University of BRISTOL

Faculty of Engineering

Research

Global partnerships with leading industry.

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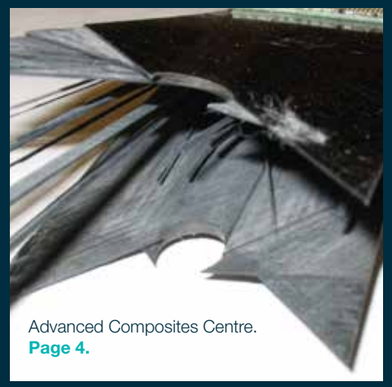

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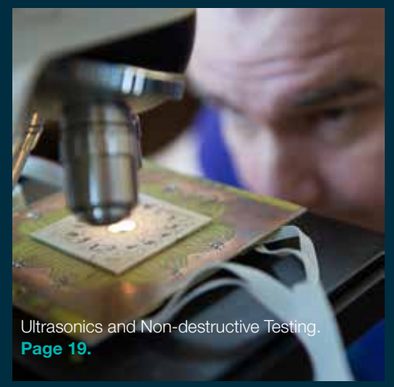

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Collaboration and interdisciplinary work have been key to our success here at the University of Bristol.

As a research intensive university our leading academics cover the breadth of fundamental research through to its novel application and implementation. Our aim is to address big societal issues and grand technical challenges in science and engineering. Through dedicated, strategic research groups, we tackle diverse issues in areas including transport and the built environment, through to energy and advanced healthcare.

Industrial links are a key part of our research strategy and we have strong partnerships and strategic alliances with local and global industry. Our undergraduate and postgraduate programmes, as well as our research activity, are shaped at all stages by the emerging needs of business. Our exceptional research has resulted in the opening of two University Technology Centres: The AgustaWestland University Technology Centre (UTC) in Vibration Reduction and The Rolls-Royce UTC in Composites. This, along with the launch of the National Composites Centre and expansion of our Advanced Composites Centre for Innovation and Science are leading the way in composites research activities.

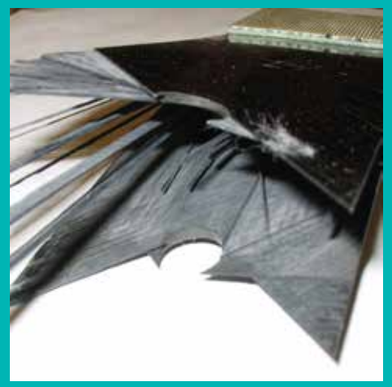
The Faculty has also received many large grants from UK research councils and other major funders to support centres, partnerships and cohort programmes for doctoral training. Since 2006, the Faculty has attracted almost £30 million in funding to its six Centres for Doctoral Training: Advanced Composites; Complexity Sciences; Communications; Neural Dynamics; and The Industrial Doctorate Centres in Systems and in Composites Manufacture. The Faculty also hosts major research centres, including the Bristol Laboratory for Advanced Dynamics Engineering (BLADE), and we are central to the Cabot Institute, the University's multidisciplinary research hub dedicated to environmental systems and technologies; and to the Nanosciences and Quantum Information Centre, a £7.6 million investment containing some of the 'quietest' labs in the world.

By the very nature of research it constantly evolves and develops. To acknowledge and nurture such progress, new groups in the Faculty do emerge such as Earthquake and Geotechnical Engineering which has extended its interests to the wider aspects of Structural Dynamics. This brochure provides a brief overview of the activities and collaborations of our research groups within the Faculty of Engineering. We aim to build upon these recognised areas of excellence, and look forward to working with current and future partners to achieve this together.

Professor Paul Weaver
Faculty Research Director

Advanced Composites Centre for Innovation and Science

The Advanced Composites Centre for Innovation and Science (ACCIS) aspires to be a world leading centre for composites education and research, combining cutting edge fundamental science with strong industrial links for exploitation and technology transfer.



Based in the Engineering Faculty in new £5.4 million offices and laboratory facilities, ACCIS comprises a core team of 15 academic staff and over 80 postdoctoral researchers, postgraduate students and research visitors, working on composites. Research encompasses four broad themes: Multifunctional Composites and Novel Microstructures; Design, Analysis and Failure; Intelligent Structures; and Composites Processing and Characterisation.

Since forming in 2007, membership of ACCIS has steadily grown with the establishment of strong research links throughout the Engineering, Science and Medical faculties. As such, ACCIS successfully brings together composites research across the University. It extends this on a national and international scale through long-standing links with industrial partners and other academic institutions. In 2009 the ACCIS Doctoral Training Centre was established, funded by the Engineering and Physical Sciences Research Council (EPSRC). This has further strengthened the ACCIS research base by substantially increasing student numbers and widening collaboration with industry.

Industrial partners include Rolls-Royce, Airbus, Vestas, BAE Systems, AgustaWestland, GKN Aerospace and Dstl. The Rolls-Royce University Technology Centre on Composites involves approximately 20 people, focusing on the development of analysis methods that can be used in the design of composite components. Successes include methods for analysing tapered sections such as the root of a fan blade, assessing the effect of defects on performance, and methods for high cycle fatigue analysis and testing. ACCIS also enjoys participation in Research Council funded collaborative projects alongside other academic institutions, which frequently attract additional support from industry. Of note is the EPSRC funded £6 million six-year Programme Grant on High Performance Ductile Composites (HiPerDuCT), a collaboration between ACCIS researchers and Imperial College London which benefits from industrial partnerships with BAE Systems, Dstl, Hilliburton, Hexcel, Mouchel, Rolls-Royce and Vestas. HiPerDuCT aims to create a new generation of high performance ductile or pseudo-ductile fibre reinforced polymer composites which are able to sustain large deformations without breakage.

