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ROYAL ACADEMY OF ENGINEERING

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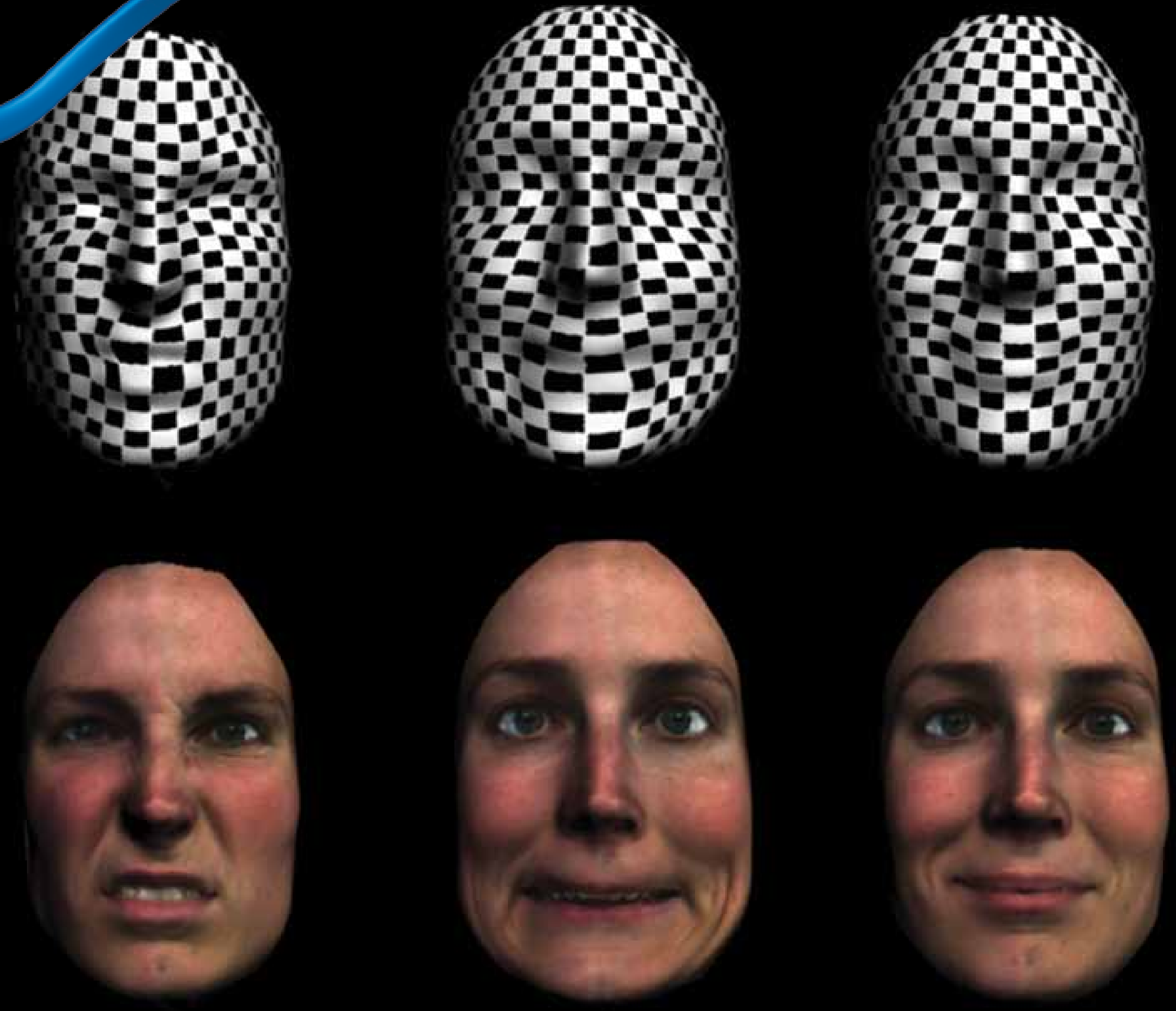
Researcher case studies



The Royal Academy of Engineering supports innovative engineering and funds the following research schemes:

Research Chairs – The scheme funds full-time professional appointments at UK universities to develop research programmes that will attract significant sponsorship and support from UK industry with the aim of strengthening industrial and academic links.

Senior Research Fellowships – These senior appointments in UK universities enable individuals with a wealth of postdoctoral experience to further their careers in engineering research. The scheme aims to create or enhance internationally renowned centres of engineering excellence.

Research Fellowships – These postdoctoral Fellowships help outstanding engineers develop their research careers at UK universities.

Research Chair in Emerging Technologies – This ten-year Chair enables an eminent research professor to have the freedom to develop technology that will ultimately grow into something of great industrial interest.

Enterprise Fellowships – The scheme aims to encourage aspiring entrepreneurs to commercialise technology-based business ideas from UK universities into spin-out companies. The Fellowships provide seed funding and salary support for 12 months, plus mentoring.

Industrial Secondment Scheme – These secondments enable engineering lecturers to spend up to 12 months in UK industrial organisations gaining experience and pursuing a research project that will benefit their teaching.

Distinguished Visiting Fellowships – The scheme allows an engineering department in a UK university to host a Visiting Fellow from an overseas academic centre of excellence for up to a month.

Research Exchanges with China and India – A UK academic researcher can spend time at an Indian or Chinese university, or an Indian or Chinese researcher can visit a UK university under this scheme, which aims to foster international working relationships.

***Ingenious* –** This grants programme encourages engineers to communicate their passion and expertise with public audiences in innovative ways.

For more information, please visit: www.raeng.org.uk/research

Front Cover: Dynamic 3D facial movements that can be used in the animation of facial sequences exhibiting the natural behaviour of a person. Read about Dr Darren Cosker's research on page 8. Image by Darren Cosker.

Sir John Parker – foreword

At the Royal Academy of Engineering, our vision is to bring engineering into the heartland of society and our support for innovative engineering and cutting-edge research is a critically important part of that mission.

