle and Gateshead area to explore the issues that hinder women breastfeeding in the UK.

Many said they found the prospect of breastfeeding in public nerve-racking, not least because of the possibility of exposure, but also because they were unsure how the public would respond.

The FeedFinder app, supported by the EPSRC-led RCUK Digital Economy theme, works much in the same way as Trip Advisor, encouraging women to leave reviews for places where they have breastfed, as well as add new venues when they breastfeed somewhere that isn't already listed on the map.

Dr Balaam (pictured) says: "We are extremely proud that several NHS Trusts now use and recommend FeedFinder to new mothers as part of their community midwifery service."

Over 4,000 users have registered to use the app, and have collectively mapped and reviewed over 2,000 locations in the UK.

Search engine: FeedFinder

Dr Anna Kalogirou, Dr Vijaya Ambati and Professor Onno Bokhove, from the University of Leeds, have developed a unique new computer model built on highly complex mathematics that can show exactly how sea waves affect fast ships.

Developed with EPSRC support, the model could aid the design of fast ships better able to withstand the effects of rough seas, and also make it possible to design safer versions of the fast ships for operations such as search-and-rescue, anti-drugs and anti-piracy.

Search engine: Kalogirou ships

A team of EPSRC-supported scientists at Heriot-Watt University, led by Dr Krystian Wlodarczyk, have created 'tamper-proof' holograms that could provide a blow to the counterfeit goods trade.

The team used an ultra-violet laser to sculpt unique patterns on to metal. Individual laser pulses were used to melt the metal in an extremely precise way. They hope the technique could be used to create security markings for often-faked items such as high value watches or aircraft parts.

Search engine: Tamper-proof holograms

To mark Women in Engineering Day, *The Telegraph* published its list of the Top 50 Women Engineers in the UK. Featuring prominently on the list were: Professor Helen Atkinson; Baroness Brown (Professor Dame Julia King); Professor Muffy Calder; Professor Dame Ann Dowling; Professor Lynn Gladden; Professor Dame Wendy Hall; Professor Karen Holford; Professor Sue Ion; and Professor Eleanor Stride, all of whom have led ground-breaking EPSRC-supported research, or supported it in an advisory capacity.

Search engine: Telegraph Women in Engineering

Professor Lionel Tarassenko, from the University of Oxford, who leads Oxford's Institute of Biomedical Engineering, has been named for The Queen's Anniversary Prize for pioneering work in biomedical engineering.

Professor Tarassenko has been supported by EPSRC for over two decades.

Search engine: Tarassenko Queen's award



Parasitic *Schistosoma* worms infect around 200 million people each year.

Turning the worm



The parasitic *Schistosoma* worm, prevalent in tropical and sub-tropical areas, infects around 200 million people each year – many of them children – and can cause liver, kidney and bladder damage, infertility, and stunted growth.

The parasite infects snails in freshwater ponds, lakes or rivers. Microscopic larvae are then released from these snails into the water where they infect people by burrowing through their skin and into the body. These larvae then transform into worms inside the body.

Now, a team of scientists at the EPSRC Centre for Synthetic Biology and Innovation at Imperial College London have created a new test that could instantly detect the presence of *Schistosoma* in the water supply.

The test, which uses a similar technology to a pregnancy test, and changes colour when the parasite is detected, deploys genetically modified versions of bacterial cells to detect the parasite. The team used bacterial cells as they can be freeze-dried and, in theory, transported around the world. Once they arrive at their destination they can be rehydrated with a drop of water, and ready to use within 24 hours.

Dr Alex Webb (pictured), lead author of the research, says: "Current tests need expensive equipment, or require samples to be sent to a lab for testing. Neither of these make it ideal for many of the regions of the world affected by this parasite.

"Using synthetic biology approaches we have engineered the biosensors to be 'housed' in two bacterial chassis – *Bacillus subtilis* and *Escherichia coli* – and we have further designs that will enable a cell-free based biosensor."

Although the researchers caution the work is at an early stage, they now have proof of principal, and hope it could provide a cheap and easy test for remote areas with limited resources.

The technology originated as an undergraduate project for the International Genetically Engineered Machine (iGEM) Competition by Imperial College students. The work was then continued by members of Professor Paul Freemont's synthetic biology group.

The *Biomphalaria* snail, usually found in tropical standing water or fresh water, serves as an intermediate host for the deeply unpleasant *Schistosoma* worm.



Current methods of analysing the quality of drinking water take more than 12 hours and use expensive reagents. This is not fast enough to meet people's needs in disaster zones and poor communities.

Professor Bridgeman (pictured) says: "Microbiological waterborne

Stuff of life

Over 750 million people globally do not have access to safe drinking water supplies, and 2.5 billion do not have access to improved sanitation services.

An EPSRC-supported research team led by Professor John Bridgeman at the University of Birmingham have developed Duo Fluor, a unique device that could save lives around the globe by quickly and simply testing whether water supplies are safe to drink.

The prototype optical equipment, developed at the university's Department of Civil Engineering, uses water's natural fluorescence to 'scan' the water and highlight pollutants that are present in the sample – almost instantly revealing whether supplies are safe to drink.

Duo Fluor uses portable and inexpensive off-the-shelf equipment to reveal unsafe sources of drinking water in less than 30 seconds.

disease remains a significant concern for the global water community...

"Duo Fluor is a huge step forward in managing water and wastewater systems and has particular relevance in areas of poor sanitation such as refugee camps and disaster zones, where it is vital to ensure that people have access to safe water supplies. It should also help reduce the risk of future widespread outbreaks of cholera and other water-related diseases.

"Duo Fluor allows water experts to interpret results but also uses user-friendly technology to allow non-experts to test whether water is safe to drink. This means that people in the poorest communities could help to protect themselves from unsafe drinking water."

The researchers are working with Oxfam and the Diageo Foundation to refine the instrument design and make it ideally suited to disaster relief and areas of poor sanitation.

Search engine: Duo Fluor

Seeing's believing



Dr Martynas Beresna, from the EPSRC-supported Optoelectronics Research Centre at

the University of Southampton, has received a prestigious Royal Academy of Engineering Research Fellowship; one of only eight awarded in the year.

The award will enable Martynas to develop a manufacturing platform that uses laser-assisted engineering

technology to restructure the glass in optical fibres.

Combined with the flexibility of fibre optics, the technology will enable the production of new types of all-fibre optical devices for the next generation of telecom networks, high power light sources, low cost sensors and high-resolution imaging systems.

Royal Academy of Engineering Research Fellowships provide support for high-quality engineers and encourage them to develop successful academic research careers.

Search engine: Beresna ORC

Professor Sir Andrew Wiles, who famously solved Fermat's Last Theorem, which stood as an unsolved riddle in mathematics for over 300 years, has received the Abel Prize – the mathematical sciences equivalent of the Nobel Prize.

After a distinguished international career, Professor Wiles rejoined the University of Oxford in 2011 as Royal Society Research Professor, supported by an EPSRC Strategic Package.

Search engine: Wiles Abel Prize

Professor Andrew Blake, director of the EPSRC-supported Alan Turing Institute (see page 17) has received the 2016 BC Lovelace Medal, the top award in computing in the UK, awarded by BCS, The Chartered Institute for IT.

Search engine: Blake Lovelace Medal

Professor Robert Mair CBE FREng has been appointed to the House of Lords as an independent crossbencher. Professor Mair is founder and director of the EPSRC-supported Cambridge Centre for Smart Infrastructure and Construction (CSIC) (see page 21). He has advised on many large-scale underground engineering projects including the Channel Tunnel Rail Link, and is a member of the Expert Panel for Crossrail in London – currently Europe's largest construction project.

Search engine: Mair House of Lords

SimPrints, a non-profit company co-founded by Alexandra Grigore, a student at the EPSRC-funded Nanotechnology Centre for Doctoral Training at the University of Cambridge, has been named Startup Company of the Year at the *Business Weekly Awards*.

The accolade follows a US\$250,000 award in seed funding by the Bill and Melinda Gates Foundation's Saving Lives at Birth competition. The R&D phase will be matched by ARM Ltd, making it a total grant of US\$450,000.

SimPrints' biometric fingerprint scanner accurately connects people to their digital records via a simple fingerprint scan – thus solving a long-standing problem in the delivery of mobile services in healthcare in developing regions (see page 20).

Search engine: SimPrints

Science for a Connected Nation

In the modern world, everything is connected. Social media joins people across the globe; satellites tell our cars how to park safely; remote systems keep our electricity grid safe; computers predict global weather patterns; we use our phones to check our heart rate – and, if the internet sneezes, everyone could catch a cold. EPSRC's Chief Executive, [Professor Philip Nelson](#), explains how EPSRC is supporting science for a connected nation.

The connected world we live in depends on joined-up research to make it tick. As the UK's main investor in research and doctoral training in engineering and the physical sciences, EPSRC has developed a profoundly multidisciplinary portfolio of research and training – spanning academic disciplines and economic sectors; connecting people, things, data and the environment together in smart, safe and productive ways.

The research we support underpins and complements that of the other six UK Research Councils, as well as funding agencies such as Innovate UK.

To name but a few cross-disciplinary collaborations with other research councils, EPSRC-supported scientists and engineers are developing non-invasive imaging techniques for fine art research; devising sensors that help environmental scientists predict hotspots in earthquake-prone regions; creating the e-infrastructure used in social scientists' longitudinal studies; providing the data analytics tools needed in genomics and healthcare; inventing new medical imaging equipment to help surgeons save lives; and creating next-generation robotic and autonomous systems that are becoming essential across society.

We are also charting new research frontiers in disciplines such as Big Data Analytics, complemented by an approach to responsible innovation that ensures new technologies, and indeed ideas, are developed securely, ethically and legally.

By analysing Big Data sets, using Artificial Intelligence and semantic technologies, it is possible to identify new connections across society and the economy – from spotting business

trends that will help give the UK a commercial edge over its competitors to helping to prevent diseases and combat cyber crime.

The recently launched £42 million Alan Turing Institute, co-founded by EPSRC and the universities of Cambridge, Edinburgh, Oxford, Warwick and UCL, was set up to make sense of the extremely large and complex data sets that characterise Big Data. The institute is well placed to play a leading role in providing guidance on ethical, legal and technical issues to allow UK data science to develop quickly, appropriately and productively. This will help the UK gain a global competitive advantage across economic sectors and academic disciplines.

