Research

2017

WARWICK

SCHOOL OF ENGINEERING

Warwick Engineering Research in Numbers

4
DISCIPLINE STREAMS

80
TEACHING AND ACADEMIC STAFF

65
POSTDOCTORAL RESEARCHERS

150
POSTGRADUATE RESEARCH STUDENTS

£14.5M
total research income
(Aug 2014-July 2016)

£1M
research income from industry

£4.75M
international income

Photo courtesy of Claire Mackintosh/Clickers Photography Ltd

Introduction

by the Head of Research

Our academic and research staff work with partner organisations to conduct enquiry-driven, fundamental and pioneering research. We strive for significant impact to make the world a better place.

We live in a world which is changing rapidly. New technological solutions emerge every day; at the same time new challenges are constantly appearing. Tackling these challenges is the essence of engineering and, as a unified department, the Warwick School of Engineering is perfectly placed to address real-world problems and to be at the forefront of life-changing technology.

As you will read in this publication, our research engineers hold expertise in a remarkable range of subjects: from nanotechnology to structural engineering; computational fluids modelling to field-based watercourse studies; power semiconductors through to reinforced concrete. From the small scale to the large, and from fundamental theory through to implementation of practical solutions, we offer flexible opportunities for research and development for all engineers. This range of expertise sitting within a single, integrated School combines to offer uniquely broad-ranging and adaptive solutions.

I am proud to act as Head of Research to a growing department which brings together so many internationally recognised researchers. Our core themes of Energy, Biomedical Engineering and Sustainable Cities drive our research portfolio, and our plan to add an additional priority area of Advanced Materials will draw together our world-leading materials research and offer wider opportunities. The emerging areas of resilience and humanitarian engineering are widening our scope for research to aid those who have critical need of our expertise.

If you are interested in collaboration with Warwick School of Engineering, coming here to study or would like more information about any of our research, you'll find contact details at the back of this publication or you can visit our website: **warwick.ac.uk/eng**

Professor Phil Mawby
Head of Research

Our structure

Our academics and research staff sit in a research group, and each group is part of a stream.

This structure supports the work of the researchers whilst giving them the opportunity to collaborate with other disciplines.

Mechanical and Process Stream

- Fluid Dynamics and Multiscale Modelling
- Measurement, Machines and Manufacturing
- Reaction and Material Engineering
- Sustainable Thermal Energy Technologies

Electrical and Electronic Stream

- Connected Systems
- Electrical Power
- Sensors and Devices

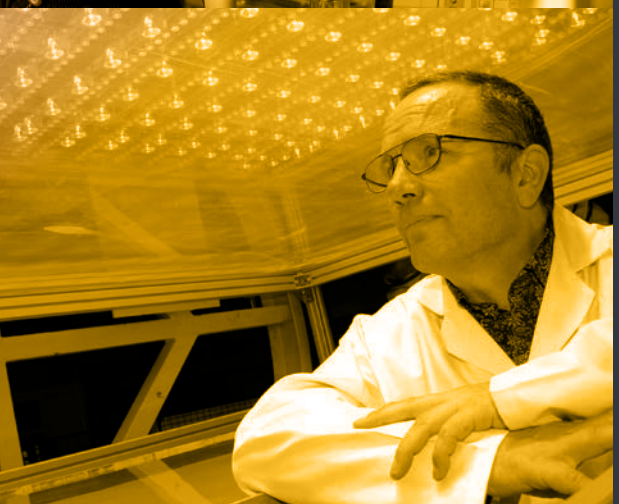
Systems and Information

- Biomedical and Biological Systems
- Information Engineering
- Systems Modelling and Control

Civil and Environmental Engineering Stream

- Ground Engineering
- Structural Engineering
- Water

We also have a research group dedicated to Engineering Education, which is cross-disciplinary.



Research Themes

Our position as a general engineering department strengthens our capabilities, enabling multi-disciplinary, collaborative research.

We work closely with the University of Warwick's Global Research Priorities programmes to develop solutions to world-wide problems, primarily in: Biomedical Engineering, Energy and Sustainable Cities.