Engineering innovation brings many benefits - it not only creates wealth and jobs but also addresses today's challenges both great and small.

This collection of case studies demonstrates the wide variety of ways that engineering research can improve our lives – from optimising heart surgery to increasing the quality of live music recordings. I hope that this resource inspires the research engineers of tomorrow by showing the incredible career opportunities available.

The skills of graduate engineers are essential to the UK economy and are needed across academia and industry. There is new evidence to show that demand for engineers outstrips supply. This can be seen in a persistent, sizeable wage premium for graduate engineers in industry- a premium that has grown over the last 20 years, which is certainly great news for engineering graduates!

In the UK, around 1.25 million science, engineering and technology professionals and technicians will be needed by 2020, including a high proportion of engineers, to support economic recovery. This represents a huge opportunity for young people.

The Academy has been funding engineering research since 1982 and right from the beginning received support from government and engineering companies, building crucial links between academia and industry. We now support over 120 research posts all over the UK and the programme is currently worth £25 million annually.

The research profiled in this publication gives a flavour of the wide spectrum of projects and people that the Academy now supports.

As someone who has spent an entire career in industry, benefiting from and building on the valuable work done by researchers, I hope you will enjoy reading these profiles as much as I have.

Sir John Parker GBE FREng
President, Royal Academy of Engineering

Engineering dreams and **flying machines**

Name:	**Dr András Sóbester**
Position/Award:	**RAEng/EPSRC Research Fellow and Lecturer**
Organisation:	**University of Southampton**

The 21st century is a great time to be an aerospace engineer. Game-changing developments such as the advent of multidisciplinary design optimisation and rapid prototyping have matured and are on the verge of universal adoption across the industry. András' research focuses on how best to deploy these technologies in the development of high altitude unmanned research aircraft.

The challenge

András' aim is to develop high-altitude aircraft and balloon-borne instrument 'pods' to advance researchers' understanding of climate, weather and atmospheric chemistry. It is currently difficult for researchers to construct detailed, uniformly accurate maps of physical parameters (such as volcanic ash plume concentrations) across blocks of the atmosphere, but András and his colleagues plan to change this by developing mission-specific, customisable aircraft at a low cost and in a short space of time.

A balloon-launched glider being tested at a Met Office research facility.

András's favourite aircraft is the world's first passenger airliner, the de Havilland DH 106 (Comet). András says: "It was underpowered, difficult to fly, it was prone to catastrophic structural failure and needed constant maintenance – even during flight – but it was the first airliner to cruise in the stratosphere, slashed journey times by 60% and changed the world of air transport."

Windows Phone attached to a balloon at 18,233 metres above South Wales.

The journey

- **1999** BSc in Design and Manufacture, University of Central Lancashire
- **2000** BEng in Mechanical Engineering, Technical University of Cluj-Napoca, Romania
- **2000-2003** PhD in Aerospace Engineering, University of Southampton
- **2003-2007** Research Fellow, University of Southampton
- **2007-present** Lecturer and RAEng/EPSRC Research Fellow

Achievements

- Four research collaborations
- 12 peer-reviewed journal publications over the period of the Research Fellowship
- One book called *Stratospheric Flight: Aeronautics at the Limit* in which András explores the challenges of flying deep into the stratosphere

András caught the aeronautical bug on his first flight. "The mere act of getting airborne was already impossibly exciting but then we hit turbulence. It was probably what a pilot would describe as 'moderate chop' but to me it felt like we were being thrown around the sky by some invisible force and bizarrely I found it exhilarating and still do. I decided there and then that I wanted to spend my life learning about flying and what lifts such a heavy machine in the air."

The big idea

András began his Fellowship by investigating whether installing engines above the wings of passenger airliners could offer a feasible solution to reducing the amount of noise reaching the communities below.

It was the experimental side of his noise shielding work and his search to find the best layout for an over-the-wing architecture that led him to use rapid prototyping and 3D printing, which inspired a change in the trajectory of his research.

An early flight test of an ASTRA rapid prototyped glider, launched from the top of a radio-controlled 'mothership'.

Printing a 20% scale airliner nacelle (streamlined engine cover) in just a couple of days prompted András to explore whether he could print high-altitude instrument pods using the same technology.

András says that he is likely to return to his airliner noise research. However, his current focus is the ASTRA (Atmospheric Science through Robotic Aircraft) programme, which investigates new technologies for making low-cost observations of the physical parameters of the atmosphere.

András describes ASTRA as a project that "many engineers dream about" as he and his colleagues are able to take a product from concept to testing and operation. ASTRA develops platforms capable of delivering scientific instruments to altitudes ranging from hundreds of metres to the upper stratosphere (40km) to help researchers better understand processes that influence weather and climate. The project combines András' expertise developed on his noise shielding work with rapid prototyping.

A balloon-borne instrument 'pod' or high-altitude glider can be designed, produced and launched in a matter of weeks. This speedy process enables researchers to respond to unexpected atmospheric phenomena such as volcanic ash clouds and, thanks to 3D printing and electronic prototyping, the aircraft can be fully customised to suit their mission.

Working with atmospheric scientists from the University of Cambridge, the Met Office, the British Antarctic Survey, as well as with the Facility for Airborne Atmospheric Measurements, the current goal for András and the ASTRA initiative is to develop customised unmanned air systems for a variety of atmospheric research missions, ranging from the mapping of aerosol clouds to making observations of high-altitude atmospheric gravity waves.