Driving the digital economy

Our lives are increasingly connected to the digital world. To harness multidisciplinary research and support doctoral training across this fast growing landscape, EPSRC leads the Research Councils UK (RCUK) Digital Economy theme, in conjunction with the Economic and Social Research Council (ESRC) and the Arts and Humanities Research Council (AHRC). The theme has a portfolio of 129 projects within a total investment of £170 million.

The research and doctoral training we support in this area is helping to ensure information technology becomes as commonplace as any other utility – technology so simple, useful, accessible and reliable that it becomes second nature (see pages 24-25).

A key research area is the so-called Internet of Things (IoT). In the not-too distant future, billions of things we take for granted in daily life, such as streetlamps and food packaging,

housing and public transport systems, will become connected to the Internet, many with the ability to sense, communicate, network and produce new information. We need to understand this phenomenon and be alive to its challenges and possibilities.

Our investments in the Internet of Things include numerous research projects and technologies (see pages 24-25), as well as dedicated centres of academic excellence, such as PETRAS (Privacy, Ethics, Trust, Reliability, Accessibility and Security) a new £9.7 million multidisciplinary research hub in the cyber security of the Internet of Things involving nine leading UK universities.

PETRAS works with over 60 partners from industry and the public sector and has received partner contributions of around £24 million. Featuring a strong social science component, PETRAS is part of IoTUK, an integrated, three-year, government programme that seeks to advance the UK's global leadership in IoT and increase the adoption of high quality IoT technologies and services throughout businesses and the public sector.

With Innovate UK and the Digital Catapult, the Digital Economy theme is also co-investing £45 million in six new multidisciplinary research centres focused on developing a suite of innovative digital technologies across UK society – from personalised digital health services to interactive media in education. The centres bring together over 150 university, industry and regional enterprise partners.

Research and training in Information and Communication Technologies

Continued on page 18

“Our investments underpin and complement those of the other six UK Research Councils, as well as agencies such as Innovate UK”

Continued from page 17

(ICT) is another priority for EPSRC, dovetailing with the Digital Economy theme and providing technologies vital to the prosperity of the UK, as well as the safety and wellbeing of its people.

EPSRC's ICT theme supports a £443 million research portfolio through 570 grants, helping to develop next-generation technologies in areas such as Artificial Intelligence, software engineering, cyber security systems, computer science, and the increasingly important research field of Robotics and Autonomous Systems (RAS).

To harness potential in this field, through our Engineering theme we have launched a national network for Robotics and Autonomous Systems. The UK-RAS Network provides academic leadership, expands collaboration with industry and integrates and coordinates activities at eight EPSRC-funded RAS capital facilities, four Centres for Doctoral Training and UK partner universities.

To name but two EPSRC-supported robotics research projects, scientists at Lancaster University are developing submersible remote-controlled machines to help accelerate clean-up at nuclear sites such as Fukushima. Elsewhere, University of Hertfordshire researchers have developed Kaspar, a minimally expressive humanoid robot, as a therapeutic toy for autistic children.

Tackling the cyber threat

The more connected we become, the more we are vulnerable to threats to our cyber security – both technological and human. In addition to our support for The Alan Turing Institute, through the ICT theme EPSRC has invested £5 million with Innovate UK in a £14 million cyber security research and training hub based at Queen's University Belfast (see page 50), focusing on cyber security for Smart Cities and the Internet of Things.

To develop the cyber security experts of tomorrow, we have set up two EPSRC Centres for Doctoral Training in Cyber Security at Royal Holloway, University of London and the University of Oxford. We also support

13 Academic Centres of Excellence in Cyber Security Research formed under the Research Councils UK Global Uncertainties Programme. Across the wider digital landscape, we support investment of over £40 million in EPSRC Centres for Doctoral Training in different areas of data science to ensure industry is provided with the data skills it needs.

Among many cyber security-related research projects we support, scientists at the University of Bristol are harnessing the mind-boggling potential of quantum physics to design unbreakable encryption codes into new products and services – thus pre-empting and thwarting possible criminal attacks (see page 40).

Joined-up infrastructure

For nations to thrive in the modern world, they need joined-up infrastructure – from visible structures like highways, railways and utilities to unseen systems, such as communications networks, traffic control systems, and energy storage and transmission.

EPSRC supports around 350 research projects that relate to infrastructure across engineering and physical sciences, helping stimulate growth and create jobs domestically and globally.

Acting on behalf of the UK Government, EPSRC is delivering a major £138 million capital investment programme to support our infrastructure and cities. The UK Collaboratorium for Research in Infrastructure & Cities (UKCRIC), involving 13 UK university partners, focuses on ways to make our infrastructure more resilient to extreme events, and more adaptable to changing circumstances. It also aims to make services more affordable, accessible and useable to the whole population.

Another long-term EPSRC investment, the Infrastructure Transitions Research Consortium (ITRC), focuses on understanding the bigger picture – how do things join up? It has developed the world's first national infrastructure system-of-systems model, which has

Continued on page 20

“The more connected we become, the more we are vulnerable to threats to our cyber security”

Thwarting e-crime: e-crime is estimated to cost £205 million every year in the UK retail sector alone. But in a move that could help put online fraudsters worldwide out of business, EPSRC-supported physicists at the University of Strathclyde and Heriot-Watt University are using quantum physics to crack down on internet fraud.

The systems which currently underpin the security of Internet transactions, known as digital signatures, are founded on complex mathematical formulae. These can be cracked and are therefore vulnerable to e-crime.

The team have used quantum technology to develop what is effectively an unbreakable digital signature. This prevents malevolent third parties from 'listening in' to the transaction – making hacking, cyber-fraud and theft near-impossible.

The process takes place without shoppers having to make changes to their normal security precautions.

Continued from page 18

been used by many organisations and government to analyse long-term investment strategies for energy, transport, digital communications, water, waste water and solid waste.

The ITRC's work has also been used by the Department for Transport to analyse the resilience of the transport network, National Grid to help plan the integration of solar energy, and by Lockheed Martin to analyse the risks of cyber attack on electricity substations. Now in its second phase, the ITRC is also informing the Committee on Climate Change in its 2017 Risk Assessment.

Smart cities

In the UK, 80 per cent of us live in urban areas and 61 per cent of UK growth is generated by city regions. In addition to capital infrastructure investments such as UKCRIC, EPSRC-supported research into tomorrow's cities includes the £6 million Digital City Exchange at Imperial College London, which is researching how to digitally link a city's utilities, such as energy, transport and waste, in such a way that enhances the quality of life in our cities; maximises new business opportunities and enables valuable new services to emerge.

We are also co-investing in the Urban Living Partnership (ULP), a unique project involving all seven UK Research Councils and Innovate UK aimed at forging a new blueprint for urban regeneration, initially through five city pilot projects.

The ULP is harnessing talents from across the research, innovation and civic sectors to develop solutions to interconnected challenges such as crime and social housing and to harness commercial opportunities arising from them.

Further afield, researchers from UK and Chinese universities are collaborating on four new projects to work towards achieving low carbon cities in the UK and China. The projects will receive over £3 million from EPSRC, with matched equivalent resources from the National Science Foundation of China (NSFC).

In the commercial sector, Intelligent Energy, a company formed to commercialise EPSRC-supported research at Loughborough University, recently signed a billion-dollar deal to supply India with sustainable hydrogen fuel cell-based power to 27,000 telecoms towers across the country.

A healthy nation

The new age of connectivity brings with it new challenges to UK and global health and wellbeing, and new opportunities to predict and manage healthcare problems. We need only look at the Ebola outbreak of 2014, or more recently the Zika virus, to understand the threats to humankind generated by the global movement of people around the globe. Correspondingly, an ageing population poses clinical and economic challenges to the UK as a whole.

Through our Healthcare Technologies theme, we are investing £347 million in research spanning engineering and the physical sciences, and supporting 340 research grants.

A core strand of the Healthcare Technologies portfolio focuses on transforming community health and care through self-management, particularly through the use of smart connecting technologies such as mobile phone apps and novel sensors.

Key investments include £32 million in three Interdisciplinary Research Collaborations (IRCs) investigating the use of sensing systems in healthcare. Among these, the i-Sense project, led by UCL, is developing disposable sensor chips for mobile diagnosis of HIV, and smartphone-based diagnostics to detect pathogens such as MRSA for use in hospital and community settings. It is also working with Google and Harvard University to develop a new generation of global early warning systems to identify disease outbreaks.

Meanwhile, the Sphere IRC, led by the University of Bristol, is developing sensors for the home to diagnose diseases and help manage health and wellbeing – enabling more patients to live independently at home. The third
Continued on page 22

“A society's infrastructure has many layers – from visible structures like highways and utilities, to communications networks, energy storage and transmission, to name just a few”



The photograph on this page, of a doctoral student preparing monitoring equipment before it is installed in an abandoned rail tunnel, was taken by Dr Phil Catton, from the EPSRC-supported Centre for Smart Infrastructure and Construction (CSIC) at the University of Cambridge – which is developing an innovative and impactful research portfolio. The picture, which has been cropped for publication, was a runner up in the 2014-15 EPSRC Science Photo Competition.

Phil writes: "Once this tunnel carried four million letters a day across London. Today, the Post Office Tunnel is a relic from an era before e-mail, and has been mothballed since 2003. Despite its city centre location, it is deserted and eerily quiet.

However, the tunnel is perilously close to the new Crossrail tunnels – part of Europe's biggest construction project to build a new high capacity railway for London and the South East. Researchers at CSIC are using innovative measurement systems to monitor the behaviour of the old, cast iron tunnel as the Crossrail construction takes place.

The 'Mail Rail' also runs just beneath the Central Line – damage to the tube network could have catastrophic knock-on effects. However, as it is of a similar design to much of London Underground's network, the real benefits from the systems this PhD student is installing come from learning how similar tunnels behave during nearby construction. This will help engineers plan future projects and continue to grow our capital safely and efficiently."

Turn to pages 44-49 for a gallery of winning images from the latest EPSRC Science Photo Competition.

Continued from page 20

IRC, Proteus, led by the University of Edinburgh, is developing technology that will sit next to the bedside of critically ill patients in the intensive care unit. This equipment will monitor conditions deep inside the patient's lung in real time, enabling doctors to diagnose disease more accurately and select the correct drugs to treat the patient should lung infection occur.