Warwick Engineering in Biomedicine goes beyond our Biomedical and Biological Systems group; biomedical research is also undertaken by engineers in fluids, mechanics and sensors. Core areas of research are: Synthetic Biology; Medical Sensors and Diagnostics; Systems Medicine; Neural Engineering; Systems Pharmacology; and Nanobioengineering. Our research covers a broad range of human conditions, including cancer, diabetes, Alzheimer's disease and epilepsy.

Our **Energy Theme** brings together a wealth of research into sustainable, clean and financially-viable energy sources and technologies. Core areas are: Semiconductor research, solar energy, heat pumps, cooling technology, energy efficient systems, chemical energy, and storage solutions. We house a number of state-of-the-art facilities including: a 150 m2 ISO class 6 semiconductor fabrication cleanroom; a large area continuous solar simulator; and a thermal plant modelling and simulation laboratory.

Sustainable Cities focuses on two main areas: how cities can grow in a sustainable way; and smart cities, using ICT to facilitate the underlying mechanisms and operational performances of urban areas. These two broad areas encompass many areas of engineering expertise, including all civil groups, as well as electrical and electronic topics such as sensors and wireless communications.

Fluids Dynamics and Multiscale Modelling

Processes that span wide-ranging time and space scales are encountered in science and engineering in a vast number of fundamental and applied contexts.

Examples are wide-ranging: the flow of blood in humans' complex vasculature; precision fuel injection in high-performance car engines; turbulent flow over drag-reducing coatings on aircraft; efficient mixing of particles or powders in the food and pharmaceutical industries; dislocation creep and crack propagation in failing materials; and the flow of the oceans and atmospheres, which impact our climate and weather. The challenge of understanding and predicting these multiscale processes, particularly those in the field of fluid dynamics, is the core motivation of the group.

Several members of our group work on developing the underpinning science and enabling methodology for a diverse range of fluid flows in nature and technology.

These flows span scales (from atmospheric to the nanoscale), phenomena (from cavitation to combustion), constituents (from granular to rarefied), biology (from pulmonary air to microvascular blood) and engineering application (from turbulent-drag reduction to explosion hazard detection). We also use modelling for a wide-range of processes including the progression of fire, chemo-mechanical processes in materials, and changes in nano-crystalline structures.

Experimental capabilities in our group include: Particle Image Velocimetry (PIV), Laser Doppler Anemometry (LDA), microfluidic analysis, small to large-scale rotating-tank facilities, and Ultrasonic Velocity Profiling (UVP). The group features a wealth of computational expertise and a range of multi-scale modelling and simulation techniques including uncertainty propagation and quantification.