The **pioneering researcher giving disease victims heart**

Name: **Dr Silvia Schievano**
Position/Award: **RAEng/EPSRC Research Fellow**
Organisation: **UCL Institute of Cardiovascular Science and Great Ormond Street Hospital for Children**

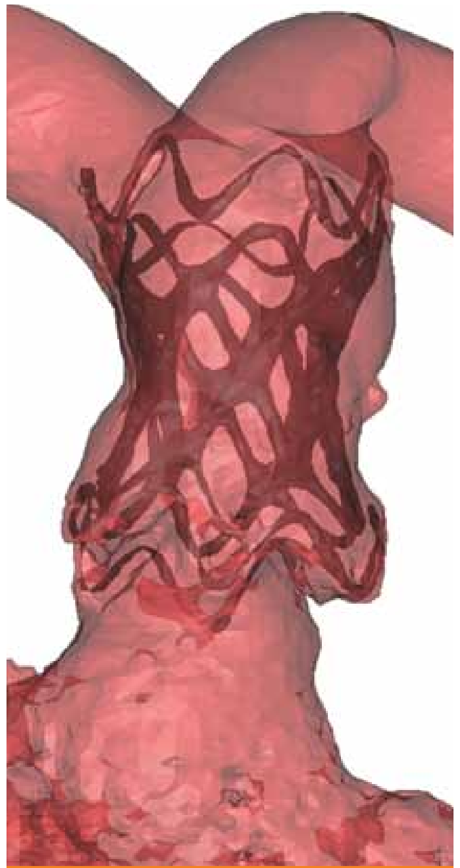
Silvia has pioneered the development of bespoke heart valves that can be implanted without surgery, triggering what cardiologists describe as a 'paradigm shift' in how they treat patients.

The challenge

Approximately 200,000 people with serious heart disease require open-heart surgery every year to replace heart valves. The operation involves a general anaesthetic, opening the chest, stopping the heart and sewing in a new valve, which can lead to serious complications such as a stroke, heart attack, bleeding, risk of infection, and even death.

Over the last 10 years, a non-surgical technique for heart valve replacement has been successfully used to implant some 3,000 pulmonary valves. The procedure uses a catheter inserted into a vein in the leg and fed through the vessels into the heart to position the new valve.

This technique has proven successful and decreases the risks associated with open heart surgery as well as increasing patient comfort and accelerating their recovery. However, owing to the shape of their heart, just 15 in 100 people can benefit from the device in its current form.



Silvia's team has developed a non-surgical valve replacement solution

The journey

- **1992-1997** Italian Scientific Lyceum
- **2002** Research Student, Imperial College London
- **1997-2003** Bachelor and Master's degrees in Biomedical Engineering, Politecnico di Milano, Italy
- **2004-2008** PhD in Biomechanical Engineering, UCL Institute of Cardiovascular Science, London
- **2006** Dynamics and strategies elective, London Business School

Achievements

- £5 million in third-party funding
- One patent and six research collaborations
- Nine invited lectures, 80 conference presentations and 40 peer review journal publications
- The Royal Academy of Engineering Sir George Macfarlane Award, MED Innovations Prize, and ESB Clinical Biomechanics Award among others

The big idea

Silvia and her team have used engineering methods to better understand the shape of the heart and its movements. Their aim was to provide a non-surgical valve replacement solution for people who cannot benefit from the current method on offer.

Silvia's research team helped to develop a new device that consisted of a biological valve in an expandable hourglass-shaped mesh tube (or 'stent') that could be inserted into the heart non-surgically via needle puncture of the skin. The team created computer models to enable visual simulation of valve implantation into the heart to explore the expected effectiveness of using different devices.

This was the first time that the interaction between the replacement valve and its implantation site in the patient had been studied. This research was not only beneficial for the knowledge base but has led to breakthroughs in actually deciding which and how patients should be treated. By using computer models tailored for each patient, doctors will now be able to predict the likely success or failure of the replacement valve before the operation has taken place.

Using computer modelling, Silvia was able to virtually test three subtly different potential designs in the implantation sites of 60 patients, which were reconstructed from magnetic resonance images. All the patients needed valve replacements but were unable to benefit from the current non-surgical procedure available. By using her computer model, Silvia could compare the different designs to assess safe anchoring and suitability for these patients and could ultimately create patient-specific heart valves.

Over the last five years, Silvia's team has worked with Medtronic Inc to develop the device and computer, bench and animal testing has been used to assess its performance.

A successful outcome

During the final stages of pre-clinical testing, a patient came forward who had undergone multiple open-heart surgeries and could not endure further invasive treatment. Silvia's new device was the only remaining option. Patient-specific data was used to influence the design of the device using images of the implantation site, while computer modelling allowed her to customise the device and test positioning and anchoring before the cardiologist performed the operation. The customised device was safely and successfully implanted into the patient as predicted by the pre-procedural modelling. The device and valve function were found to be stable at a three-year check-up and to have improved the patient's quality of life.

Clearly, a new device that cuts the number of open-heart surgeries performed is of great benefit to many patients and the NHS. The imaging, computing and engineering techniques may also help to reduce the number of animal experiments necessary for testing new medical devices prior to human application.

What's next?

Silvia is building a team of biomedical engineers who will work closely with cardiologists and cardiac surgeons at Great Ormond Street to find engineering solutions to other clinical needs.

An **internationally green future**

Name: **Dr Sai Gu and Dr Jasvinder Singh**

Position: **Lecturer and Professor in Renewable Energy and Senior Technical Officer**

Organisation: **Cranfield University, UK and the Indian Institute of Petroleum, India**

Academy award: **Research Exchange with China and India programme**

The need to produce clean energy has boosted interest in biofuels, which produce energy from the decomposition of organic material. While the first generation courted controversy as they rely on the use of food crops, the second generation use non-food-related crops. There have been notable advances in non-food crop biofuels but one of the big challenges is generating these fuels on an industrial scale.

Exchanging ideas

The Indian Institute of Petroleum (IIP) was actively seeking international collaboration in 'biomass fast pyrolysis' - a smart new thermochemical process that converts biomass to liquid, which can then be converted into second generation biofuel. The process rapidly heats the biomass to a carefully controlled temperature, then quickly cools the volatile products that are formed.