Mathematics in healthcare

Mathematics underpins all technology, and is crucial to the algorithms and systems underpinning all computer modelling. EPSRC is investing £10 million in five UK-wide Mathematical Sciences in Healthcare Research Centres to help doctors gain a better understanding of diseases, make faster diagnoses, plan better, more targeted treatment for patients and predict disease progression in individuals and populations.

EPSRC is also part of a consortium of 10 partners in the Farr Institute of Health Informatics and Research, led by the Medical Research Council, which aims for the UK to become a global leader in health data science by accelerating the understanding of disease and improving health and care for patients and the public.

Pioneering the e-infrastructure

In the modern era, next to the human brain, computers are the most important tool for scientific research. Researchers from across disciplines – from art historians to climate scientists – rely on a connected e-infrastructure that enables them to connect with computers beyond the reach of their own labs. It also helps them move and analyse vast amounts of data, as well as access, develop and utilise the software they need for their work.

Through strategic investments stretching back over a quarter of a century, EPSRC has administered some of the UK's fastest computers, including the current service, ARCHER, the national High Performance Computing (HPC) facility at the University of Edinburgh. Funded by EPSRC and the Natural Environment Research Council (NERC), the ARCHER

supercomputer is run on behalf of all the UK Research Councils and stakeholders, crunching through two thousand trillion calculations every second. In addition to its core functions, ARCHER's outreach programmes of software development, training courses, public engagement and encouraging women into HPC are making headlines.

Since 2011, we have invested £8 million across the UK in five regional centres of computing excellence, which enable academics to locally access high performance computing. Funding for these centres has been matched by host institutions and collaborators; and EPSRC plans to invest a further £20 million to support its portfolio of HPC centres of excellence.

EPSRC also founded and continues to support the Software Sustainability Institute, which, with new partners BBSRC and ESRC, helps researchers from across disciplines accelerate their research through the use of reliable, reusable and reproducible state-of-the-art software. We have also invested in training through the Research Software Engineers Fellowship, enabling skilled software developers to work with scientists and engineers.

Joining the dots

We are all connected. To make sure that some aren't more connected than others, EPSRC takes a proactive approach to diversity and equality and is committed to driving out conscious and unconscious bias. Among ongoing initiatives, we will ensure that by 2020 EPSRC's Council, its governing body, has a 50-50 gender split; the same will be true for our Strategic Advisory Network.

Together with Resilience, Health and Productivity, Connectedness underpins UK prosperity. Indeed, we focus our investments around these outcomes. By working across disciplines, and by encouraging the development of a holistic understanding of the challenges and opportunities of a connected ecosystem, EPSRC is helping drive UK research and innovation forward, making sense of the complex world in which we live.

"The new age of connectivity brings with it new challenges to global health and wellbeing"

Right: A family of forest-dwelling Mbendjele Pygmies in the Republic of Congo learn to use a smartphone for the first time.

The phone has been equipped with an app that enables them to map their local resources and record evidence of illegal logging activity, following which the data can be transmitted via SMS to the local authorities.

The app has been designed for users who have no textual, numerical or technological literacy, as although much of the world is becoming increasingly connected, few (if any) people in this community will have seen a mobile phone before.

Unlike regular smartphone apps, the interface is entirely picture-based and has been designed and developed by UCL's EPSRC-funded Extreme Citizen Science (ExCiteS) research group, together with the communities who are the intended end-users. This process ensures that it is both usable and relevant to their needs.

This photograph and summary is by ExCiteS researcher, Gillian Conquest, who won the People category in the 2013 EPSRC Science Photo Competition. The winning images from the 2015/16 competition are featured on pages 44-49.



Joined-up thinking

From eco-friendly mobile phone masts to Artificial Intelligence systems that can identify cancer cell types, EPSRC-supported researchers across the UK are designing new technologies for a smarter, safer and more connected world.

Signal success

An EPSRC-supported team at the universities of Bristol and Cardiff have made a breakthrough in the design of signal amplifiers for mobile phone masts. Their research, which involved development of sophisticated new computing algorithms for incorporation into the amplifiers' inbuilt electronic management systems, could lead to a massive cut in the load on power stations and reduce CO₂ emissions.

If 10,000 base stations in the UK were fitted with the new amplifier, it is estimated that the total saving would amount to half the output of a mid-size, 400MW power station. There are currently around 50,000 phone mast base stations in the UK, so the potential energy and carbon-saving benefits could be even greater.

The team are now working with a major electronics company to take some of the project's key findings towards commercialisation. Follow-up funding has also been secured through an EPSRC Impact Acceleration Award.

AI detects cancer

EPSRC-supported researchers at Swansea University have developed a new method to identify different cell types – such as cancer cells – by training computers to detect them using Artificial Intelligence (AI) algorithms.

Principal Investigator, Professor Paul Rees, says: "To identify different types

of cell, for example cancer cells, within a healthy cell population, scientists usually have to use special fluorescent stains that bind to components of the cell to allow detection using microscopy. Unfortunately these stains alter the cell's behaviour and modify the system being investigated.

"The new method we have developed avoids the use of these stains using AI machine learning algorithms. The researchers train the algorithm to recognise the specific cell of interest by giving examples of the cell to be identified.

"After learning what the cells look like, the computer algorithms can then identify the target cells in a population of previously unseen cells."

The new method is so accurate it is also able to determine the position of the cell within its life cycle.

Super-fast flood prediction

EPSRC-sponsored researchers from the University of Exeter have developed a smart computer model which can rapidly predict when and where flooding will occur. The model is 1,000 times faster than existing flood prediction systems and uses Artificial Intelligence to 'learn', in the same way that biological neural networks in the human brain process data.

Designed for urban areas, the system can provide instant updates as bad weather conditions unfold. The model uses

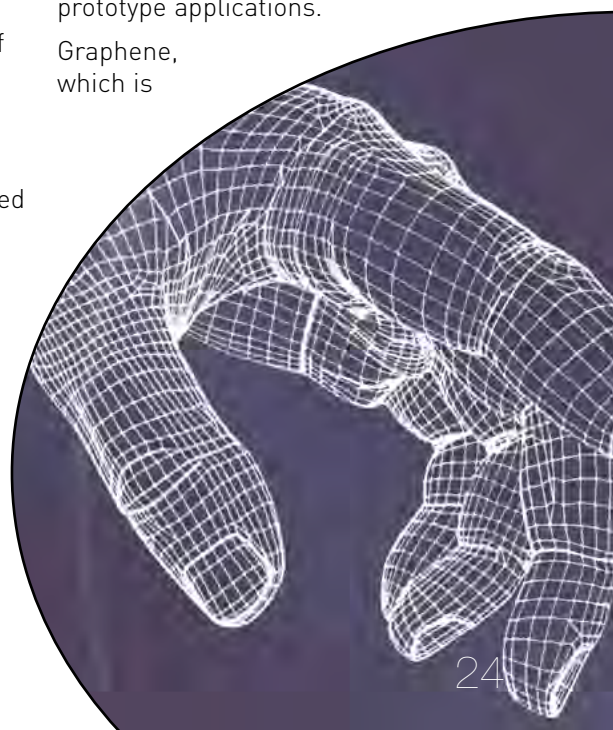
information about the drainage and sewage systems to predict the volume and flow of flood water in real time. Although not yet in general use, it is hoped the model will soon be rolled out nationwide.

Graphene blocks radio waves

EPSRC-supported scientists from Queen Mary, University of London and the Cambridge Graphene Centre have discovered that, in addition to its other unusual properties, 'wonder material' graphene can absorb electromagnetic radiation.

The team suggest that graphene could be used to secure wireless connections and improve the efficiency of communication devices. They have already started working on prototype applications.

Graphene, which is



effectively transparent, could be added as a coating to car windows or buildings to stop radio waves from travelling through the structure. This, in turn, could be used to improve secure wireless network environments, for example.

Donor exchange

EPSRC-supported researchers at the University of Glasgow have developed sophisticated algorithms which allow the NHS to help patients who require a kidney transplant, and who have a willing but incompatible donor, to exchange their donor with that of another patient in a similar position, in what is known as a paired exchange.

According to NHS Blood and Transplant, each kidney transplant saves the NHS £240,000 over 10 years – based on a comparison with the cost of dialysis over that time period, and taking into account the cost of the operation itself.

By enabling an increase of 67 new kidney transplants, the University of Glasgow researchers have potentially saved the NHS around £16 million over the next 10 years, with additional savings to come with each new three-way pairing identified.

Deep impact

Scientists at Imperial College London have developed quantum navigation technology that could allow submarines to determine their exact location without needing to surface, which conventional GPS systems require them to do.

The technology, which is accurate to one metre, has the long-term potential to be applied to planes, cars and even mobile phones. It might also be used for indoor navigation, where GPS cannot currently work, such as in multi-storey car parks, shopping malls, airports and tunnels. The global market for GPS systems is £17.5 billion.

On the rails

Technology for enhancing strength, stiffness and resilience in rail track, developed by EPSRC-supported researchers at Heriot-Watt/Edinburgh universities, has led to cost savings of at least £50 million in the UK and overseas.

The XiTrack technology, which is a unique geo-composite solution for ballast strengthening using a polymer compound, has reduced track maintenance by a factor of up to 40 and increased maintenance intervals from three-monthly to 10 years. Track speeds have also increased up to 125 mph in critical sections of the UK, Italy and Hong Kong rail networks.

The technology, developed with additional support from the Natural Environment Research Council (NERC) and the Technology Strategy Board (now Innovate UK), has been applied at many strategically important sites across the UK and has been used to stabilise the track bed at Clapham Junction – one of the busiest railway junctions in Europe with over 2,500 trains passing through the junction every day.

Apple goes vocal

US technology giant Apple has bought VocalIQ, an artificial intelligence spin-out company formed to bring EPSRC-supported research to market. The deal is estimated to be worth up to U\$100 million.

VocalIQ's software helps computers and people speak to each other in a more natural way using 'deep learning' to understand the context in which words are spoken.

The Cambridge-based company sells its natural

language database as a service to app developers, who can use VocalIQ as the personal assistant in their apps. The platform then stores and learns from all communication from app users to provide more intelligent and relevant answers in the future.

Smartphone cancer test

Dr Nuno Reis, from Loughborough University, has developed what is believed to be the first in a new generation of rapid detection tests for prostate cancer – with the help of smartphone technology.