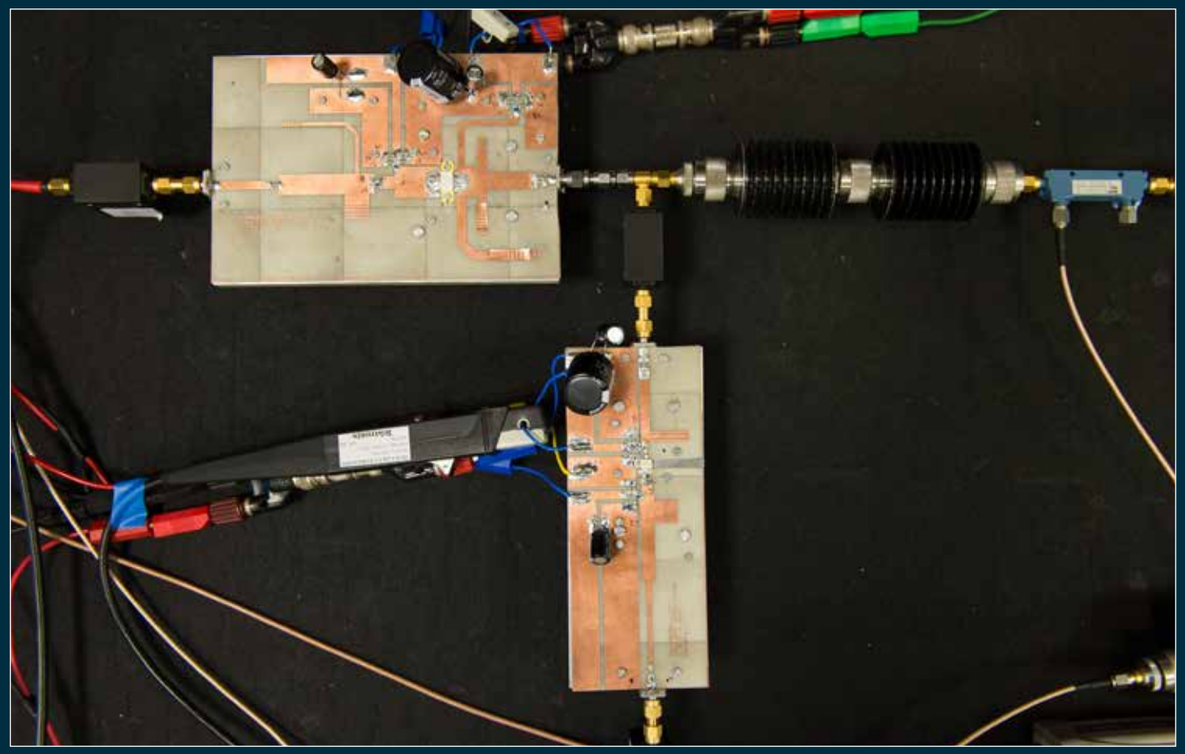
ACCIS were proud to play an integral part in the creation of the independent, open-access National Composites Centre (NCC) in Bristol. Located on the Bristol and Bath Science Park, the NCC is evidence of the unified approach to composites research and development adopted by the University of Bristol, hand in hand with industry. ACCIS staff have been working with the industrial partners on the design and specification of the Centre and developing the research programme. A number of ACCIS researchers are working with NCC both as members of the permanent staff and seconded on projects.

The NCC exists as a result of UK Government funding that was awarded following the UK Composites Strategy announcement in November 2009, topped up by the South West Regional Development Agency and European Regional Development Fund, and aims to strengthen the UK's position in the composites manufacturing sector whilst moving towards a low-carbon economy. NCC is part of the High Value Manufacturing Technology and Innovation Centre launched in October 2011.

> **ACCIS is at the heart of composites research and is a focus for collaboration regionally, nationally and internationally.**
>
> **Professor Michael Wisnom,** ACCIS Director

The EPSRC Centre for Innovative Manufacturing in Composites was another notable award. This £10 million collaborative project involving ACCIS and the Universities of Nottingham, Manchester and Cranfield, led by Nottingham will investigate major research challenges in composites manufacture including cost reduction, increased production speed and increased sustainability. This collaboration focuses on fundamental research and is linked to the National Composites Centre as a route for technology demonstration and exploitation. There is additional support from major composites producers and users including Rolls-Royce, GKN, Airbus, Bentley, Lotus, Caparo, Luxfer and Vestas.

Communication Systems and Networks



Communications is responsible for contributing some £129 billion to the UK economy per annum across its application sectors. Importantly, Bristol's Communication Systems and Networks group has been at the forefront of world research and development for more than 25 years with many major technological achievements to its credit including: Wireless Local Area Network technology, Wideband Code Division Multiple Access for 3G, 4G, SMART antennas, breast cancer detection, smart grid/smart metering, sensor networks, wireless network coverage Computer Aided Design software (propagation modelling), computational electromagnetics and power efficient Radio Frequency (RF) transmitters for Digital Video Broadcast (DVB) and cellular communications.

The Group continues to maintain its world-leading position at the cutting edge of communication technologies and their applications to sectors such as energy, healthcare, transport, aerospace and telecommunications.

Industry has adopted the Group's pioneering research in single carrier multiple access schemes, which has also led to several mandatory techniques being incorporated into the standards for Long Term Evolution (LTE) and LTE-Advanced (4G). The award winning breast cancer research is undergoing clinical trials at a local hospital in Bristol. The RF Power Amplifier research team has set a world record with Toshiba Corporation (Japan) for power efficiency in highly linear RF power amplifiers, a result that will lead to a considerable reduction in CO_2 output globally and reduced demand for electricity from power stations as the technology is increasingly utilised.

The Group lies at the heart of Bristol's Centre for Communications Research (CCR), and works closely with other researchers from both within the Centre and across the University, together with industry, government bodies and academia. It is actively involved in Technology Strategy Board (TSB), EU and EPSRC projects. It has a well established track record for collaboration with industry to exploit research and technology transfer. Several research group members have key advisory roles to Government as well as acting as national representatives for EU COST actions.

Many international awards and prizes have been received for the Group's research and enterprise. This includes the Prince of Wales Award for Innovation for its development of a speed scrambler for use by the UK police force, and awards from Motorola and Schlumberger for its research in Radio Communications and Propagation. Numerous awards have been received for its work on breast cancer detection.

The outstanding research capabilities of this Group have been recognised with EPSRC awarding the UK Centre for Doctoral Training (CDT) in Communications to Bristol, winning this award ahead of nine other leading UK research universities.

The Group's international success is underpinned by access to state-of-the-art test and measurement facilities developed through a combination of research council, industry and university funding.

Playing a vitally important role in nearly every aspect of our society.

Cryptography

Bristol's Cryptography and Information Security group is a leading player on the world stage of cryptographic research.

The Group, which is unique in its combination of theoretical and practical work, conducts research into cryptography, the underlying hard problems on which it is based and the hardware and software needed to implement secure systems. The Group has particular interest in techniques for proving security of cryptographic systems, the efficient implementation of such systems on small computing devices and the verification that such implementations do what they say they do. It also has an interest in security auditing and computer forensics.