With the help of the Academy's Research Exchanges scheme, Jasvinder at the IIP developed a partnership with Sai, who was at the University of Southampton at the time. The two researchers were perfectly placed to help each other. While the IIP had made some progress, it needed additional technical support to build large scale demonstration plants to meet growing industrial needs. Sai's research was focused on the development of computational models for the biomass fast pyrolysis process that provides insight into complex thermal processing, process design and optimisation needed to scale up the method to industrial proportions.

Jasvinder's journey

- After joining IIP, Jasvinder's first placement was in the field of R&D in chemistry, where he acquired chemical engineering qualifications
- Postgraduate degree in chemical engineering, University of Roorkee, India
- PhD Chemical Engineering, Indian Institute of Technology Roorkee, India
- **1983 - 2009** Technical Assistant, IIP, progressing quickly to various Technical Officer roles
- **2010 - Present** Senior Technical Officer and coordinator of the Faculty of Advanced Thermodynamics' postgraduate programme

Sai's journey

- **2000 - 2002** Postdoctoral Researcher, University of Cambridge
- **2002 - 2007** Lecturer, Aston University
- **2007 - 2012** Senior Lecturer, University of Southampton
- **2012 - Present** Professor in Renewable Energy, Cranfield University

Two heads are better

The Research Exchange successfully enabled a mutually beneficial knowledge swap and helped the two researchers expand their networks and contacts.

The exchange has had a big impact on Jasvinder's research. He has published two reviews on biomass conversion techniques in India and the UK. Together with UK researchers, he has developed a new computational model of liquid collection process during fast pyrolysis, culminating in a joint paper.

The exchange enabled Sai to build links with the IIP, one of India's largest research institutes that licenses almost every technology used in country's refineries. Sai was also able to carry out a critical review of biofuels development in India and how fast pyrolysis technology may contribute to the future development in this field.

The partnership developed from this visit will enable more constructive collaborations to follow and a senior delegation led by the Director of the IIP visited Southampton to discuss strategic partnerships between the two institutions. Now that Sai is at Cranfield University, there might be an opportunity for further collaboration.

"The Research Exchange programme helped me build up experience for international collaborations. Since then I have developed collaborative research projects with partners in India, China, South Africa, Ghana and several EU countries with grants of over £3 million."
Dr Sai Gu

Game on: making animated humans more realistic

Name: **Dr Darren Cosker**
Position: **Lecturer**
Organisation: **Bath University**
Award: **RAEng/EPSRC Research Fellowship**

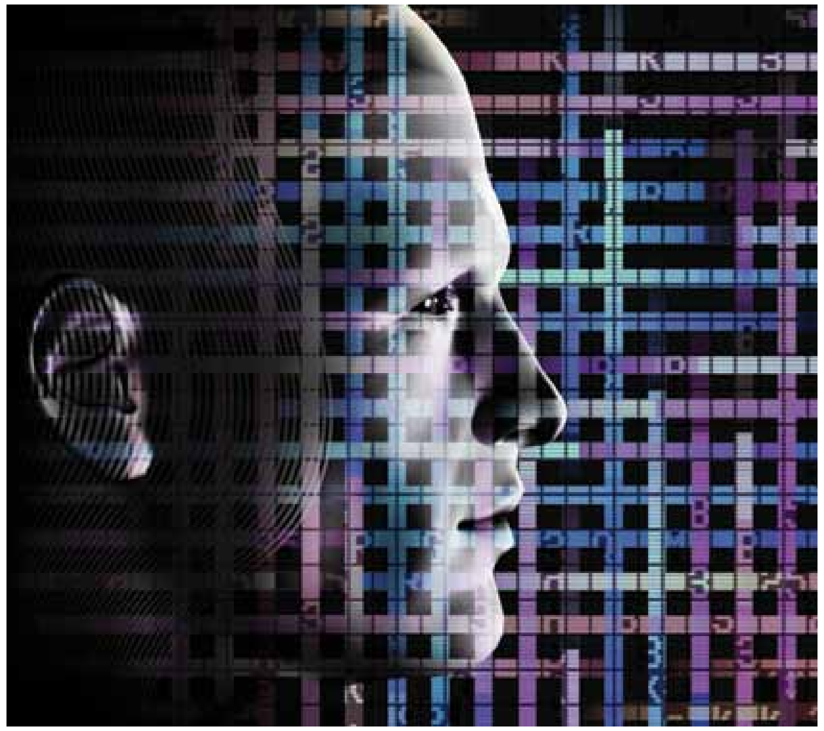
Early adopters of computer games might have been satisfied with pixellated ghosts and blue hedgehogs, but as games consoles become more advanced, televisions higher definition and cinema more immersive than ever before, we expect animated humans appearing in the latest films or video games to be hyper-realistic - and that is difficult to engineer.

However Darren, a computer vision and graphics specialist, has come up with a way to create more realistic and believable human animations.

The challenge

One of the biggest challenges in the computer graphics industry is creating realistic human characters, in both their appearance and movements, according to Darren. Perfecting the dynamics of human faces is really difficult - viewers need to feel that characters have genuine emotions. This is a problem in the film industry as well as gaming and actors usually wear 'markers' or painted patterns on their faces to help studios create more realistic animations, which can be distracting for actors on set. While there are commercial systems that do not require markers, at present, the animator still has to fill in much of the detail.

Darren admires Pixar's films and the studio's philosophy that "the animator is king", as well as the company's traditional animation approach that gives life and humour to characters.



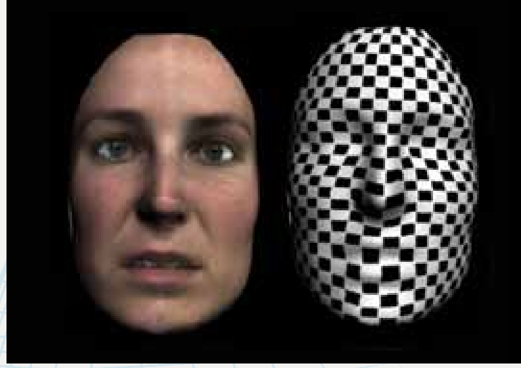
The journey

Darren was first interested in coding at the age of seven, when he was given a ZX Spectrum games console. He began programming games in BASIC and spent weeks planning and writing games, sometimes jotting down code in school lessons. In secondary school, Darren was interested in maths as well as in art and english, finding the mix of the technical and creative inspiring.