The technology was used successfully to conduct a test for prostate cancer – the second most common cause of cancer in the male population worldwide – using a small sample of blood, a new affordable microfluidic test strip, and a smartphone camera.

Dr Reis says the point-of-care and over-the-counter test has the potential to "revolutionise the healthcare system", by making reliable lab and consumer test results accessible to everyone, even in remote areas of developing countries where laboratories are limited.

The study was co-funded by EPSRC and Capillary Film Technology Ltd, a UK SME.

Reducing rail delays

Researchers at the University of Birmingham have developed a train-mounted system that spots railway track faults before they cause passenger disruption.

The system, which is in use throughout the world, collects and analyses track data using bespoke instruments designed to be resilient to the harsh and variable environments of the railway.

Monitoring of 5,600 trackside point machines has led to a reduction of over 60,000 minutes in UK train delays in one year, equating to an average annual saving of £6 million.

The project has influenced the successful £7 billion Department for Transport order to Hitachi for new trains; and the researchers are currently advising on instrumentation systems for the proposed High Speed 2 railway line.

Quantum ballet

Professional ballet dancer and quantum physicist, Merritt Moore, describes her dual careers

My professional and academic journey has always been a balance – jumping from lab shoes to pointe shoes; from laboratory goggles to tutus.

I have juggled being a professional ballet dancer with the Zurich Ballet, Boston Ballet and English National Ballet while graduating in physics at Harvard, and pursuing a PhD in Quantum Optics at Oxford.

It's a double life that has sometimes caught me literally in awkward positions. I've been found doing the splits underneath my desk, or balancing with my leg above my head in full cleanroom gear, waiting for measurements. I've frantically put on and removed stage makeup in taxis as I rushed between two performances a day with the Boston Ballet Company to finish experiments at Harvard.

Now, during my PhD at Oxford, I focus on creating pairs of photons to be used for quantum information experiments. These photons exhibit fascinating properties of quantum mechanics, such as superposition – which is a phenomenon where, for example, very small particles can be in two places at the same time. A state I mirror in my dual careers.

I recently had the opportunity to combine these two seemingly disparate worlds for a Dance Your PhD contest, a light-hearted way for PhD students to share their research with the world through dance. With Nuno Fernandes, a professional salsa dancer, I danced a tango up and down a staircase in the physics department to demonstrate what's known as quantum entanglement – which occurs when pairs of particles don't interact independently, but rather as part of a whole system.

I feel very strongly that the arts and sciences are not mutually exclusive.

Creative thinking is required in science to explore unsolved questions and come up with innovative solutions, and yet often there is a stigma that science is a single-tracked pursuit that doesn't require creativity. I've worked hard to pursue both in the hope that other students can be encouraged to do the same. I hope to inspire students (and especially more girls) to study science by showing them that there is no 'standard' personality or path for doing so.

There are many ways to do this, and one example starts with a production I'm working on for the Barbican in 2017, called Zero Point, which is an immersive performance through the synergy of multiple art forms that gains inspiration from physics.

Merritt is a doctoral student at the Networked Quantum Information Technologies Hub at the University of Oxford, part of the UK National Quantum Technology Programme, a joint government, industry and academic initiative delivered by EPSRC and Innovate UK, in partnership with other stakeholders.

Merritt Moore in full flow. Among current dance projects, she is working on Zero Point, a synergy of multiple art forms that gains inspiration from physics, which premieres at the Barbican in 2017.



“There is a stigma
that science is a
single-tracked pursuit
that doesn't require
creativity”

Super brain

Can computers help unravel the mysteries of the human brain? They might if they think like one.

Professor Steve Furber CBE, from The University of Manchester, is on the case – and is creating a revolutionary electronic model of the brain using a million ARM microprocessors. The project is particularly close to his heart – not least because Furber co-designed the 75-billion-selling ARM chip, one of the most significant British inventions of the last 50 years.

Words and pictures: Mark Mallett

In 1981, Steve Furber, fresh from completing his EPSRC-funded PhD at the University of Cambridge, took the lead in designing the hardware for Acorn Computers' 1.5 million-selling BBC Micro. He was just getting started.

Furber went on to co-develop the revolutionary Acorn RISC Machine (ARM) 32-bit microprocessor, one of the most significant British inventions of the last 50 years, which became commercially available in 1987 and variants of which have since sold in their billions.

The ARM processor's key feature is its combination of high performance and very low power usage, making it highly suitable for use in mobile devices such as smartphones and tablet computers as it enables long battery life. Today it's estimated there are around 75 billion devices powered by ARM microprocessors, and that 75 per cent

of everything connected to the Internet is ARM-powered.

In 1990, Steve Furber left Acorn Computers to assume a professorship at The University of Manchester, where today he is ICL Professor of Computer Engineering, and Director of the EPSRC Centre for Doctoral Training in Computer Science. Since 1990 he has been supported by over 30 EPSRC research grants – worth more than £20 million.

A few months after Furber's departure from Acorn, the company's R&D team formed ARM Limited, today the world's leading semiconductor IP company. ARM's success, and Steve Furber's role in its good fortunes, are down to a very British combination of limitless ambition, shoestring resources, happy circumstance – and pure genius.

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Genesis

The story begins in 1977 with Steve Furber's doctoral thesis, in aerodynamics, funded by EPSRC's predecessor, the Science and Engineering Research Council. With a natural talent for electronics, Furber built and programmed a computer in his spare time, with the express purpose of using it to write his thesis on.

Crucially, he had built his machine using what he describes as "new-fangled" technology at its core – a microprocessor, bought mail order from America, which was leading the way in cutting-edge computer processing technology. He says: "The microprocessor, which is a computer processor on a microchip, is the engine that drives all modern computers, but the technology it uses was still in its infancy in 1977, and frowned upon by some enthusiasts, who still preferred to assemble their own processors using logic gates."

Furber's hobby led him to meet Chris Curry and Hermann Hauser KBE, the founders of Acorn Computers, one of the British companies at the vanguard of the 1980s personal computer revolution.

Furber subsequently moonlighted for Acorn while finishing his thesis. In lieu of payment, he recalls, he was given "bits of technology with which I could carry out my next project".

Enduring partnership

By the end of Furber's research fellowship at Cambridge, Acorn had secured the contract to build the BBC Micro, commissioned by the BBC as part of its Computer Literacy Project. Furber's partner on the project was software engineering genius, Sophie Wilson, whom he first met at an informal electronics club night at the University of Cambridge, and who created the Micro's programming language, BBC BASIC. It was the start of a remarkable partnership.

Furber says: "We were up against the clock, so the machine that went on sale was actually based quite heavily on the design I'd been building at home for fun. It wasn't directly cut and paste,

but the principles of operation were the same." He keeps his first home-made computer on a shelf in his office at The University of Manchester.

Inspired by the US microprocessor revolution, and after a fact-finding trip to the US that helped shape their thinking, Furber and Wilson, now full-time employees at Acorn, set about designing their own processor from scratch, this time for a 'budget' desktop computer. How hard could it be?

Furber says: "Hermann Hauser was very confident we would succeed, and identified two advantages over the likes of Intel and Motorola, the first being no money and the second being no people.

“**Hauser said we had two key advantages over the likes of Intel – no money and no people**”

"Actually that isn't too far from the truth. We really had no other option than to keep things simple. First, the processor had to be reasonably cheap, so we chose to encase it in plastic, which cost 50 cents. A ceramic package would have cost 10 dollars. We also had to make sure the processor didn't use much power – otherwise it would have got too hot, and the whole thing would have malfunctioned."

Powered by thin air

On 26 April 1985 they activated the prototype for the first time. It worked – but the team were baffled when they discovered the processor's power supply had failed, meaning it appeared to be running on thin air.

Furber says: "It turned out the processor was being powered by the tiny amounts of energy it could gather from the signals of the devices connected to it. We had intended it to be used in a faster desktop computer, but this was the first inkling we had that the

processor was suitable for more than one application, such as in a mobile device. Low power wasn't a target. It was a consequence of the simplicity."

At launch, in 1987, the media were incredulous –and sales were disappointing. Salvation came in the form of Apple Corporation. Furber says: "Apple could see we had the basis for very small, low power technology, and so used our processor at the heart of its Newton PDA, an early forerunner of the iPhone and iPad."

Acorn's deal with Apple allowed its R&D team to spin off into ARM Ltd, in late 1990, just months after Furber's departure. Despite the Newton's brief lifespan, it had been influential, and in the mid-1990s the ARM processor was chosen by Nokia for its mobile phone handsets. The rest is hi-tech history.

Focused business model

Key to ARM's success is its highly focused business model, which has effectively remained unchanged since launch. ARM designs its chip technology but allows other firms to fabricate its processors, thus keeping its overheads and liabilities relatively low. ARM also charges an upfront fee. Furber says he has no regrets about leaving Acorn to become an academic, and enjoys the freedom that university-based research gives. He also retains close ties with ARM.

He says: "In the UK there is a general feeling that we Brits do the research then the Americans do the exploitation and make the money. I like to think that with the ARM processor we showed the perfect reversal of that. We took US research and turned it into commercial success."

In July 2016, ARM Holdings' Board recommended the company's acquisition by Japanese technology giant Softbank, which has valued it at £24.3 billion. Softbank has provided assurances to at least double UK employee headcount; preserve the ARM organisation and senior management; and retain the partnership-based business model.

The companies say the transaction will enable the combined group to 'fully capture the Internet of Things opportunity'. *Continued on page 32*

If it ain't broke... Steve Furber with the home-made computer he built as a PhD student to write his thesis on. When he came to co-design the 1.5 million-selling BBC Micro computer, he drew heavily on his student creation, which he keeps on a shelf in his office at The University of Manchester.



“For an android robot to fully emulate the workings of the human brain it would need a nuclear power station in its head just to keep the computer going”

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Breaking new ground

But what does a microchip designed 30 years ago and which you can buy today for tuppence have to do with cutting-edge 21st century academic research into the nether regions of the human brain? The answer, in a word, is power.

In a world increasingly dependent on super-powerful but energy-hungry computer processors, Steve Furber is at the forefront of several pioneering international research projects, including a number of academia/industry ‘Grand Challenges’ set by EPSRC to break vital new ground in global computing.

Much of Furber’s research revolves around the challenges, opportunities and potential applications offered by many core computers.