warwick.ac.uk/fluidsandmodelling

Measurement and Machines

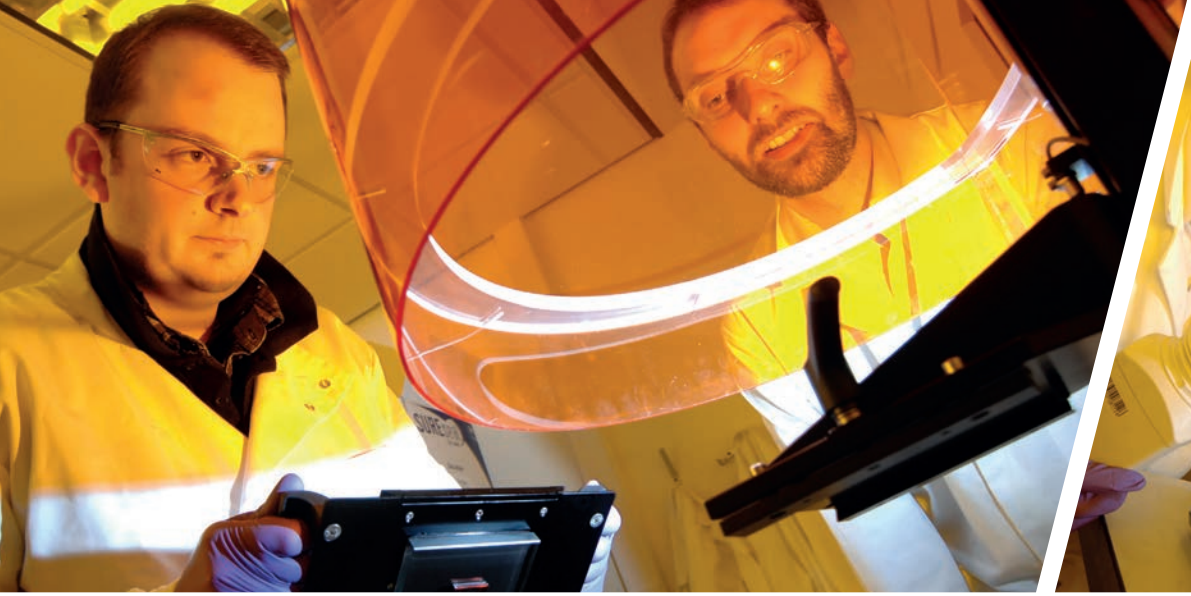
Modern society requires tools for the measurement and characterisation of everything from biological cells to large structures.

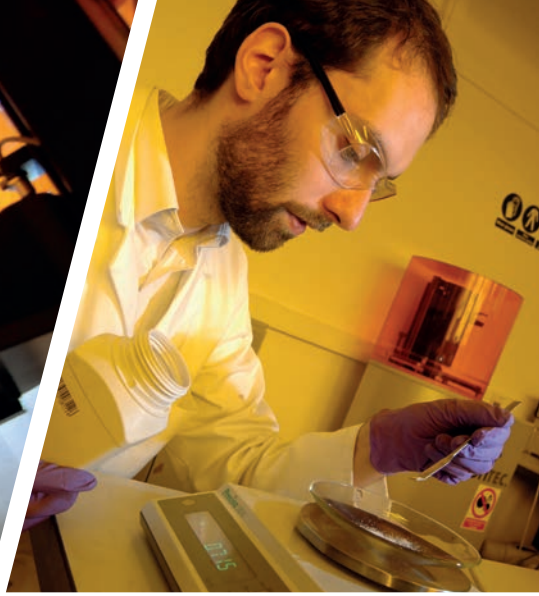
It is important to be able to determine the properties of many different materials, from biological tissue and polymers all the way through to construction materials and dynamic machines. Our research group specialises in technologies and models for determining material properties, the use of modern sensors and microscopes to measure surfaces, the ways to image below the surface of materials, and to predict what will happen in the future.

There are many ways to characterise a material surface or an internal structure, for example a cell can be characterised in terms of its shape and size, but also its mechanical properties. Instruments such as atomic force microscopes can be used for this purpose, but optical techniques are becoming increasingly important in providing not just information on structure, but also to provide optical tweezers to move cells around. In all such measurements, precise knowledge of the dynamic movement and location of different components of machinery is important – a key skill of our research group.

The knowledge of material properties is important in many engineering disciplines, such as the design of lightweight gearboxes, where the wear of surfaces is important. Imaging of internal structure is also important – the mechanical properties of a material or structure will depend on variations within the structure. Our group specializes in optical and ultrasonic techniques for this purpose, and we undertake active research on the imaging methods that can be used for imaging both within the human body, and also for industrial materials, including concrete and metals.

warwick.ac.uk/measurementmachines





Reaction and Materials

This group is a crossroad of physics, chemistry, ICT, materials science and engineering; drawing together expertise to provide cohesive solutions to a number of challenges in sustainable energy and manufacturing.

It brings together six key laboratories: Energy Intensified Reactor Engineering; Energy Materials & Green Chemistry; Catalysis for Renewables; Heterogeneous Catalysis; Electronic Materials for Energy; and Digital and Material Technologies.