Work in cryptography at Bristol has had an impact in various applications. In pairing based cryptography the Group has contributed a number of algorithms to the IEEE 1363.3 standard. Earlier work in elliptic curve based cryptography led to the establishment of this key technology as the security cornerstone of many products, such as mobile phones, game consoles and operating systems. The Group's research in side-channel attacks and defences has also had wide impact in the electronics industry. Current work is examining exciting ideas on the long-term technological horizon, including Fully Homomorphic Encryption, Multi-Party Computation, automating security proofs, and information extraction from secure web communications.

Work carried out by this Group will also be a major part of the Faculty's Centre for Excellence in Cyber Security Research. This prestigious status was awarded to the Faculty for its world-class research in the field of cyber security. This status means that this Group will work more closely with the Government Communications Headquarters (GCHQ) to support its cyber defence mission, the UK cyber community and industry, and will play a pivotal role in helping to make government, business and consumers more resilient to cyber attack.

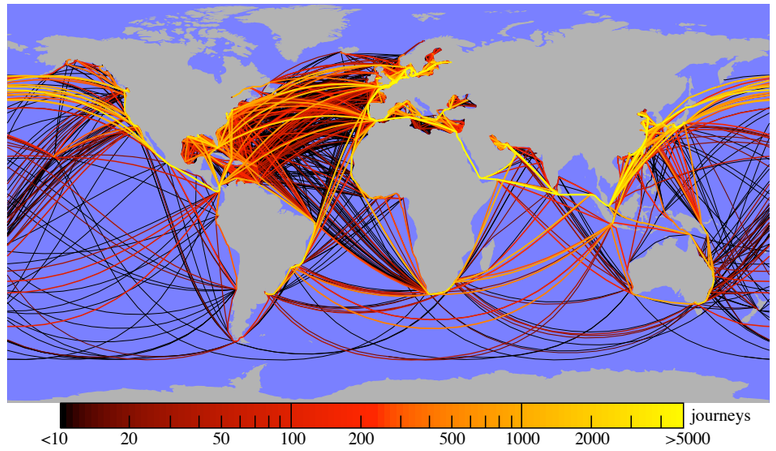
Applied Nonlinear Mathematics

The Applied Nonlinear Mathematics research group is world leading in Nonlinear Dynamics and Complexity. Research in the Group covers a wide range of theoretical and computational topics, which have many end-user applications.

Imagine the Millennium Bridge without the wobble, driving to work without stopping at a traffic light or being able to prevent the spread of a virus through targeted vaccination. This Group is pushing boundaries in mathematics in specialist areas such as complex networks, piecewise smooth systems and mathematical modelling to make such things possible.

Bristol University is unique in having a mathematics group as part of its Engineering Faculty. The Group provides quick mathematical solutions to many challenges faced by engineers, which greatly benefits industry, particularly in the areas of aeronautical, mechanical and civil engineering. Its work saved one manufacturer approximately £10 million by solving a gear rattle problem.

A steady stream of problems from industry and society at large drives forward new mathematical theories and approaches. In the relatively new area of complexity, this Group aims to provide an even greater set of tools that will be useful to engineers in the future, such as the ability to predict human social behaviour using mathematics. New mathematics is being used to generate novel solutions to the original problems. By operating in this way, the research of the Applied Nonlinear Mathematics Group remains highly relevant to the wider world.



Systems

The history of Systems research at Bristol dates back to the early 1990s when systems-based approaches began to be researched and advocated for engineering applications, particularly in relation to safety, risk and uncertainty management.

A key principle of the Systems group's research was to recognise explicitly that engineered 'hard' systems are embedded in the 'soft' human systems, including those of research, design, manufacture and end use, and therefore, that all technical 'hard' systems risks need to be understood within a socio-economic context.

In the last decade new themes of multidisciplinary fundamental and applied research in Systems have emerged and in 2009-2010 the Systems Centre was launched to lead in application of Systems Thinking to complex engineering problems.

One focus of research for the Group is the design and integration of complex engineered systems, which investigates and develops new approaches to engineering design that apply appropriate techniques from complexity and social sciences, environmental monitoring and modelling.

The development and application of innovative approaches to complex systems design can stimulate step changes in performance improvements as well as the anticipation of possible unintended consequences. A key example of a practical challenge being addressed under this research theme is the design, development and operation of resilient infrastructure and large-scale complex systems.

Consolidating on its world-class research in Safety Critical Systems and Risk, the Group's next step is to develop enhanced techniques for handling cross-disciplinary 'wicked problems', which include technical risk analysis and uncertainty modelling, including due diligence; asset condition monitoring and management; Secure Systems design and security management; design for sustainability and sustainability appraisal; understanding and managing development of technical capability, and cyber-capability – an emerging field in security and defence research.

With more than 80 industry Engineering Doctorates in Systems research projects and approximately 40 companies supporting these, the Group aims to deepen an understanding of Systems Thinking as a set of methods and tools, as well as a purposeful human activity. Research work is also looking at developing methods and tools for generic networking analysis and agent-based modelling of complex systems, including applications areas in improved reliability and vulnerability analysis.

Bristol's Systems Centre collaborates across faculties at the University of Bristol (Education, Management, Sciences) , nationally and internationally and within broad range of industrial sectors including civil engineering and construction, the water industry, rail, automotive, electronics and electrical engineering, energy, aerospace and defence, information technology and software, and industrial manufacturing.

From the Group's research into learning and leadership in engineering organisations, the preliminary findings show that many partner organisations are in the process of transforming their business to orientate it around a Systems Thinking approach. The benefits to industry and society from this area of research are far reaching and include the development of future engineering leaders with systems thinking qualities, who are capable of building and transforming engineering organisations and leading multidisciplinary teams; facilitating interdisciplinary working which will overcome the limitations of the natural technical silos of an organisation; integrating understanding of customer needs through collaborative working and research.

> "The Systems approaches that are being developed by the Systems Centre are playing a leading part of the advances in Systems Thinking in the UK. Systems Centre focus on needs driven approach to engineering design, its training in diverse research traditions and the emphasis on interdisciplinary problem solving are aligned with business needs to deliver timely, imaginative and effective outcomes and overall helping UK Industry to achieve their goals."
>
> **Prof Tim Broyd** Halcrow Group Technology & Innovation Director, Halcrow Group Sustainability Director (up till 2012)

Intelligent Systems

The University of Bristol has a long tradition of excellence in Artificial Intelligence, with research groups dating back to the 1970s and 1980s.