We already use dual, quad, and octa-core technologies in our laptops, tablets and smartphones, but the potential of ‘embedded’ multi-core technologies grows hugely as the number of cores increases; and will lead to ultra-powerful portable devices and super-smart technologies used in everything from ‘predictive’ traffic lights, intelligent MRI scanners, and autonomous systems such as driverless cars and nominally ‘clever’ domestic robots.

Furber says: “The new generation of embedded systems will change the way we work, do business, shop, travel, and care for ourselves through a wide range of applications where low energy consumption and reliability are central.

“Ultimately, these systems will shape the emergence of a new digital society for the 21st century.”

A key area of focus for him and his team is what is known as massively parallel computing, where a large

number of processors simultaneously perform a set of coordinated computations in parallel with each other. Unfortunately, as the number of processors grows, so do the challenges, such as finding ways to lengthen a chip’s lifetime before a ‘hard’ fault occurs, and ensuring the software can run glitch-free. Stability and sustainability are the watchwords.

Grand Challenges

Recent EPSRC grants have focused on a range of interrelated Grand Challenges through which researchers are tackling everything from developing pocket-sized supercomputers, to creating ‘intelligent’ prosthetics by interfacing living organisms with electronics. The most ambitious of these projects – creating an electronic brain inspired by how our biological brains function – sees Steve Furber and his team taking bold steps towards the development of an extremely powerful computing concept. Dubbed SpiNNaker (Spiking Neural Network Architecture), it is radically different from anything that currently exists.

SpiNNaker, largely funded by EPSRC, is based on a computing platform made up of a million ARM microprocessors, aligned in parallel, which emulates the way brain neurons fire signals in real time. Capable of modelling up to a scale of one per cent of the human brain, it is the first low-power, large-scale digital model of our brain functions. With it researchers will be able to accurately model areas of the brain and test new hypotheses about how it might work.

SpiNNaker is an integral part of the €1 billion Human Brain Project, a major European initiative involving over 100 universities and research centres to develop an ICT-based research infrastructure to enable scientific

and industrial researchers globally to advance knowledge and work together in the fields of neuroscience, computing and brain-related medicine.

The team hope that the lessons learned from SpiNNaker, which is already available on line through the Human Brain Project, will help develop powerful new tools to treat conditions and diseases like Depression and Alzheimer’s. They also hope it will help pave the way for a new generation of ultrafast, energy efficient chips.

Absolute power

Power, again, is key; and a core goal for Furber and his team is to reveal how the brain is able to do so much while consuming so little energy. He says: “The human brain runs at about 20-25 Watts, the same as a low-power light bulb. We can’t get close to this.

“For a full-scale computer model of the brain we’d be looking at a machine that consumes tens of megawatts. You won’t be building that into your walking, talking Android robot any time in the foreseeable future – it would need a nuclear power station in its head just to keep the computer going.

“There are interesting parallels between the development of the original ARM chip and SpiNNaker, the intellectual property for which has been made available by ARM Ltd to aid design and manufacture. Both have to consume under a watt of electricity and both must be encased in a plastic package. Both designs are very much driven by a baseline of simplicity, albeit on vastly different scales.”

The final word goes to Mike Muller, ARM Ltd’s Chief Technology Officer. He says: “Steve is part of the ARM family, so this project is a perfect way to partner with him and The University of Manchester, and for ARM to encourage leading research in the UK.”



ARM POWERED



SpiNNaker-5
DMC-STJ Aug 13

SAKCL-8-24W-6
KCL-1339



Setting sail: The 864-processor SpiNNaker board. The SpiNNaker computing platform incorporates one million ARM chips.

Driving ambition

Researchers at the EPSRC Centre for Sustainable Road Freight (CSRF) at the University of Cambridge, working with Waitrose, have developed a new trailer design for articulated vehicles that makes the vehicle more aerodynamic – cutting fuel consumption and pollution by around seven per cent.

Stemming from early EPSRC-supported research at Cambridge by a student team led by Professor Holger Babinsky, the blueprint for the new trailer design was developed through systematic wind tunnel testing aimed at optimising aerodynamic performance, followed by further testing supported by the Technology Strategy Board (now Innovate UK) and

the Office for Low Emission Vehicles (OLEV), as part of a programme to encourage road haulage operators in the UK to buy and test low carbon commercial vehicles.

To accurately gauge how the truck moves through the air, the CSRF team used a novel water tank test facility. Moving scale models at different speeds through the water, researchers used lasers to accurately measure the displacement and flow of the water around the vehicle. To help visualise drag and rolling resistance, the team simply added milk to the tank. Teabags were an optional extra.

The centre's Director, Professor David Cebon, says: "Every year, truck drivers

clock up around 16 billion miles on UK roads. That's a lot of driving – and a huge amount of fuel and CO₂ emissions.

"A vital feature of our work at the CSRF is our close links with the freight industry, which has invested £1.4 million in an industrial consortium comprising freight operators such as DHL, John Lewis Partnership, Tesco and Wincanton, as well as vehicle industry partners including Firestone, Goodyear, Haldex and Volvo. These companies help set the research agenda as well as the pace in the adoption of results.

"With fuel representing, on average, 45 per cent of operating costs, and

To accurately gauge how the truck moves through the air, the CSRF team used a novel water tank test facility – deploying lasers to accurately measure the displacement and flow of water around the vehicle.



with aggressive emission-reduction targets set by government, the road freight industry has substantial incentives to minimise its use of energy.”

A key aspect of the research was the need to optimise the design of the trailer without impeding performance or capacity. The result was a tapered ‘boat-tail’ solution at the back of the trailer which cuts into its insulation rather than lowering the door height. The capacity of the trailer is not affected and the number of loadable cages remains the same.

To reduce drag further, the ride height was lowered and folding side skirts were fitted to cover half the

wheels. The underside of the trailer was smoothed, making it more aerodynamic and helping air flow out from underneath. Up front, the tractor unit was fitted with a matching aerodynamic kit.

With the design optimised, a prototype vehicle was built and successfully tested on the test track. The results speak for themselves: 14 per cent reduction in aerodynamic drag coefficient and a three to six per cent reduction in rolling resistance coefficient for the modified vehicle; in comparison with the unmodified vehicle. This equates to a real-world seven per cent reduction in both fuel consumption and CO₂ emissions when

driving the modified vehicle at highway speeds. This saving was verified by Waitrose in back-to-back highway tests against an unmodified design.

Waitrose has already added 36 of the modified trucks to its fleet. UK bakery company, Warburtons, will specify the new design for all future purchases.

David Cebon says: “The research not only demonstrates a successful collaboration between academia and industry; it is also important evidence for Government which, under the 2008 Climate Change Act, has committed the UK to reducing its emissions by at least 80 per cent by 2050.”

www.csrf.ac.uk

Only connect

Researchers at Imperial College London are rewriting the rule book on the way we use electricity.

Words: Matt Shinn

“The trouble with electricity,” says Professor Tim Green of Imperial College London, “is that it is the ultimate in perishable goods. As things stand, you have to sell electricity pretty much as soon as you produce it; there’s no cost-effective way to warehouse it or store it.”

So, until now, the way we’ve run our power system has been to use fast-acting power generators, running on fossil fuels, to react quickly to demand. With every spike in energy use (say when the nation turns on its kettles during half time in a big football match), gas and coal-burning power stations are fired-up to deal with it.

The clean energy challenge

The trouble is, some two-thirds of our existing power stations (most of them of the old fossil fuel type) are due to close by 2030, as they reach the end of their working lives. If we’re to switch to using cleaner forms of energy, as a replacement for these dirty old power stations, we’re faced with some problems. Wind and sunlight are unpredictable, so the electricity supply from turbines and solar panels can’t be relied upon. Nuclear power stations need to operate under constant

conditions, so they also can’t respond quickly when there’s a sudden spike in demand.

Internet of Energy

For Tim Green, who is Director of the Energy Futures Laboratory at Imperial, there are three main ways in which we could get round these problems, which seem to limit our ability to make use of greener energy. “First,” he says, “we can try to ensure that demand isn’t king. Can we make demand respond to supply instead?”

It’s known as demand flexibility: the idea that, in a world of Web-enabled household appliances, you could create an Internet of Energy, with your washing machine or fridge able to talk to the power network it’s connected to. At times of high demand, a computer belonging to your energy provider would contact your freezer, say, and ask it to power down for a while: being well-insulated, a few minutes or so shouldn’t make much difference. Then when supply is plentiful (when the sun is shining, or the wind is blowing), your energy provider’s computer might ask your washing machine if it wanted to turn on, to make the most of cheaper power.



Professor Goran Strbac



Professor Tim Green

Multiplied across millions of households, this demand flexibility would mean that fewer conventional power stations were needed to meet demand, and that renewable energy could be incorporated more easily into the network.

Another solution would be to become much better at storing energy from intermittent renewable sources such as wind and solar. Storage technology is accelerating rapidly, and the UK has the potential to become a world leader in it.

Finally, we could make life easier for ourselves by connecting our power network to those of our European neighbours, smoothing out supply and demand between us. Better

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interconnection could give us access to cheap, green power supplies such as those of Norway or Iceland.

Smart power

This three-pronged approach, of greater interconnection, better storage, and increased demand flexibility, was the basis of a report produced in March this year by Professor Goran Strbac, who is also a member of the Power Systems research team at Imperial. The report was produced for the National Infrastructure Commission (NIC), which has been set up to help with long-term decision making regarding the UK's infrastructure.

The Smart Power report estimates that by 2030 the UK could save up to £8 billion a year, as well as meet its 2050 carbon targets and secure its energy supply, by bringing about a smart energy revolution. By focusing on interconnection, storage and demand flexibility, the report argues, these benefits could be gained without the need for much more infrastructure, which would require huge amounts of public spending.

As well as advising the government, together with colleagues in other universities the Imperial team have been helping some of the big power generators and networks companies to make decisions around investment in infrastructure.

Advising an industry

Since 2008, the team have assisted National Grid in defining new investment affecting £3 billion worth of network assets now approved by the regulator. They also provided tools to develop the first offshore networks design standards, saving an estimated £500 million by 2013 and leading to a projected overall saving of £1-2 billion by 2020. In addition, they've helped energy infrastructure company Alstom to design a new generation of High Voltage DC converters for offshore wind generation. They have also enabled UK Power Networks to think differently about the future.