Efficient and sustainable materials for energy and manufacturing are a core part of the research, as well as the reduction of waste. Energy Materials and Green Chemistry uses electrochemical synthesis for research around fuel cells as well as waste water treatment. The work in Heterogeneous Catalysis deals with the problems of waste, inefficiencies in processes and adopting the life-cycle approach to process and product development. Catalysis for Renewables aims to develop a complete understanding of catalytic reactions at catalytic surfaces through experimental and computational studies; a wide range of applications is studied relevant to the development of clean and sustainable processes for production of fuels and chemicals. Energy Intensified Reactor Engineering aims for the development of composite magnetic materials for microwave and radio-frequency heating, study of organic synthesis in flow reactors and study of capillary hydrodynamics of multiphase flows in micro-reactors. A UK-wide EPSRC SuperSolar consortium to improve silicon substrates to enable the production of cheaper solar cells is led by academics in the Electronic Materials for Energy laboratory. Digital and Materials Technologies brings together the latest in additive manufacturing and 3D printing technology for the efficient and cost-effective production of components and devices for a wide variety of applications.

warwick.ac.uk/reactionmaterials

Sustainable Thermal Energy Technologies

Efficient and sustainable energy development is an ever-present need in the modern world.

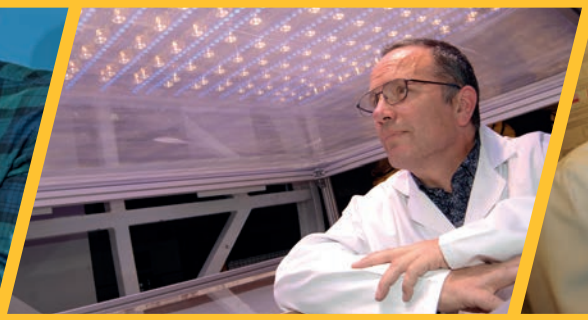
The need to reduce waste energy in a cost-effective manner, whilst keeping convenience, is a driving force in the work of our STET group.

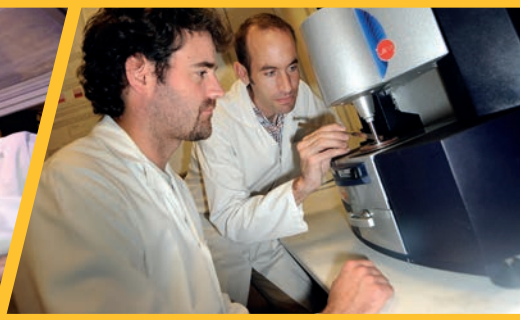
With an 80% reduction in greenhouse gas emissions by 2050 a priority for the UK, the group is collaborating with industry to develop innovative, efficient low carbon heating and cooling technologies to help meet this target.

These include heat driven refrigeration, air conditioning and heat pumping systems, solar heating systems, thermochemical energy storage technology and materials with enhanced properties for use in these technologies.

STET have a range of outstanding research and development facilities to support innovation: the Thermal Properties Lab evaluates the conductivity and thermal storage characteristics of materials; our Thermal Technologies Lab develops novel thermal stores and thermal compressor designs; the ThermExS Lab tests heating and cooling technology on a pilot-plant scale; Environmental Chambers provide a temperature and humidity; the Solar Development Lab includes solar simulators for PV cell and small thermal collector testing; and our Solar Systems Lab includes a large area continuous solar simulator to evaluate the performance of solar thermal and photovoltaic systems. These are available for industry use for the research and development of products and services. In 2016, STET received £1.95million through InnovateUK as part of the Thermal Energy Research Accelerator research theme, which will be used to further develop the facilities to establish a Centre for Thermal Energy Technologies.