He left school after his GCSEs to work as an apprentice at the Ford Motor Company, where he took a BTEC OND in electrical engineering. After realising it was not the career for him, Darren made the choice to study computer science.

- **1998-2001** BSc degree in Computer Science
- **2001-2005** PhD in Computer Science
- **2004-2007** Associate Lecturer, University of Cardiff
- **2007-2012** RAEng/EPSRC Fellow, University of Bath
- **2009-2011** Consultancy roles at DNeg and Sony Computer Entertainment Europe
- **2012-Present** Royal Society Industry Fellow at DNeg and the University of Bath
- **2007-Present** Lecturer, Department of Computer Science, University of Bath and Senior Visiting Fellow, Centre for Vision, Speech and Signal Processing, University of Surrey

The big idea



Darren has pioneered a new method of analysing expressions across a wide variety of faces using 3D video without the need for markers. He has created a way of computer modelling facial expressions that was originally developed for use in psychology experiments to help understand facial emotion. However, his research has several other potential applications, including identity-recognition systems (useful for airport security) and animating people for computer games or films.

He says: "If you want to recreate a human who genuinely looks happy, or sad, you have to first understand the important signals responsible for this. The face is particularly interesting, as it is such a rich source of communication, and is the key to creating a human realistic character."

Darren's 'dynamic facial capture' technique tracks individual pixels in each video frame, using computer algorithms. The footage is filmed by a 3D depth camera but the frames are read as 2D images, which are projected onto a cylinder and then 'unwrapped'. Individual pixels are matched to vertices on a triangular mesh placed across the face in each frame. Tracking the pixels allows the computer to model how the mesh moves and to identify facial expressions. This is a similar technique to one used by psychologists called the Facial Action Coding System

Although an engineering researcher, his work uses expertise and knowledge from a number of subjects, including the acquisition of visual information about humans (computer vision), the display and movement of humans (computer graphics) and the experience of truly believing the character is real (psychology).

Why it matters

Darren's innovation could be used by the film industry to create more realistic animations. He has already worked with Double Negative Visual Effects (D-Neg), Electronic Arts and Aardman Animation so his technology could be coming to a cinema near you! The system could also be used by security systems to spot if people's expressions are genuine and even to identify individuals based on their facial expressions, which could prove useful in a number of security scenarios.

What next?

Darren is dedicated to continuing his work to create realistic humans and is currently exploring the potential of other hardware such as Near Infra-Red (NIR).

He plans on working together with industry and academia and has recently begun a Fellowship with D-Neg, one of the world's leading visual effects studios, to help him do this. His ultimate aim is to create a place where academic and leading Hollywood talent can work together.

Stopping light to **trap rainbows**

Name: **Kosmas Tsakmakidis**

Position/Award: **RAEng/EPSRC Research Fellow**

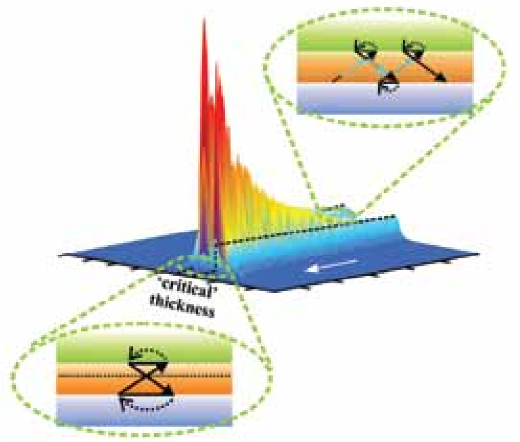
Organisation: **The Blackett Laboratory, Imperial College London**

In a world that relies on the internet and mobile phones, there is always demand for higher quality connections and faster computers. Kosmas Tsakmakidis' research could be the key to enabling just this, as well as creating ultra-fast and environmentally friendly lasers. Kosmas is an expert in ultraslow and 'stopped' light and he can even trap a rainbow.

The challenge

Kosmas' research focuses on the use of slowing light to improve the routing of data in optical communication networks. Engineers could control busy connection points, where billions of optical data packets converge, by slowing some packets down in order to let others through, like directing cars at a busy junction. This would allow the optical traffic to flow more smoothly and quickly.

Previous attempts to slow and store light were expensive and required incredibly low temperatures, ruling out useful applications. Researchers want to control and slow down the speed of light to a complete stop under practical conditions such as room temperatures, and in structures made entirely of solid materials, rather than the gases that have been used until now. Kosmas is using metamaterials (artificial materials engineered to have properties that may not be found in nature) in his investigations to stop and store light, but these materials can absorb light instead of storing and maintaining it. Solving this problem and therefore preserving the light stored is one of Kosmas' challenges.