Barry Hatton, UK Power Networks' Director of Asset Management, says:



"Using the innovative Imperial model, we have estimated that more than £130 million could be saved through the application of demand-side response, dynamic rating technologies and various active network management techniques, and we have included this in our business plan."



The message is consistent: smart technology enables existing infrastructure to be used much more intensively, which works out much cheaper than building infrastructure from scratch.



Opportunity knocks

Goran Strbac says: "There's no question that without EPSRC, without the years of fundamental research, there's no way that all this would have happened..."

"The Smart Power report, for example, used evidence based on models we produced under an EPSRC-funded Grand Challenge project. Developing these finer-grained models took a lot of sleepless nights, but thanks to EPSRC, we were able to do it."

Tim Green is like-minded. He says: "If the smart power revolution is to become a reality, EPSRC-funded research will be at the heart of it, in many different guises."

Looking ahead, Goran Strbac concedes that managing the UK energy system will be a challenge. But there are enormous opportunities too, not just to give the UK an efficient, flexible and secure energy infrastructure, potentially saving billions of pounds, but also for the country to take the lead internationally in the kinds of innovation that are set to transform the world electricity market. And that means not just developing new hardware, but new forms of system management and new business models, too.

Professor Strbac says: "Provided that we keep developing our knowledge base, the UK can lead the world in the smart power revolution, helping to bring jobs and investment into the country, at the same time as cutting energy bills for consumers."

"If the smart power revolution is to become a reality, EPSRC-funded research will be at the heart of it, in many different guises"



Fossil fuel power stations like this coal-fired station in Ferrybridge, Yorkshire, are due to close by 2030. The Imperial team are proposing radical alternatives as the switch-off nears.



BBOXX

BBOXX, a company formed by students at Imperial College London to tackle the challenges and opportunities arising from unreliable electrical supplies within the developing world, drew its technical inspiration from EPSRC-funded research at Imperial involving Professors Tim Green and Goran Strbac. Their expertise

in photo-voltaic integration and techno-economic analysis helped pave the way for the development of off-grid energy kiosks for electrification in rural Africa, first set up by e.quinox, a student-run charity at Imperial. BBOXX took the concept further.

Energy kiosks offer basic electricity to local communities, and can be life changing for off-grid villages. They also

help create local jobs. Customers pay to borrow a BBOXX unit from the 'owner', and the amount depends on their needs.

By providing households with off-grid electric lighting, children can do their homework and families can run a business without incurring threats to their health by paraffin smoke. In turn, BBOXX has created a sustainable non-subsidised business model.

BBOXX now designs, makes and distributes innovative solar power systems. Easy-to-use solar kits power lights and phone chargers in individual homes, while larger solar installations can replace noisy, costly and polluting diesel generators used by businesses.

Since its formation in 2010, BBOXX has expanded rapidly from three founders to a global staff of 140. BBOXX products have already saved over a million dollars' worth of energy, and offset over 19,000 tonnes of CO₂.

The company is currently a partner in a five-year, £1.2 million EPSRC smart grid project tackling key global challenges such as those faced by developing countries suffering from an intermittent electricity supply.



Connected for success

A new generation of EPSRC-supported doctoral students and early career researchers are turning their bright ideas into commercial success through successful companies that are helping to make the UK a more connected and productive nation.



Quantum Base

Jonathan Roberts is on a roll. Fresh from winning the Grand Prize at the EPSRC-led ICT Pioneers awards in 2015 for his research into nano-

identification, he is commercialising his invention through Quantum Base, a spin-out company set up by his supervisor, Dr Robert Young, and Philip Speed.

The invention uses next-generation quantum nano-technology to 'brand' any object or product with its own unique identity, making it 100 per cent impossible to copy.

Each product is given a unique identity based on atomic-scale imperfections. In their quantum state, atoms,

which comprise the fundamental building blocks of matter, cannot be 'transmitted' or manipulated without being unintentionally altered.

Jonathan says: "By slimming digital fingerprints down to an atomic scale we've created devices that are not only smaller and cheaper but also fundamentally more secure than any other existing technology.

"Each device we've made is unique, 100 per cent secure and impossible to copy or clone."

Robert Young says: "One could imagine our devices being used to identify a broad range of products, and could be used to authenticate branded goods, for example, or SIM cards, or important manufacturing components. The possibilities are endless."

Jonathan was invited to the 66th Lindau Nobel meeting, an annual gathering

of Nobel Laureates. Held in Lindau Germany, the event gives some of the world's most promising scientists below the age of 35 the opportunity to meet 35 Nobel Prize winners.



Aesthetic Integration

Aesthetic Integration, a company co-founded by Dr Grant Olney Passmore,

whose doctorate was supported by EPSRC during a studentship at the University of Edinburgh, has won the UBS Future of Finance Challenge, a major international competition for entrepreneurs, start-ups and growing companies.

The UBS Future of Finance Challenge is a global open innovation competition

aimed at changing the way finance works and how banks meet their clients' needs. Aesthetic Integration won for its pioneering Artificial Intelligence technology, which automatically analyses financial algorithms for glitches, ultimately helping make financial markets safer, fairer and more transparent.

The company saw off 600 international entrants, picking up a cheque for US\$50,000 and a commitment from UBS to help it commercialise and scale-up its ideas and technologies.



Synaptec

Synaptec Ltd, a Strathclyde University company formed to bring to market research by Dr Philip Orr, a former EPSRC Doctoral Prize holder, whose doctorate was supported by EPSRC, is going from strength to strength.

The award-winning company, set up by Philip and two colleagues from the university, has developed sensor-based technology, originally designed for the oil and gas sector, that enables energy and telecoms companies to quickly isolate network faults, reducing the length of service cuts and minimising fines by regulators.

The system piggy-backs on existing fibre networks, thus minimising the cost of installing, expanding or enhancing sensor coverage on power systems. By gathering many different measurements on a single fibre, Synaptec is able to make protection and monitoring schemes simpler and more efficient.

Philip founded the company when working as a postdoctoral research associate at the University of Strathclyde in Glasgow. He was subsequently awarded an Enterprise Fellowship from the Royal Academy of Engineering, which led to a further £260,000 in funding from Innovate UK to

adapt the technology to meet industry standards for power systems.

In December 2015 Synaptec signed a partnership deal with ScottishPower, GE Grid Solutions, ABB and The University of Manchester to develop a smarter electricity network for consumers. The project is led by ScottishPower Energy Networks.



Dynamon

Dr Angus Webb, an EPSRC-supported researcher from the University of Southampton, has received a Royal Academy of Engineering Enterprise Fellowship to develop his start-up company, Dynamon.

Dynamon provides an online data analytics service to the road haulage industry, combining big data from vehicles with dynamic modeling and statistics to provide hauliers with tailored recommendations on ways to help them make the greatest savings.

Ahead of the commercial launch of its products, Dynamon is already working with Southampton City Council, First Group and Go South Coast to quantify the impact of fuel saving devices they are fitting to buses to improve city air quality. A significant number of hauliers have expressed early interest in the company's products.

Ultrahaptics



from investors to grow its business globally. The company's revolutionary technology is creating a new way to

Ultrahaptics, a spin-out company formed to bring to market technology developed with EPSRC support at the University of Bristol, has received £10.1 million backing

touch and feel devices – by removing touch from the equation entirely.

Using ultrasound it is possible to create the sensation of touch in mid-air – allowing the user to feel virtual objects without touching them, or wearing any special equipment. An array of small ultrasound emitters creates the feeling in the user's fingers, and is linked by software to a camera which sees how the hand is moving.

The effect of a touch sensation, known as haptic feedback, could lead to applications in many sectors including healthcare, manufacturing and gaming. In the future there could be no need for a keyboard or mouse.

If the success of the company weren't enough, Tom Carter – who co-founded Ultrahaptics alongside his PhD supervisor Professor Sriram Subramanian – has been named Young Engineer of the Year by the National Microelectronics Institute.

This follows his Rising Star – New Engineer of the Year award at *Electronics Weekly* magazine's 2015 awards, which recognise excellence in Europe's electronics industry, and the Top Picks Award from *Laptop Mag* for Best Enabling Technology.

Mark Spoonauer, Editor in Chief of *Laptop Mag*, says: "Ultrahaptics has developed something completely different; the ability to feel virtual objects in mid-air will revolutionise how we interact with our computers, automobiles and games. I cannot wait to see this integrated into real products."

The company's early development was supported by an EPSRC Impact Acceleration Account, and arose thanks to a decade of EPSRC-supported research into ultrasonic wave phenomena.

Complementary technologies have been developed by colleagues at the universities of Bristol, Bath and Dundee. Among a range of projects, they are using sonics to manipulate microparticles by what has been described as an invisible pair of hands. Carried to its illogical sci-fi extension, the technology could one day be used in *Star Trek*-style tractor beams.

Swinging wings

A multidisciplinary research team have developed and test-flown technology inspired by bat flight that could pave the way for a new generation of unmanned micro air vehicles (MAVs), which are increasingly used in a wide variety of civil and military applications, such as surveying remote and dangerous areas.

The team, from the University of Southampton and Imperial College London, created innovative membrane wings that work like artificial muscles – similar to how bats fly.

The researchers noted how bats vary the shape of their wings based on the wind's direction and speed. Thus the MAV's wing membrane's shape is constantly changed under varying wind conditions to optimise its aerodynamic performance, enabling the MAV to fly over long distances.

This approach typifies the team's methodology. Instead of a traditional approach of scaling down existing aircraft design methods, they borrowed the bat's biological technology to create a unique wing design that incorporates electro-active polymers, which make the wings stiffen and relax in response to an applied voltage.

By changing the voltage input, the shape of the membrane and therefore aerodynamic characteristics can be altered during flight, further enhancing their performance.

The wings have been developed through a unique combination of hands-on experimental work at the University of Southampton and computational research at Imperial

College London, with funding from EPSRC. The United States Air Force, through its European Office of Aerospace Research and Development (EOARD), provided additional support.

Professor Bharath Ganapathisubramani, from the University of Southampton, led the overall project. He says: "The combined computational and experimental approach that characterised the project is unique in the field of bio-inspired MAV design."

To inform and speed up the design process, the Imperial team built innovative computational models and used them to aid the construction of a test MAV.