Intelligent systems form part of our communication infrastructure, we trust them enough to plan journeys, recommend news, filter emails and monitor financial transactions. These are just some of the many areas of application where artificial intelligence technology has been deployed in the past decade. Other areas include law enforcement, automation of scientific research, robotic cars and aircraft, space exploration, and much more. Research undertaken by the Intelligent Systems group at Bristol is engaged in a series of projects covering areas as applied as detecting penguins in the wild, and monitoring the contents of Twitter, to theoretical fields as abstract as the study of patterns in the human genome.

Animal Biometrics is one area of this Group's research. The ability to identify individual animals is a prerequisite for many questions in behavioural ecology, cognitive research, conservation monitoring, and wildlife epidemiology. With the increasing availability of remote audiovisual recording devices, such as camera or video traps, standardised data collection has become much easier, in particular in the wild. The core objective is to study, develop and evaluate computer vision systems that exploit the structure of animal skin patterns for a robust biometric identification of individuals in natural habitats. The project's primary focus is on great apes and elephant. A further major project in animal biometrics is concerned with an automatic recognition of individual penguins in a colony.

The Group is also focussing on data mining which is concerned with the automated analysis of large scale data in order to extract the useful knowledge hidden in it. Our approach to dealing with data has essentially remained unchanged for the past 25 centuries: we categorise it, divide it into small chunks and then build indexes and catalogues so we can find what we want. But with terabytes of data becoming available every second in areas such as finance, medicine and commerce, this is no longer a viable strategy.

As a result there is an urgent need to find new ways of solving the following types of problems. In finance, methods are needed to predict stock trends, based not only on traditional statistical indicators but, potentially, incorporating all the information that a human trader might use such as social and political trends and current events. Financial institutions need to generate credit scores before making loans, whether to individual home buyers or major corporations. Retailers need to mine associations from store card and online transaction data in order to customise advertising and promotions to customers. Banks, companies, universities, governments and other organisations are increasingly concerned with online security and the need to detect intrusions and anomalies.

Web mining and studying online media content is another of this Group's research areas, be it analysing news stories or Twitter messages. Their software is monitoring the contents of thousands of newspapers in 23 languages, extracting information – among others – about elections in the USA, about flu levels in the UK, and what show-business celebrities are up to.

The field of Intelligent Systems research provides the theoretical framework underpinning these remarkably diverse set of technologies. It includes aspects ranging from computer vision to machine translation, from speech recognition to information retrieval. And the centre of it all is machine learning, the technology that enables computers to learn from observing large quantities of data.

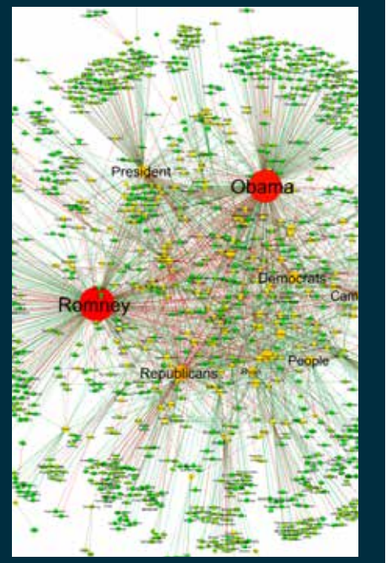
Election Watch

Academics at Bristol's Intelligent Systems Laboratory developed an online tool, Election Watch, to analyse the content of news about the 2012 US election by the international media. Election Watch automatically monitored political discourse about the US presidential election from over 700 American and international news outlets. The information displayed was based on around 91,456 articles. After analysing these, the researchers found patterns in the political narrative.

Nello Cristianini, Professor of Artificial Intelligence, said: "The number of news articles devoted to the US election was so large that no exhaustive analysis could be attempted by conventional means. Even if just focusing on the leading English-language outlets, there were hundreds of thousands of articles to analyse just for the primary phase. So any large-scale analysis of global coverage necessarily needed to make use of computational methods.

"However, most computational approaches to news content analysis are limited to sophisticated forms of keyword counting, be it for sentiment analysis, or topic detection, and relative statistical analysis. This would miss many aspects of the narration to which voters were exposed, and which would therefore have been of interest to analysts."

The researchers aim was to access information that is closer to what a human analyst could extract, but still simple enough to be reliably extracted by computational means in a Big Data setting. The statistical corrections coming from the use of very big datasets delivered a sufficiently clean signal for political observers to monitor the state of play of a complex process such as a US presidential campaign.



Dynamics and Control

The dynamics and control research activity is concerned with research problems relating to modelling, simulation and control of civil, mechanical and aerospace engineering systems.

> **The MVF laboratory is an important facility for both academic research and industrial technology developments.**
>
> **Dr Dario Di Maio,** Research Associate

The Group's ethos involves the development of advanced analytical techniques in combination with numerical simulations and a strong element of experimental testing. The Group has a variety of projects funded by the EPSRC and the European Commission, as well as projects in collaboration with and funding from industry. New Laboratory facilities were established in 2004 as part of BLADE (Bristol Laboratory for Advanced Dynamics Engineering), including state-of-the-art dynamic testing capabilities which allow the Group's research to cover the core areas of structural dynamics and control engineering.

Structural dynamics research spans a wide range of activities and applications. Large structures, bridges, machines and aircraft all have dynamical properties which need to be modelled, measured and designed for. Research activity is focused on the dynamic behaviour of these systems – particularly those with significant nonlinearity. The Group hosts the University Technology Centre (UTC) with AgustaWestland, and the Rolls-Royce UTC, and has a range of other industrial projects that link with its major themes of research, which include aircraft dynamics, modal testing and structural integrity.

Control engineering research includes expertise across a range of topics. Collaborative work includes projects with the University of Bath on the energy-efficient adaptive control of servohydraulic systems, and on the adaptive control of the University of Bristol shaking-table. Work with industry includes projects with Zwick Controllers Ltd, on the adaptive control of servohydraulic testing machines, and with BAE Systems on adaptive navigation in uncertain urban environments.

There is also a strong cross-over between the dynamics and control activities, for example via research into structural control. This is focused on topics such as semi-active devices for reducing unwanted vibrations, protecting structures from earthquake damage, and developing low power autonomous damping devices.