How to stop light

Achievements

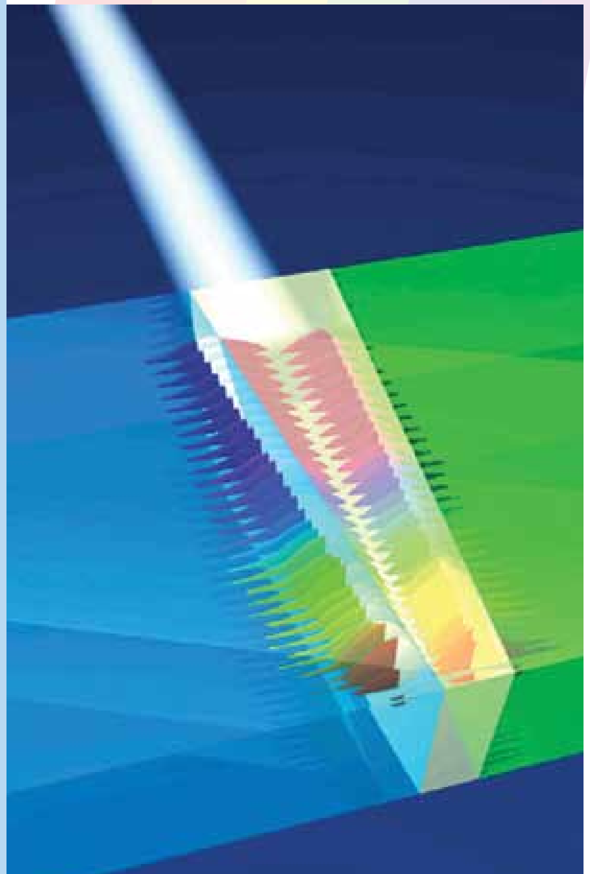
Kosmas Tsakmakidis, Alan Boardman and Ortwin Hess' 'Trapped rainbow, storage of light in metamaterials' research paper was published in *Nature* in 2007 and created a stir.

He won the Institute of Physics' Quantum Electronics and Photonics PhD Thesis Prize and the runner-up prize in the Science, Engineering and Technology (SET) for Britain 2010 competition for early-stage researchers, awarded by the Parliamentary and Scientific Committee of the House of Commons.

The team at Imperial College London is currently collaborating with a number of national and international experimental and theoretical groups, exploring and advancing the ideas supported by Kosmas' Research Fellowship.

The journey

- **2002** Diploma in Electrical and Computer Engineering, the Aristotle University of Thessaloniki
- **2003** Masters in Electronic Engineering, University of Surrey
- **2008** RAEng/EPSRC Research Fellowship awarded
- **2009** PhD in metamaterials and slow light, University of Surrey, followed by post-doctoral training
- **2011** Kosmas moved to Imperial College London to work in the Condensed Matter Theory group of the Blackett Laboratory.



A beam of light is trapped as a rainbow

The big idea

Kosmas and his team are working on the possibility of stopping and storing light by forcing it into a highly unusual state: a situation where the wave stops even though there are no barriers in its way. This technique could be used to create fast miniature lasers, next-generation photovoltaics for efficient harvesting of light, telecommunications equipment, ultra-fast computers and even Harry Potter-like 'invisibility' cloaks and 'trapped' rainbows.

Unlike previous approaches, Kosmas' research allows light to be stopped and trapped inside solid-state structures, at room temperatures, and be split into a rainbow. This means that different bits of optical information can be separated and stored, which could lead to memories using photons rather than electrons.

He has replaced the tiny barriers used by previous researchers to stop light, with a new cone-shaped structure made of a metamaterial core that can bring light to a complete standstill by effectively locking a light ray into a tight spin. The idea works because the metamaterial core has a negative index of refraction, allowing a light ray to make backward 'steps' as it travels, and thereby be decelerated and stopped. Meanwhile, a gain medium (used to amplify energy inside molecules) is integrated into the fabric of the metamaterial core to supply energy and prevent the light from being absorbed. Tapering the metamaterial core of such a structure allows researchers to create 'critical points' where the thickness of the cone prevents light from travelling further and each frequency of light is stopped at a different point, allowing researchers to trap a rainbow.

Why it matters

Kosmas' method of slowing and storing light is more efficient than previous approaches and allows for multiple frequencies to be stored at room temperature. His 'trapped rainbow' investigation and technique, conducted with Professor Ortwin Hess of Imperial College London, could lead to an increase in the operating capacity for computers. It could also pave the way for the development of new hybrid optoelectronic devices for information processing and telecommunication networks. By controlling the flow of optical data, a faster network can be produced to facilitate higher quality and faster phone calls, as well as efficient transfer of information over fibre optic cables used for broadband internet. Kosmas' research could also potentially be used to build miniature lasers that are more efficient and run on much less power than those used at the moment. These new lasers would be more environmentally friendly and faster than their present-day counterparts. Kosmas' team's breakthrough could, in the future, be used to create nanoscale 'invisibility' cloaks that could hide objects from visible light.

Changing the **music industry's tune**

Name: **Dr Joshua Reiss**
Position: **Senior Lecturer**
Organisation: **Queen Mary University of London**
Academy Award: **Engineering Enterprise Fellowship**

The modern music industry offers great potential for growth with revenues from new digital music markets continuing to increase and the live music industry growing by 60% from 2005 to 2009. There is an ever-growing appetite for new technology that can increase the efficiency of recording, production and the quality of live sound.

Dr Joshua Reiss has developed an automatic music production system that could revolutionise the way music is recorded. There has not been a significant technological breakthrough in music production since the introduction of digital mixing desks in the 1960s.

Joshua has been developing his system for the past five years. The Engineering Enterprise Fellowship will enable him to focus on commercialising his engineering research and he has set his sights on licensing his technology to leading companies such as Yamaha and Avid.

Translating research into the market place

Joshua will focus on three revenue streams: licensing agreements with music technology companies; selling 'plug-ins' for digital musical instruments plus mixing consoles and audio workstation software; and selling self-contained automatic mixing systems to consumers.

Just three months into his Fellowship, Joshua says that 'progress has been significant'. He has submitted a patent for his technology, developed two prototype plug-ins, is discussing licensing options with two big industry players and is also in the process of securing a sizeable investment for commercialising his research, with plans to form a company.

The journey

- **1995** BSc degrees in physics and mathematics at Georgia Tech, USA
- **2001** PhD in Physics at Georgia Tech
- **2001-2003** Research Associate for the Department of Electronic Engineering and Computer Science, Queen Mary, University of London
- **2003 - present** Senior Lecturer at Queen Mary and leader of his audio engineering research group within the Centre for Digital Music. Joshua founded the Digital Audio Effects module and co-founded the BEng, MEng and MSc music technology-related degree programmes
- **2012 - present** Awarded an Engineering Enterprise Fellowship to take time off from his teaching duties and focus on commercialising his research

Inspiration

Joshua always wanted to be a researcher and is inspired by the challenges of solving unsolved problems, "changing the world and understanding the universe".