warwick.ac.uk/structuraleng





Connected Systems

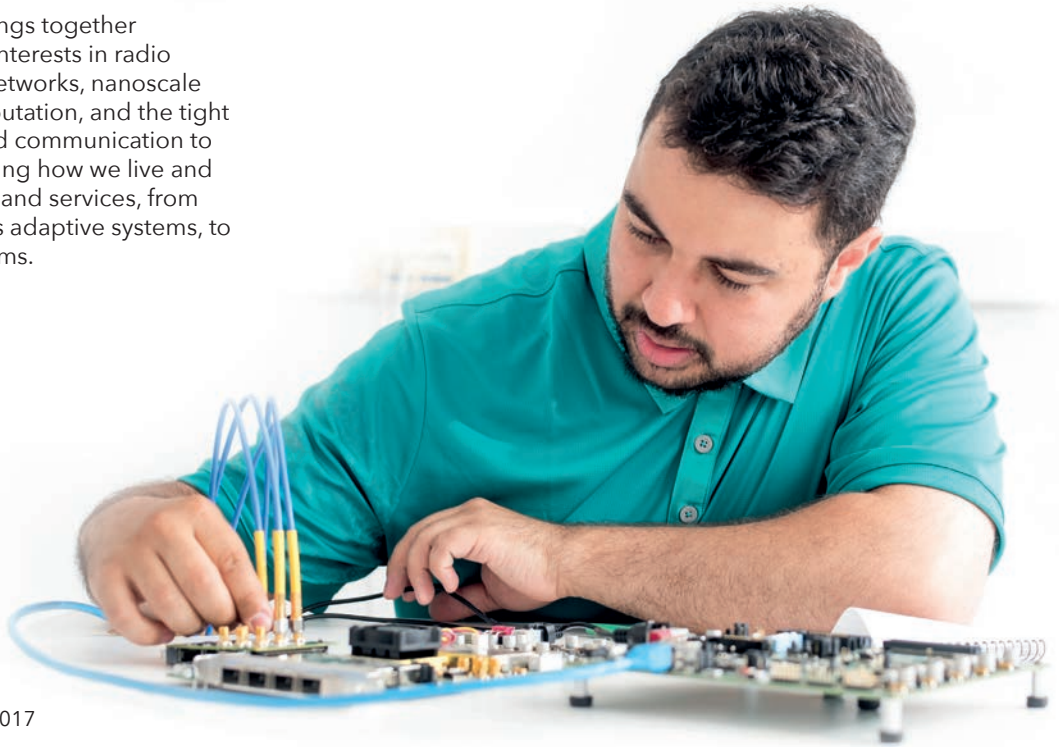
Connectivity is the defining feature of the modern world and has enabled many of the exciting technologies that we have come to rely upon every day.

From personal social interactions to crowd-driven applications, from device-to-device communication to long-distance remote sensing, from vehicular networks to smart infrastructure, integrating computation with varied methods of communication is fundamental to this advancement. As this trend continues apace, we must address questions of how to scale bandwidth to support exponentially increasing numbers of connected devices, how to integrate more intelligence in these constrained systems, and how to do this within a more environmentally conscious power budget.

Our Connected Systems Group brings together academics and research staff with interests in radio and optical communications and networks, nanoscale communications, embedded computation, and the tight interplay between computation and communication to explore technologies for transforming how we live and interact with modern infrastructure and services, from online processing and autonomous adaptive systems, to secure networks and wireless systems.

The group is made up of three laboratories. The Communication Systems Lab leads research in underwater optical communications to achieve high data rates, wireless system design and analysis, energy harvesting techniques, wireless relaying and sensing, and cognitive radios. The Communication Networks Lab covers nanoscale communications to enable very small devices to form networks and noise enhanced transmission. The Adaptive and Reconfigurable Computing Lab undertakes research in reconfigurable computing with field programmable gate arrays, applied to domains from automotive systems, through communications, to datacentre accelerators, focused on the interface between computation and communication in an embedded context.

warwick.ac.uk/connsys



Electrical Power

The Electrical Power Research Group was set up to conduct internationally leading research and drive for cutting edge technology development in tackling the great challenges in power generation, energy conversion, distribution, transmission and efficient use of energy.