The Dynamics and Control Research group is engaged with industry via a series of strategic partnerships including the University's Advanced Composites Centre for Innovation and Science (ACCIS), the Systems Performance Centre: a strategic alliance with EDF/British Energy, and the Research Centre for Non-destructive Evaluation (RCNDE).

These partnerships allow industrial collaborators to have direct access to cutting edge research activity carried out by world leading experts on topics of relevance. In addition, the academic partners are able to engage with the most important technological developments currently being perused by industry, to give a highly mutually beneficial relationship. These types of partnerships are of wider benefit to society as they enable the rapid development of new ideas to be integrated into new technology, for example, in making more energy efficient engineering systems such as increasing fuel efficiency of aircraft.

'Mechanical failure Composites components under High Cycle Fatigue (HCF) loading is one of the core research topics of Rolls-Royce. I am part of the Rolls-Royce Composites UTC for developing next generation mechanical testing strategies of Composites. One of my research goals is to develop High Fidelity Structural Dynamics models capable of predicting life of aerospace components. This research strategy is being developed along two directions which are experimental and modelling capabilities. The first one has reached important successes as the Faculty of Engineering has been integrated with a new laboratory called Model Validation Facility (MVF) for High Performance Testing. A unique excitation system has been developed and installed in MVF for performing HCF testing of Composites. Software, called MONTEVERDI, was developed as part of my research for performing automated HCF measurements using Scanning Laser Doppler Vibrometer technology, and this software is ready available technology for Rolls-Royce to use.'

Dr Dario Di Maio, Research Associate

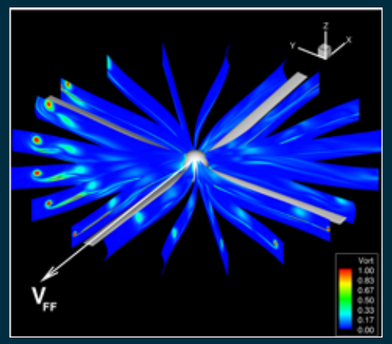
Fluid and Aerodynamics

The study of fluid dynamics and aerodynamics is critical in a large number of areas, from internal low speed flow of blood in the heart, to external high speed flow around aircraft. The Fluid and Aerodynamics research group at the University of Bristol has been performing fundamental and world-leading research into theoretical, numerical and experimental methods for fluid flow analysis for over 20 years.

Cutting-edge numerical and experimental technology has been developed to allow prediction and characterisation of flow properties around complex geometries. This technology has lead to improved aerodynamic design techniques used in both academia and industry.

Experimental and numerical approaches have different objectives: experimental methods have the advantage of analysing 'real' fluid flow. However, they are extremely expensive, and it is not normally possible to model the real flow scales correctly in a wind tunnel; numerical fluid simulation methods solve the governing fluid flow equations by filling the flow domain with a computational 'mesh' of cells, and using numerical modelling techniques to predict the flow properties within each cell. Hence, these can approximate the correct flow scales, and can be used for multiple geometries for design space investigations and even for shape optimisation, the only restriction being the computer power available. However, they `model' the flow physics, so will always be approximate. Therefore, it's important to consider complementary experimental and numerical methods.

Experimental methods have been developed using both Laser Doppler Anemometry (LDA) and Particle Image Velocimetry (PIV) techniques. These are non-intrusive techniques providing high resolution flow properties, and can give deep insight into detailed flow physics, essential for aerodynamic analysis. These advanced techniques have been used, for example, to



characterise acoustic signatures from aerofoils and rotor blades, and investigate transition at low Reynolds numbers, to analyse problems such as rotor and turbine noise, and to analyse wake profiles behind wind turbines in large arrays to optimise energy extraction. They also provide critical validation data for numerical methods.

In this time the Group has also been developing world-leading numerical simulation methods. Research has been in various fields, with applications including propeller and wind-turbine design, modelling of vortex shedding, free surface flows, unsteady fixed-wing and rotary-wing flows, aeroelasticity and aeroservoelasticity. Recent efforts have concentrated on `empowering' technology; universal methods that make numerical simulation codes easier to use, and methods to extract maximum information from the output of these codes. Examples include approaches to simplify and automate mesh generation, allow aerodynamic-structural dynamic coupling for aeroelastics, surface shape parameterisation and optimisation.

The impact of the research has been far-reaching, and has resulted in the Group being invited members of both the PUMA and Rotorcraft DARP (Defence and Aerospace Research Partnerships) collaborative programmes, the UK Applied Aerodynamics Consortium for supercomputing in aerodynamics, and the national Centre for Fluid Mechanics Simulation. It also has collaborative links with many internationally-renowned research institutes, including DLR, FOI Stockholm, UTIAS (Toronto), Caltech, Stanford, Toledo, and US Air Force Research Labs. Significant funding has been obtained from Government via DTI and TSB, Research Councils, Royal Academy of Engineering, Royal Society and the EC.

Improved aerodynamic design in many application areas has resulted directly from the research output of this Group, which has had significant industrial impact and benefit. Many of the methods developed have been integrated directly within industrial simulation codes, primarily with industrial partners in the aerospace and automotive industries, with renewable energy companies and F1 teams. These methods have been used directly to design aircraft wings including aeroelastic deformation effects, UAV platforms, optimise rotorcraft blade shapes and predict wind turbine wakes.

Electrical Energy Management

The Electrical Energy Management group researches, designs, builds and tests advanced energy conversion systems containing renewable energy, power electronic and electro-mechanical conversion systems and energy storage elements, in order to optimise efficiency or power and energy density.

The Group's work is core to new emerging low carbon technologies. Its specialist areas focus on high efficiency electrical power conversion solutions, rolling out smart energy grids, designing hybrid and all-electric vehicles, and replacing conventional hydraulic and mechanical actuation in aircraft with reliable more electric alternatives. Research examples include the design, modelling and prototyping of the electrical machines, power electronics converters and battery management systems found in modern aircraft and electric cars, with designs ending up in vehicles around the world. The development of full-scale prototype demonstrators in collaboration with industrial partners is essential to these activities.

New electrical energy management and control techniques are developed, and demonstrated on systems subjected to realistic load regimes and environmental conditions. Where possible, testing is carried out using fully representative, 'real-world' operating scenarios; using test methods such as 'hardware-in-the-loop' and 'sub-structuring'. This enables complex system interactions to be understood, leading to the evaluation of optimal control methods and development of new energy conversion technologies.

"Collaborations on vehicles such as the Bluebird Electric car demonstrate that the UK is at the forefront of low carbon vehicle engineering, and highlight the importance of Electrical Engineering in such projects."