During his education, he took classes in chaos theory and enjoyed how "elegant maths" could open up new areas of research. Having then become interested in signal processing, he focused on creating systems that understand music, but moved into manipulating sound as he wanted the "satisfaction of solving problems as well as exploring uncharted territory."

Joshua was also inspired by a talented PhD student from an applied audio engineering background whom he supervised - so much so that it clarified his own direction of research into intelligent systems for sound engineering.

The big idea

Joshua's new system can provide musicians with the tools to make good recordings without a sound engineer.

Joshua has created an automatic music production system that replicates actions that sound engineers undertake when creating professional-grade musical material.

The technology uses signal processing combined with intelligent systems design to create a mix from multiple audio tracks in real time. The system ensures that voices and instruments are automatically balanced to achieve the best quality musical recordings.

The technology has been trialled and shown to work in a live performance situation, letting the audience hear an optimised mix of the music in real time. As well as benefiting the professionals, this will also help the many up-and-coming young bands who at present tend to suffer poor quality live sound until they can afford a professional production crew.

In listening tests, subjects consistently preferred the automatically mixed music over that of amateur mixes of live and recorded music.

Achievements

- Twice recipient of the Audio Engineering Society Board of Governors Award
- Over 100 peer reviewed publications in print or accepted, including 24 in premier academic journals
- Is the co-inventor on three patents

Why it matters

Joshua's system creates opportunities for different types of businesses within the music industry and high-skill manufacturing firms, as well as benefiting artists and consumers.

As well as digital audio manufacturers, his innovation could benefit games companies and console manufacturers that require an intelligent audio system for realistic and high quality sounds.

Professional musicians and TV and radio stations require highly-skilled sound engineers, and this system will allow them to deploy them efficiently. However, the intelligent system also addresses the needs of amateur musicians who lack advanced knowledge of complex software, enabling them to produce professional sounding tracks with minimal time and effort spent on production. Small music venues without the budget for a sound engineer and mixing console could also benefit from this affordable and compact system. In short, Joshua's product covers a broad range of markets.

Fighting disease with **microbubbles**

Name: **Dr Eleanor Stride**

Position: **Reader in Biomedical Engineering and Fellow of St Catherine's College, Oxford**

Organisation: **University of Oxford**

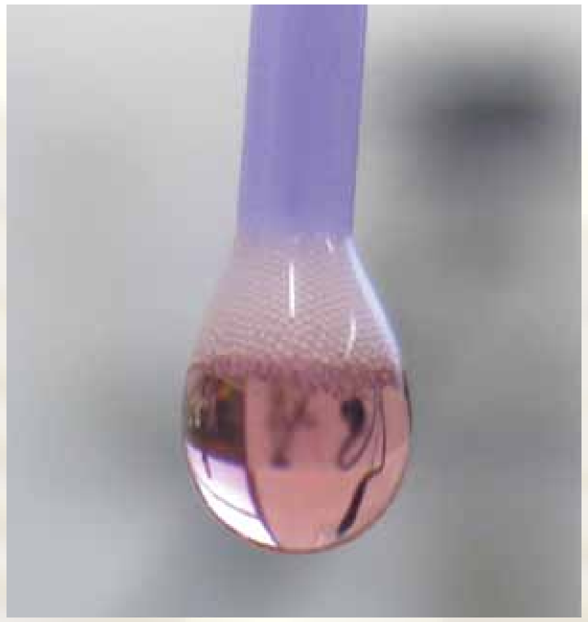
Award: **RAEng/EPSRC Research Fellowship**

While there have been huge developments in the treatment of cancer in recent years, few of us might have predicted that minuscule bubbles could be used to treat this disease that will affect one in every three people in the UK. However, Eleanor and her research team are doing just that and using microscopic bubbles to deliver tiny doses of cancer-beating drugs to precise locations in a patient's body.

The challenge

Ultrasound is used as the safest and fastest method of scanning the body to provide medical diagnosis, but the quality of images can be poor compared to other more expensive methods. It was known that microbubbles could be used to boost the quality of ultrasound images enabling the flow of blood through different parts of the body to be traced, for example to detect cancer. They had also been proposed as vehicles to deliver drugs.

To investigate, Eleanor needed to improve microbubble detectability under ultrasound, find a way to send them to a target site in the body so the drugs could be administered accurately and control their uniformity to make sure that the drug dose is correct, all of which presented many challenges.



"My art teacher inspired me to become an engineer. My A-level projects involved a lot of what was essentially industrial design and she introduced me to the design engineering courses being run by the Royal College of Art. It is the combination of creativity with scientific rigor that makes engineering unique and exciting."

The journey

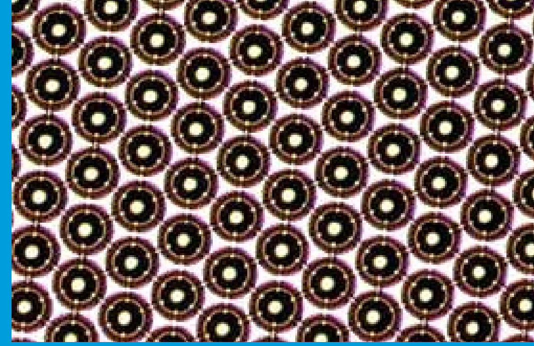
- **1998- 2001** BEng in Mechanical Engineering, University College London (UCL)
- **2001-2005** PhD in Mechanical Engineering, UCL
- **2005-2010** Appointed to a lectureship at UCL and became an an RAEng/EPSRC Research Fellow
- **2010** Appointed to a Readership
- **2011** Joined the Institute of Biomedical Engineering, University of Oxford and became a Fellow of St Catherine's College

Eleanor's five years as a Research Fellow allowed her to build her own team at UCL. Two years after completing her Fellowship, she has her own lab and team at the University of Oxford. The scheme was successful in allowing a talented engineer to progress in her engineering research career and become a team leader.