Dr Rafael Palacios of Imperial's Department of Aeronautics, who led this aspect of the project, says: "No-one has tried to simulate the in-flight behaviour of actuated bat-like wings before, so we had to go back to fundamentals, develop the mathematical models and build the multi-physics simulation software we needed from scratch."

The Southampton team incorporated some of these findings into a 0.5m-wide test vehicle, designed to skim over the sea's surface and, if necessary, land there safely.

After extensive wind tunnel testing, the vehicle was put through its paces at a nearby coastal location.

The result is a micro air vehicle that is more economical to run than conventional MAVs. As it has no mechanical parts, it is also easier to maintain. The proof of concept wing will eventually enable flight over much longer distances than currently possible.

The next step is to incorporate the active wings into typical MAV designs, with deployment in real-world applications potentially achievable over the next five years.



The wings have been developed through a unique combination of experimental work at the University of Southampton and computational research at Imperial College London.



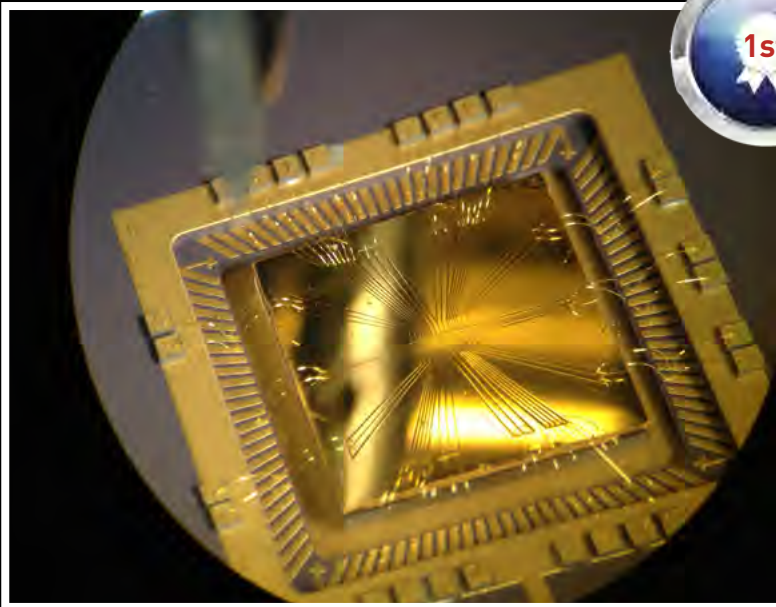
EPSRC Science Photo Competition 2015/16

The third annual EPSRC Science Photo Competition once again revealed the inquisitive and perceptive nature of the scientists and engineers supported by EPSRC, and gave them the opportunity to share their research through pictures.

The competition is open to all EPSRC-supported researchers and doctoral students and this year received over 200 entries into five categories: Equipment, Innovation, Eureka!, People, and Weird and Wonderful.

Not only are the 15 winning entries stunning images in their own right, they help to reflect the exciting research in physical sciences and engineering going on right now in the UK.



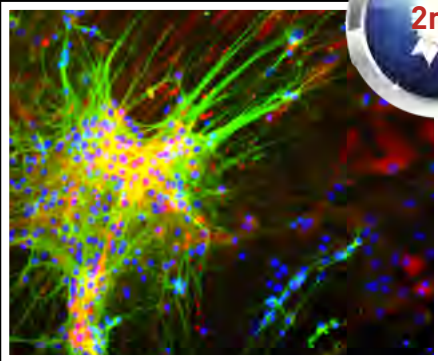


Eureka! and overall winner

Microwave ion-trap chip for quantum computation

This image of a gold chip used to trap ions for use in quantum computing, shows the chip's gold wire-bonds connected to electrodes which transmit electric fields to trap single atomic ions a mere 100 microns above the device's surface.

By Diana Prado Lopes Aude Craik, University of Oxford, with Norbert Linke, University of Maryland



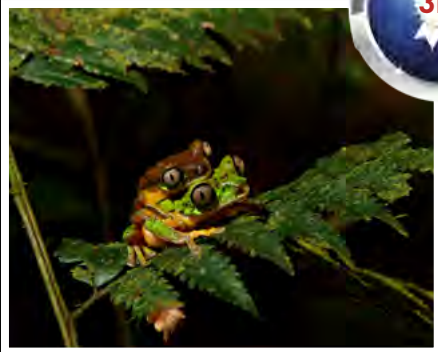
Curious neurons

This image shows the complexity of developing brain cells. Cells send protrusions to sense other cells and connect to them (in green).

This research aims to help identify the environmental elements necessary to grow stem cells for use in therapeutic treatments for people with Parkinson's and other neurodegenerative diseases.

By George Joseph, Keele University

Eureka!



Mating pair of critically endangered Costa Rican lemur leaf frogs

The lemur leaf frog is one of the rarest frogs in the world. The frog undergoes a rapid and distinct colour change most nights from pale green to dark brown, and is one of a small group of species that reflects strongly in the near infrared region, matching the reflection of the leaves it sits on beyond the visible wavelengths of light.

Seeing this pair in the same conditions, but different colourations, helped me to design new tests to better understand the unique optical properties of these frogs and the benefits they impart.

By Chris Blount, The University of Manchester

Eureka!

Innovation

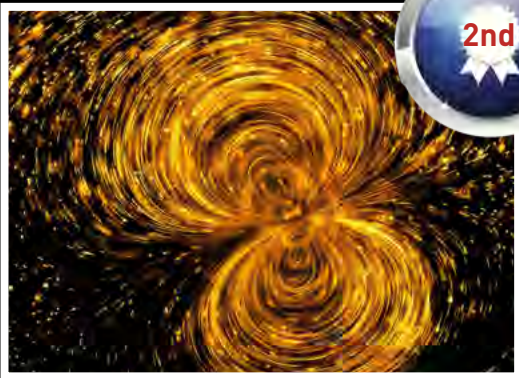


Where there is light, there is shadow

In this image, a piece of glass is being processed with a high power ultrafast, ultraprecise laser. This causes very bright plasma to form.

Extremely small, well controlled features can be created using ultrafast light pulses, which occur faster than heat can pass between the atoms of the material, resulting in very little heat damage to the surrounding areas. The laser was developed by the EPSRC Centre for Innovative Manufacturing in Ultra Precision.

By Jonathon Parkins, University of Cambridge



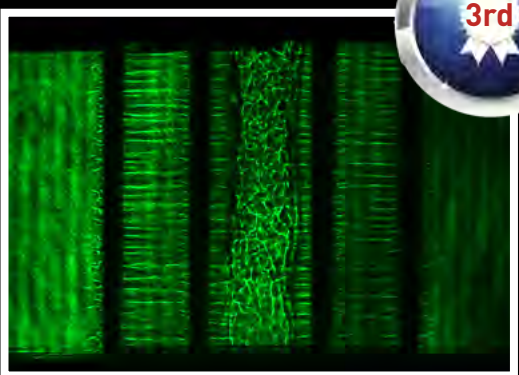
Fluid streams from an oscillating microbubble

In the presence of ultrasound, microbubbles oscillate by cyclically expanding and contracting. This causes the displacement of the surrounding fluid and the generation of a fluid flow, which takes the form of counter-rotating vortices.

In this photograph, fluorescent microparticles are added to the fluid in order to visualise the flow streamlines using a microscope. Importantly, the observed fluid flow could be exploited in therapeutic applications as a means of effectively transporting drugs towards desired locations within the body (for example, cancer tissues).

By Dr Dario Carugo, University of Oxford

Innovation



Laser image of a million degree Celsius plasma column

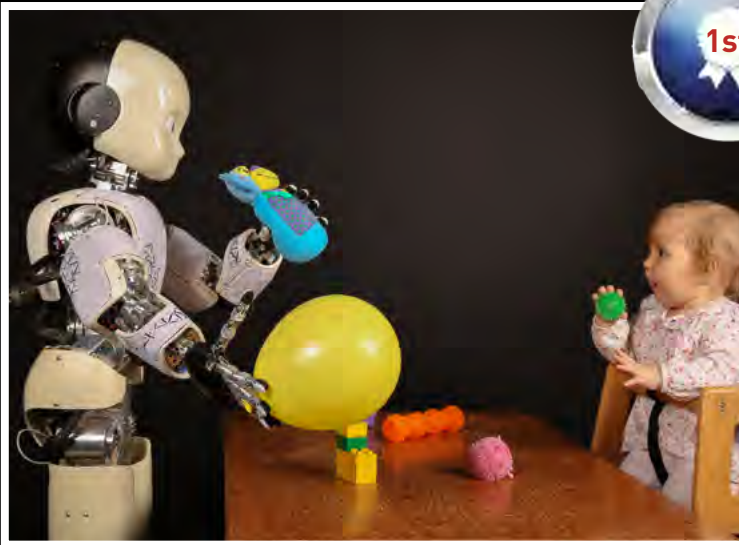
The central object is a plasma, formed when a huge one million Amp electrical current passes through a circle made of thin, upright carbon rods (the four vertical black bars).

The current heats the rods and hurls streams of plasma into the centre of the circle, forming a dense, rippling plasma column at a temperature of over one million degrees Celsius. Despite this violent formation process, this plasma is very stable, confirming a recent mathematical theorem important for computer simulations of plasmas.

By Jack Hare, Imperial College London

Innovation

People



iCub and the Tutor

During infancy, children learn from their experiences of the world around them. Researchers are modelling how young infants learn and are applying their findings to a humanoid iCub robot. The aim is to develop a mechanism for robots to learn about the basic physics of the world through understanding objects. Here, the iCub is learning about how to play from the baby.

By Dr Patricia Shaw, Aberystwyth University



Tunnelling into London's past

The key objective of this project is to investigate the potential for utilising heat accumulated in the surroundings of the London Underground tunnels for low carbon heating. In the picture, researchers are approaching the platform level, around 27 metres below the ground in a disused station at York Road, permanently closed since 1932.

The site is currently used only as a state-of-the-art technological testing facility. It is a fascinating ambience where many of the original features of the Tube stand the test of time.

By Akos Revesz, London Southbank University

People



Children welcoming earthquake engineering researchers to Lapsibot

EPSRC sponsored a number of academics to join the Earthquake Engineering Field Investigation Team's earthquake reconnaissance mission to disaster-stricken Nepal – one of five missions supported by EPSRC since 2010. While earthquakes are tragic for the affected communities they are an invaluable opportunity to understand what happens during these events and how to better protect communities from future events.