Professor Phil Mellor Head of the Electrical Energy Management Group

A growing strand of activity addresses the design synthesis and system-level modelling of vibration energy-harvesting devices, and low power electronic circuits for the management of energy. This could result in battery-free fully autonomously powered health monitoring devices.

In 2011 the Group provided the technology for the Bluebird Electric car for its land speed record attempt, joining forces with the project's Technical Director, from Tirius Ltd – a UK-based electrical and electronic vehicle engineering design consultancy.

Photonics

Photonics, the science of light, is underpinning many recent developments in communications, solar power, lighting, data storage and displays, and could even lead to a quantum revolution in computing.

Photonics research ranges from the engineering of optical communications devices through to the development of wavelength scale structures to guide, trap and collect light out to the fundamental physics of photonic quantum information.

Optical fibre communications forms the backbone of all land based communications and as the bandwidth increases we require faster devices, switches and new systems concepts. Meanwhile climate change is driving renewable energy research towards solar power and low power lighting.

As a result, the Group's research is pursuing faster information and communication technologies, and new methods of harvesting renewable energy. Eventually this could lead to inexpensive and improved sensors to reform healthcare. The research could also provide absolute security for online transactions, changing computing as we know it.

Some of the Group's research into better performance optical communication systems has already been realised with the development of ring cavity optical switches. This low power switching is fast and saves energy. Current communications switches do not offer this, meaning that this research would revolutionise optical communications to be more simple and without sight of the electronics.

Incorporated in the Photonics research group is the Centre for Quantum Photonics which spans Physics and Electrical and Electronic Engineering. This is a world-leading experimental group in quantum information and communications, working together to develop future quantum technologies, and to explore fundamental science using photons.

Adding to the strength of this research is the High-performance Networks group. This group specialises in the application of advanced technologies to future communication network infrastructures together with the study of control, node architectures and technologies best suited for future requirements.

The Photonics group's success can be seen through its industrial collaborations with Nokia, QinetiQ, Hewlett Packard, Kodak, Agilent Technologies, TRL, and Oclaro. Consequently, various spin-out technologies have emerged including Venture Photonics which was formed to commercialise Bristol's photonic component technology.

Robotics

Robots are set to impact on all aspects of our lives, from robotic exoskeletons which enhance our strength and mobility to robots that search for life in the Solar System and beyond.

Through the Bristol Robotics Laboratory, the largest robotics laboratory of its kind in the UK, Bristol is at the forefront of the robotics revolution. This innovative and spearheading venture is the result of the partnership between the University of Bristol and the University of the West of England.

The Robotics group's research spans many key areas from soft actuators to safe systems and control, flying robots and vision for robotics. These exciting topics feed directly into all areas of engineering and the Group's members include staff from Computer Science, Mechanical, Electronics and Aerospace Engineering as well as Engineering Maths. It also has close ties with colleagues that study the Psychology of Human-Robot interactions, as well as a variety of applications from robotics for the home, medical rehabilitation and agricultural robots among others. It is conceivable that in the next few decades, capable and intelligent robotic devices will be interacting, serving and cooperating with people in complex and home tasks.

In May 2012 the Group received significant funding from a major partnership between the Government and industry to develop smart machines that think for themselves. Led by the Engineering and Physical Sciences Research Council (EPSRC) and an eight-strong group of partners – BAE Systems, Schlumberger, National Nuclear Laboratory (NNL), Sellafield Ltd, Network Rail, SCISYS, DSTL and the UK Space Agency – the two projects that received funding are:

Building vehicles with legs: this looks at how visual information is used to adapt to changing terrain and environment by studying how humans behave via head-mounted cameras. This could speed up the development of vision control for land-based vehicles with wheels or legs.

RIVERAS: Robust Integrated Verification of Autonomous Systems: this will develop techniques and methodologies that can be used to design autonomous intelligent systems that are verifiably trustworthy.

Robotics research and the development of intelligent autonomous systems, such as unmanned aircraft, are vital to many major UK companies, emerging industries, and SMEs, from advanced manufacturing to oil and gas exploration, nuclear energy to railways and automotive, and healthcare to defence.

Autonomous and intelligent systems are capable of independent action in dynamic, unpredictable environments. They interact with each other and humans, using sensors to learn from their environment, adapting their behaviour and making choices based on their immediate and stored knowledge and experiences.

Commenting on behalf of the six industry partners, James Baker, Managing Director of BAE Systems' Advanced Technology Centre, said: "It is vital for the universities to work with industry to drive these technologies forward as autonomous and intelligent systems are going to be an integral part of our infrastructure and society in the near future."

> **As partners we hold a shared goal to improve the generic technology in the field so that it can transfer and benefit many industries and sectors.**
>
> **James Baker,** Managing Director of BAE Systems

Visual Information Laboratory

Vision science research at Bristol is at the forefront of the study of human and animal vision, artificial vision systems and image analysis. The Group is embodied by the Visual Information Laboratory, which stimulates interdisciplinary research in order to promote future development of this field.

Visual Information Laboratory brings together researchers from a wide range of academic disciplines, including electrical and electronic engineering, computer science, experimental psychology, biological and medical sciences, arts and drama, with external partners such as the Bristol Eye Hospital, the Bristol Robotics Laboratory and the Machine Vision Laboratory at the University of the West of England.

Since its inception, Visual Information Laboratory has been the umbrella for many new and varied research activities, which includes the modelling of camouflage and how this knowledge can improve the detection of difficult targets in an image or video; animal tracking and identification; the analysis of historical works of art; the study of how everyday motor behaviour is controlled by visual information; anatomical imaging; the understanding and modelling of how the central nervous system processes visual inputs; the development of new image quality metrics; and behavioural analysis and tracking through imaging.

Visual Information Laboratory currently represents a grouping of 38 permanent academic staff and some 70 researchers at Bristol working on vision and imaging research and its engineering applications. The scale of Bristol Vision's collaboration is unique in Europe and has unequalled potential for progressing vision research in its broadest sense, from perception to application.

Water and Environment

The Water and Environmental Engineering research group is concerned with understanding the water environment to advance the sustainable use of water resources, to provide design variables for infrastructure and to enhance the security of society regarding floods and other environmental hazards. Focus areas include hydrology, water and health, climate change impacts, water quality, risk from natural hazards and new observational methods.