Awards and prizes

- The Worshipful Company of Armourers and Brasiers Venture Prize
- The Leverhulme Trust Philip Leverhulme Prize (Biomedical Engineering)
- EPSRC and Journal of the Royal Society Interface Award, Parliamentary Science, Engineering and Technology for Britain Engineering Medal
- Royal Society Brian Mercer Innovation Feasibility Award

The big idea



Eleanor and her team investigated the behaviour of microbubbles in vivo to explore their potential to become effective drug delivery agents. The focus was to create agents that would produce distinctive ultrasound signals and enable a triggered drug release of particular amounts.

The solution was provided by the manufacturing of coated microbubbles of a particular size. Eleanor and her team were successful in creating magnetised bubbles filled with drugs that measure two millionths of a metre across. Any larger and the patient could suffer from pain, paralysis or even death due to a condition similar to decompression sickness (or 'the bends') familiar to divers surfacing too quickly from a deep dive.

The team use nanotechnology to give the bubbles a biocompatible coating which stops them bursting prematurely once injected into the bloodstream. Ultrasound is used to track the location of the bubbles in the patient's body and a magnetic field is used to retain them in the target region. A burst of higher energy ultrasound is used to trigger release of the drug exactly where it is needed.

Why it matters

The use of microbubbles will minimise the many side effects caused by chemotherapy. The team is now working with hospital clinicians to test and refine the process.

The project offers many potential benefits beyond the treatment of cancer. It enhances ultrasound therapies and potentially leads to the development of new agents for the diagnosis of stroke and arthritis.

Improved understanding of bubble dynamics in complex media will also be of interest to scientists and engineers working in different fields across the research community, from food to materials and chemical engineering to oceanography.

What's next?

Last year Eleanor received a Challenging Engineering award from the Engineering and Physical Sciences Research Council (EPSRC) under which she is developing a range of new techniques that combine imaging and therapy. She has also started a spin-out company to enable her to translate the new technology she and her team have developed into clinical use.

Eleanor is currently working closely with clinicians and an industrial partner to get her technology into hospitals as well as conducting further research on the behaviour of microbubbles in the body. She is also investigating how they can be used for emergency treatment of stroke and the delivery of drugs to the brain.

Engaging the public

Name: **Jamie Gallagher**
Position: **PhD student**
Organisation: **University of Glasgow**
Award: ***Ingenious*, the Academy's grant scheme for creative public engagement with engineering projects**

Jamie wanted to share his passion for engineering with the wider world. With the help of the Royal Academy of Engineering's *Ingenious* grant scheme, Jamie took part in an intensive hands-on public engagement training course and has since received his own *Ingenious* grant which he used to create a family-friendly show to celebrate how engineering allows us to understand everything from tiny atoms to massive stars.

What started out as material for just four shows has evolved into a one-man tour of science festivals and centres across the UK. But Jamie has not stopped there. He has also turned his research into stand-up comedy, scooped second place in a UK-wide Famelab competition for new science communication talent and received funding from his university to continue his public engagement work.

The challenge

Much of the work done by engineers touches everyday lives, but is often hidden or taken for granted. As a researcher, Jamie looks at materials that can convert waste heat to electricity and hopes that that the nano materials he studies may lead to energy solutions that are more efficient than those currently available.

Although Jamie had spoken about his work at the Glasgow Science Centre and completed a communication training course held by Imperial College London and the BBC, he was keen to do more. So when an email dropped into his inbox asking for engineers to take part in an intensive five-day communication training programme at Cheltenham Science Festival in 2010, he did not hesitate to sign up.

Supported by *Ingenious*, the training aimed to give engineers the tools and opportunities to share their passion and expertise with the public. Jamie learned the best ways to engage an audience, watched numerous shows and helped to run a rocket workshop. At the end of the week he and his fellow engineers were challenged to develop and deliver their very own live performance at the festival – in just 36 hours.

The journey

- **2009** BSc (Hons) in chemical physics from the University of Glasgow
- **2009-2013** Awarded a Kelvin Smith scholarship for interdisciplinary research. Jamie is studying for a PhD in thermoelectronics
- **2011** Toured with his show "How big can we go, how small can we go," funded by *Ingenious*
- **2012** Sold-out show at Cheltenham Science Festival
- **2012** Second place in the UK final of FameLab, a competition for new science communication talent

The big idea

The Cheltenham Science Festival was a turning point for Jamie. It exposed him to public engagement in a way he had not seen or thought of before and was in some ways a baptism of fire. For someone who shied away from public speaking, Jamie not only discovered the skills and confidence to speak in front of audiences but found that he enjoyed it too. Taking part in the festival project inspired Jamie to continue his public engagement journey and he applied for his own *Ingenious* grant, to put together a family show looking at the engineering behind scientific imaging.

The resulting show gave Jamie the freedom and opportunity to engage with the general public and tell them about his area of research in a fun and entertaining way. Thanks to its success, he is now a regular on the science communication circuit and has performed at other science and comedy nights, as well as staging his show at a music festival in Wales. To affirm his success, Glasgow University has agreed to continue to support him once he has completed the *Ingenious* programme.

Why it matters

Capturing the public's imagination and inspiring future engineers is critically important to the engineering profession. However, the *Ingenious* scheme has also benefited Jamie personally and professionally. He has developed better communication skills, which have helped him express his research findings more clearly. Since being involved in public engagement, Jamie has won more scientific poster competitions – not, he says, because he is a good designer, but because he can now engage and talk about his subject to such a broad audience. Jamie believes that when the time comes for him to apply for more funding he will also be at an advantage because he has learnt how to promote his research.

" It's been an incredible journey. Two and a half years ago I'd done nothing – I had no idea I'd have my own show and a sold-out event talking about my research. "