The smiles on the children's faces mask the devastation. Most of the houses in their village had totally or partially collapsed, and the earthquake had triggered many landslides, severely hampering relief efforts.

By Dr Sean Wilkinson, Newcastle University

People

Weird & Wonderful



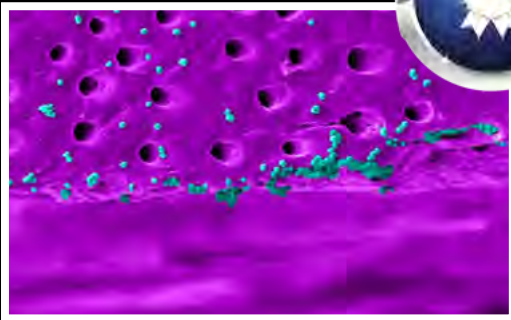
A spinning dancer

A beautiful rotating jet of viscoelastic liquid water resembling a spinning dancer that demonstrates the effect of adding a tiny amount of polymer to water and an example of fluid dynamics research at Imperial College London.

Here, this liquid jet was produced by adding a tiny amount of polymer into water, which made the liquid behave surprisingly differently from clean water.

The polymer molecules act as tiny springs in the mixture and tend to restore any deformation of the jet. This effect, together with the centrifugal force, makes the liquid exhibit a complex curved shape, like a graceful spinning dancer, while the surface tension produces ripples on the surface of the jet, just like the dress of the dancer in the wind.

By Professor Omar Matar, Imperial College London



On the Edge of Glory – sub-micron particles on the surface of a human tooth

This is a false-colour electron micrograph of the dentinal tubules in a human tooth, with sub-micron silica particles, about 800 nanometres small, hanging onto the edge of the surface.

We are investigating new ways of pushing antimicrobial particles into teeth to kill bacteria that invade the tubules during dental decay, thus preventing further damage to the tooth.

By Nina Vyas, University of Birmingham

Weird & Wonderful



Micro-metal flower

This is an electron microscopy image of a silicon (Si) wire with gold at the tip. Si wires are envisaged to find applications in future electronic integrated circuits, and are prepared in the chemistry laboratories using gases/chemicals and gold at temperatures above 500°C.

Upon completion of the process, by cooling down the experiment to room temperature the liquid metal solidified to appear as a flower-like morphology.

By Dr Dhayalan Shakthivel, University of Glasgow

Weird & Wonderful

Equipment

1st



Wowing the crowds

A spectacular 9.5 metre wave created to wow crowds at the EPSRC-supported FloWave Ocean Energy Research Facility at the University of Edinburgh, which twice a year opens its doors to the public.

The huge spike easily hits the ceiling above the water's surface, and is one of the highlights of the demonstration where a variety of 'party tricks' are shown alongside the test facility's more usual task of accurately replicating the ocean at scale.

By Stuart Brown, University of Edinburgh

2nd



Dark field light microscopy picture of a 40nm thick electrodeposited titanium oxide layer

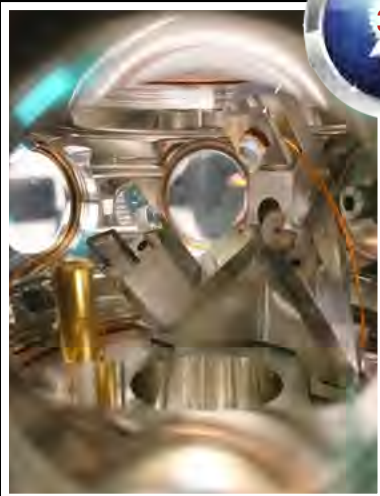
This research focuses on developing sustainable fuels, such as hydrogen, through water splitting reactions. This can be done by creating functional systems that incorporate biological and synthetic catalysts in nanostructured, often photoactive, materials such as titanium dioxide. Using photoactive materials will allow researchers to harness sunlight to drive the water-splitting reactions to produce the desirable hydrogen which can then be stored as fuel.

This process is carbon-free and it comes from an inexhaustible resource. Using dark field microscopy will bring better insights into the materials researchers are working on, and allow them to improve on the system.

By Katarzyna Sokol, University of Cambridge

Equipment

3rd



Investigating light-matter interaction using a high-finesse optical ring cavity and cold atoms

In this experiment we are studying the fundamental aspects of light-matter (photon-atom) interaction. We use potassium atoms which we trap and cool to a temperature very close to absolute zero. We probe those atoms with resonant light, to investigate the system's behaviour.

To enhance the probe light intensity, per photon, we use three high-reflectivity mirrors to form a triangular (ring) cavity. This way, a photon bounces about 700 times between the mirrors before it exits the cavity.

By having a large atom number [around 100,000] interacting with the cavity light, we enter a regime in which many interesting quantum phenomena can be observed. In this regime, light and matter cannot be thought as separate entities any more but rather as a combined system.

The photo shows the aforementioned ring cavity being used in our experiment which is placed in an ultra-high vacuum chamber.

By Andreas Lampis, University of Birmingham

Equipment

Professor Máire O'Neill

Research Director of Secure Digital Systems at Queen's University Belfast's Centre for Secure Information Technologies (CSIT), an Innovation and Knowledge Centre funded by EPSRC and Innovate UK.



What work are you engaged in at present, and what do you hope to achieve from it?

I'm involved in a range of different projects. I lead on the H2020-funded SAFEcrypto project, a major initiative that aims to develop a new generation of 'quantum-safe' technology for future ICT systems, services and applications.

Most data protection systems are based around cryptographic problems that conventional computing systems find difficult or impossible to solve. Quantum computers, however, which are predicted to become a reality in the next few decades, would find these problems fairly easy to solve. Thus, while a breakthrough in quantum computing would afford many advantages, it poses a serious threat to the security of commonly used security techniques.

SAFEcrypto will develop proof-of-concept demonstrators in the areas of satellite communications, public-safety communications and data analytics, as we seek ways to develop robust, safe and trustworthy solutions for the quantum computing age.

What are the greatest challenges facing your discipline?

A major research challenge is IoT device security, which looks at security systems for devices connected to the Internet, through the so-called Internet of Things (IoT). As the world becomes ever more connected, we will no longer have direct control over the vast number of IoT devices, either in terms of whom they communicate with or the information they hold and convey. Numerous attacks on IoT devices have already been demonstrated, and these attacks can have significant consequences.

As companies race to get IoT devices to market, many are overlooking security or build it in as an afterthought. A major challenge is how to address security and privacy needs at all layers of the IoT ecosystem – from the devices themselves to the technology that enables them to talk to each other, to the back-end systems providing secure storage and analysis of the large volumes of data generated.

IoT devices are often low-cost, low power machines that are restricted in both memory and computing power – which

pose specific challenges to keeping them safe and secure online. My team and I are investigating the development of low-power security technology you can build into the hardware of a device that is physically unclonable, theoretically even by the manufacturers themselves.

What does EPSRC support mean to you?

EPSRC support has been invaluable, particularly the EPSRC Leadership Fellowship. It has provided an excellent foundation for my academic research career. The fellowship has allowed me time to build my research reputation and led to opportunities to travel extensively to other university groups to build strong collaborative links. It also helped to accelerate my academic research career in a way that would otherwise not have been possible. EPSRC's continued support of CSIT, which has a focus on both high quality research as well as the commercialisation of research, has also been highly beneficial. Having the opportunity to research new ideas and then seeing these develop through to commercial products is very rewarding.

What do you consider your greatest personal and professional achievements?

My greatest professional achievement was obtaining my Chair position. My greatest personal achievement is balancing the demands of academia and a young family.

What are your main interests outside science?

Spending time with my children and travelling. I love to travel and experience new places and new cultures.

What have been your best and worst decisions – personally and professionally?

Applying for my first research fellowship was probably the best decision.

What's the best job you've ever had?

My research fellowships.

Who is your greatest influence?

Famous historical female engineers, like Edith Clarke – the first woman to earn a Master's degree in Electrical Engineering from MIT. In 1947 she joined the University of Texas at Austin as its first female professor in electrical engineering (and the first in the country). I became the first female professor in electrical & electronic engineering at Queen's!

If you hadn't become an academic, what would you be doing now?

I would be a veterinary surgeon. Growing up on a farm I loved animals, but I also loved mathematics. Therefore, I was considering studying veterinary science alongside electrical and electronic engineering at university.

What is the most important/invaluable tool you use to do your work?

At the beginning of my research career, I found the *Handbook of Applied Cryptography*, by Alfred Menezes, Paul van Oorschot and Scott Vanstone, to be an invaluable resource.

Who would be your ideal dinner guests?

Edith Clarke, the mathematician and cryptographer Clifford Cocks and current President of Ireland, Michael D Higgins.

If you were sent to a desert island, what three things would you take with you?

A desert island survival guide, a solar-powered desalination device and sun cream.

What keeps you awake at night?

Work deadlines and my young children.

In short

One of Europe's leading experts on digital security, Máire's research involves designing data security solutions for embedded devices and secure communications applications.

Máire held an EPSRC Leadership Fellowship from 2008-2015 and a Royal Academy of Engineering Research Fellowship from 2003-2008. She has received numerous awards for her work, including the Royal Academy of Engineering Silver Medal in 2014 and British Female Inventor of the Year in 2007. She is a Fellow of the Irish Academy of Engineering.

She has authored two research books; has had success in commercialising her research work and is also the inventor of a high-speed silicon security chip that is used in more than 100 million TV set-top boxes.

About EPSRC

Total value of EPSRC's research and training portfolio: **£4.6 billion**

Percentage of research portfolio that is multidisciplinary: **56%**

Total invested in research and training annually: **£800 million**

Organisations involved in collaborative EPSRC grants: **Over 3,553**

Percentage of research portfolio that is collaborative: **54%**

Total leveraged from users: **£1.1 billion**

About the Engineering and Physical Sciences Research Council (EPSRC)

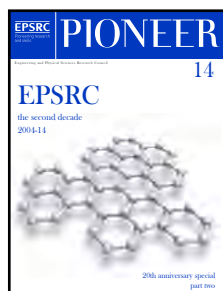
As the main funding agency for engineering and physical sciences research, our vision is for the UK to be the best place in the world to research, discover and innovate.

By investing £800 million a year in research and postgraduate training, we are building the knowledge and skills base needed to address the scientific and technological challenges facing the nation.

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