Water and environmental security is crucial for the sustainable and safe existence of both people and nature. Ensuring water security requires protection from floods and water scarcity, and the sufficient supply of freshwater of appropriate quality to ensure environmental and human health. The future of our society is less likely to be threatened by armed conflict, than by climate change, population growth, water shortages and pollution, poverty and rising food prices. The water and environment group focuses research on developing the theory and tools needed to address the complex issue of water and environmental security in a changing world.

The Group consists of an interdisciplinary team of engineers who combine process understanding, mathematical modelling and engineering principles to solve societal problems through solutions with a strong scientific basis. Water problems are complex and require technical skills as well as an understanding of the socio-economic context. For example, protecting people from the risk of flooding requires reliable short-term forecasting through the close coupling of meteorological and hydrological models at high spatio-temporal resolutions. The estimation of long-term flood risk as foundation for infrastructure planning in a changing world requires understanding of environmental flow paths, the relevance of flow variability to ecosystems, urbanisation impacts etc. Understanding how water acts as a transport medium for pathogens in Africa requires new ways for understanding, monitoring and predicting the impact of water and environmental contamination on human health in data sparse regions.

Example projects include the NERC-funded CREDIBLE project that will enhance the assessment of risk and uncertainty in natural hazards, and the AQUATEST project, concluded in 2012, that developed new low cost water quality monitoring devices and was funded by the Bill and Melinda Gates Foundation. CREDIBLE brings together statisticians and natural hazard specialists to develop, for the first time, a consistent approach to estimate uncertainty and risk across all natural hazards. The second project focuses on the lack of clean drinking water, which is a contributing factor in the proliferation of diarrhoeal diseases – killing 1.8 million people every year. In fact, diarrhoea kills more young children than AIDS, malaria and measles combined.

This Group is also connected in a leadership role to a University-wide effort through the Cabot Institute where water is one of six multidisciplinary research themes.

Solid Mechanics

Solid Mechanics aims to understand the mechanical behaviour of complex engineering components, and explores the way engineering materials respond to loading to improve the efficiency and safety of structures.

The Solid Mechanics group is a centre of excellence in this area and has a long tradition of undertaking industrially motivated research which studies how materials behave when they are subjected to thermal and mechanical loads. The Group has expertise in both metallic and non-metallic materials and undertakes research using advanced numerical and analytical methods, validated by experimental testing. A key motivation for this research is structural integrity assessment.

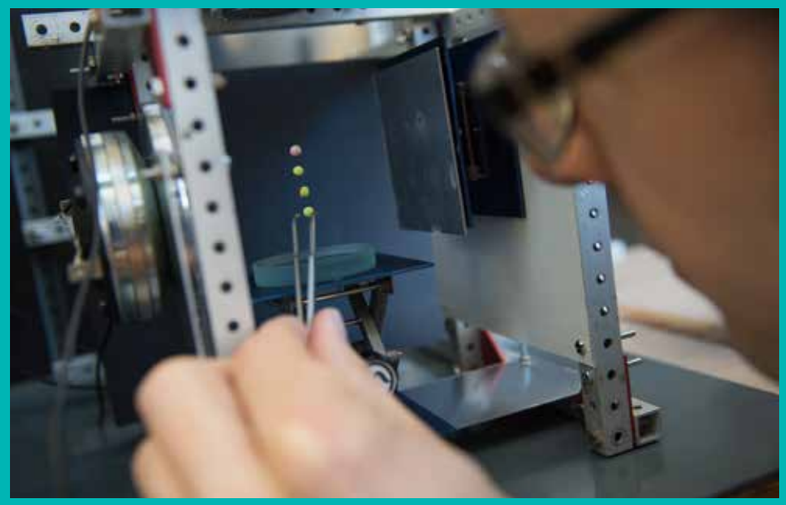
Within the broad area of solid mechanics, the main interests of the Group centre around the general theme of structural integrity, encompassing very applied research in key areas such as residual stress modelling and measurement, fracture and fatigue of engineering materials, high-temperature materials behaviour and associated design activities.

To remain at the forefront of research in these areas, the Group has formed a number of strong relationships with other UK universities and those overseas, such as University of California, Davis. The team strive to develop new models of material behaviour in tandem with strong experimentation. This approach has enabled them to establish an enviable reputation for close collaboration with industry, particularly in the power generation sector with companies such as EDF Energy and Rolls-Royce in the UK; the US Nuclear Regulatory Commission, EPRI and Westinghouse in the United States; AREVA in France; the Australian Nuclear Science and Technology Organisation; and JNES, Toshiba, Hitachi and Mitsubishi Heavy Industries in Japan. The Group has also been working closely with BARC (Bhabha Atomic Research Centre) and IGCAR (Indira Gandhi Centre for Atomic Research) in India on a civil nuclear initiative, developing advanced welding technologies through this project.

The Group's advances occur through experimentation and theory, but no one place has all facilities to do what is needed for the experiments. Success of the research relies on industry and institutions such as the Joint Research Centre, ISIS, Institut Laue-Langevin and FRM II to provide real materials, prepare specimens and to provide experimental facilities.

Such collaborations enabled the Group to pioneer the measurement technique of deep hole drilling (DHD). This technique measures stresses in large engineering components. It can make measurements in real nuclear components as opposed to very small mock-ups, allowing onsite measurements at power stations, which had previously been impossible to achieve. This technique ensures longevity and importantly, proves if a part is safe to operate.

This research was commercialised through spin-out company VEQTER Ltd in 2004. VEQTER was the first company in the world to carry out deep hole drilling commercially. The technique for this has helped to improve the safe working conditions of highly complex industrial components and has reduced the frequency and duration of downtime that can cost some clients more than £1 million a day.



Microelectronics

The Bristol Microelectronics Research group is a team of world-leading academic experts in computer architecture, design verification, fault tolerance, reconfigurable technologies and high performance computing.

The Group brings together researchers from a range of academic disciplines in order to address its primary research theme of “Energy Aware Computing” (EACO), with expertise across the entire system stack, from transistors up to software applications.

The Bristol Microelectronics group is the best place to perform collaborative research with the semiconductor industry outside of Silicon Valley. Formed in 2010, the Group has an impressive set of active industrial collaborators, including ARM, Imagination Technology, Global Foundaries, Infineon, Broadcom, STMicroelectronics, NVIDIA, AMD, Cadence, Mentor Graphics and the Numerical Algorithms Group. The Group has previously spun out a successful semiconductor start-up, XMOS, developing a new generation of high performance, low-power, parallel computer architectures targeting the low-cost consumer electronics market.

The Bristol Microelectronics group is advantageously located at the epicentre of the largest cluster of Microelectronics industry in Europe, with over 100 related companies in and around the area employing over 5,000 scientists and engineers, representing the richest microelectronics ecosystem outside of Silicon Valley. The Group has intimate ties with many of these companies, with some University staff and students having worked at, or in some cases even founded, a number of these local design centres. The Group’s industrial collaborations range from contract research to joint grant proposals and student projects. The Group also has a number of research students sponsored by industry, via Knowledge Transfer Partnerships and iCASE schemes.

The Group is funded by the EPSRC and the EU’s Framework 7, as well as by the UK’s Technology Strategy Board and industrial collaborative projects.

Interaction and Graphics

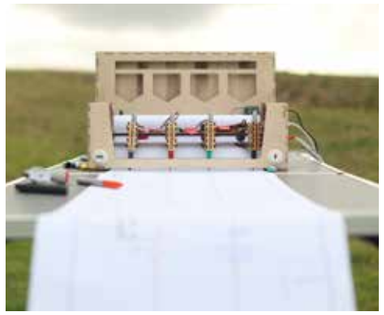
Formed in 2007, Bristol’s Interaction and Graphics research group is a creative interdisciplinary team, interested in designing novel interactive computer-mediated systems.

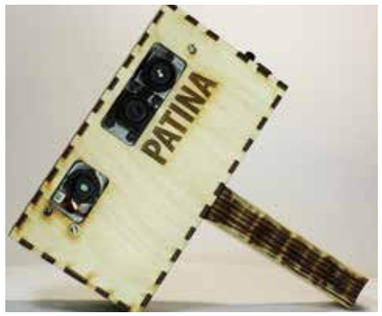
The Group is particularly interested in enhancing the user’s interaction bandwidth to enable expressive, communicative and meaningful interactions with the system.

The research combines innovative design of hardware devices that have complex electronic, electrical and physical properties with deployment and evaluation of use in everyday public settings. Linking human interaction and hardware design has helped the Group understand the importance of legible design which means that people can probe and read how the system works while they are interacting with it. Many current systems are illegible because they hide how they work from the user. Although in many cases this can lead to systems which can handle greater complexity internally, for example autonomous or abstracted designs, problems tend to arise for two reasons. Firstly, the way that someone expects a design to work and the way it actually works are often different, making it hard to use. Secondly, if systems are designed which do not exhibit their own behaviour the gap in society between users and designers is increased. As a result, the Group are designing bespoke systems that are not only novel but also legible in their operation. Imagine, for example, a wireless network in which you could see the information moving around space if you wished; or a processor which could show how it was efficiently encoding data at the same time as it was playing an mp3.

Examples of projects in Interaction and Graphics include a three year RCUK funded project, Patina, and a five year ERC fellowship, Interact. Patina will provide researchers with new opportunities to create research spaces that emphasise the primacy of research material, and support the sharing of research activities as well as results. Interact is constructing the next generation of interactive multi-touch surfaces.

The Group acts as a hub for collaboration between social scientists, artists, scientists and engineers to combine efficient and aesthetic design. It maintains close collaborations with various partners ranging from device manufacturers to schools, art galleries and local governments. These collaborations help the Group to create tailor made strategies for public demonstrators, and enable knowledge-transfer and exploitation, and generate feedback loops to drive research forward.





Ultrasonics and Non-destructive Testing (NDT)

The Ultrasonics and NDT group aim to undertake internationally leading research into ultrasonics with a focus on non-destructive testing, structural health monitoring and biological applications.

Non-Destructive Evaluation concerns the inspection, characterisation and quantification of the ‘health’ of engineering structures. The team at Bristol focus on both the fundamental science and practical applications of ultrasound. Research encompasses the development of new models of wave interactions, the use of arrays to image the interior of components and, in close collaboration with industry, practical application and technology transfer.

The Group’s major research areas include ultrasonic array imaging, nonlinear ultrasound, structural health monitoring with guided waves and ultrasonic particle manipulation. The aim of the Group is to develop the underpinning engineering science as well as to progress various technologies further up the technology readiness scale.

The research crosses the spectrum from blue skies to applied work, delivering to companies’ needs, seeing projects through from fundamental ideas to commercial products. Collaboration with major UK industrial players in the NDT sector include Rolls-Royce, Airbus, BAE Systems, EDF, Eon, RWE, Serco, BP and Shell.

Array imaging is the area of this Group’s research that currently has the greatest impact. For example, this work has enabled companies to more accurately find cracks in metallic aircraft structures, and a wide range of companies where safety is essential, such as power stations or oil and gas refineries, are now working with the Group to explore applications of array technology.

The aim of this area of research is for better quality information to find smaller flaws, defects or cracks so that it’s possible to definitively conclude if there is a crack or just a harmless anomaly. This would ultimately mean that anomalies could be allowed, whereas previous technology had to assume these were a crack. The Group’s work on post-processing-based imaging and characterisation using arrays has changed the design of the architectures of array equipment to collect data and this approach is now being used industrially.

Industrial collaborations inform and motivate research, which in turn can lead to cost savings for businesses. An Engineering Doctorate student on the Rolls-Royce research programme worked on a project to develop a miniature array to be fitted into an aircraft engine, and positioned on the blades to make a measurement to make sure the blade is safe. Previously the engine had to be stripped apart but using this array, this level of service and expense was not necessary. This project resulted in cost and time saving for Rolls-Royce and a commercially workable tool.

The areas of nonlinear ultrasound and structural health monitoring with guided waves are early stage research for the Group, but they focus on issues that industrial members of the EPSRC Research Centre in NDE (RCNDE) would like to see being solved within the next 20 years. These areas of research focus on the quality of the material itself, so that in the long-term it will be possible to measure the remaining life of metallic structures, and to monitor larger structures with permanently installed systems.

Ultrasonic particle manipulation is an area of research that has quite different application fields. Ultrasound is being used to move small objects. It could be used to position fibres and re-enforcement parts in composites. In the future it could also be used in biology for making tissue, which could eventually become replacement organs. The Group has already made a range of novel devices that are being tested by biologists in a university setting. Research in this area is in its infancy, but the impact potential is great for both industry and for human life.

Faculty of Engineering, Queen's Building, University Walk, Bristol, BS8 1TR

For further information please visit our website:
bristol.ac.uk/engineering/research