Our research is supported by state-of-the-art research facilities in three large research laboratories:

- Power Electronics, Applications and Technology in Energy Research: carries out work in electrical energy conversion, from the very small power (mW) levels to very high power levels (MW). This technology centres on developments in semiconductor switching devices

- Power and Control Systems Research: fundamental research into energy efficiency, power system modelling, simulation, control and monitoring, nonlinear control system theory and its industrial applications.

- Power Electronics Applications: application of power electronics in renewable energy systems, electrical power grids and machine drives.

The group's expertise covers power electronic devices (silicon carbide, fabrications, packaging, reliability, modelling and simulation), power electronics applications, drives and control, power system modelling and control, compressed air energy storage, wind power generation, HVDC, hardware-in-the-loop modelling, simulation and control. They have strong links with industry and work with many major companies. The group also conducts collaborative projects with other universities in the UK and internationally.

warwick.ac.uk/epeng

Sensors and Devices

The necessity for convenience and cost-effectiveness drives research in sensors and devices.

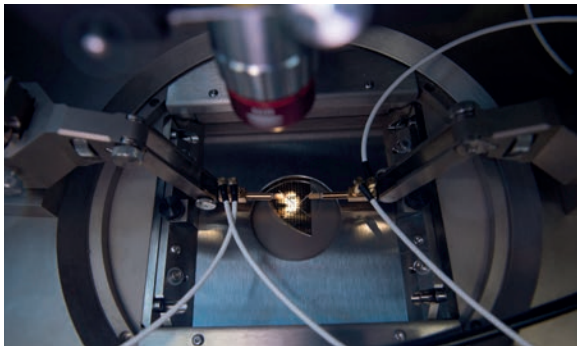
Whether it be smaller and lighter technologies, less-invasive medical procedures, or improving devices for sensing and communication, this is a fast-paced area of research.

The work in sensors takes place within four main laboratories:

- Advanced Imaging and Measurement is part of the UK Research Centre for Non-Destructive Evaluation; a consortium of six UK universities and 15 industrial members from around the world. This involves both core research, and targeted research programmes such as capacitive imaging, which is performed with input from industrial partners.
- The purpose of the Biomedical Sensors lab is to design and develop novel sensors and sensor systems applied to a broad range of application areas including medical studies, industrial applications and plant diseases.
- The Microsensors and Bioelectronics lab focusses on a broad range of technologies, including CMOS based chemical sensors, electronic noses, electronic tongues, and micro-stereo lithography.
- Quantum Devices is a rapidly growing lab group concerned with the practical challenges of fabricating devices in indium antimonide and other closely related materials.

These labs house cutting-edge equipment for use in many application areas, ranging from biomedical imaging and diagnosis through to gas sensing and materials inspection. This wide range of applications arises from the unique sensors and imaging systems that the four laboratories have developed. Central to this activity is the ability to design signals and image processing approaches that enable sensors to make more reliable measurements.

warwick.ac.uk/sensorsanddevices



Biomedical and Biological Systems

This group focuses primarily on challenges in biomedical engineering and biological sciences; both basic research in biomedical systems as well as in issues of health and wellbeing.

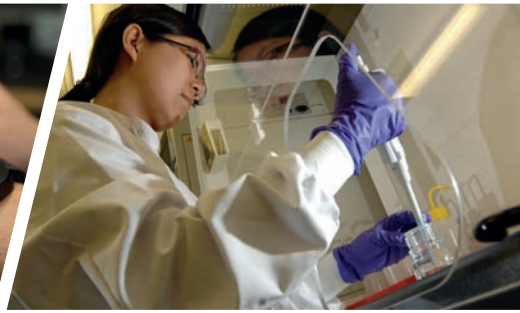
Fundamental research of humans, human systems and healthcare is interspersed with applied projects around the design, development and deployment of assistive technologies and rehabilitation techniques. Various specialties combine together through mathematical modelling, systems engineering, and signal processing alongside anatomy, physiology, pharmacology - applied to various conditions and research goals.

The group is organised into four research laboratories:

- The vision of the Applied Biomedical Signal Processing and Intelligent eHealth Lab is to develop and apply sustainable solutions to emerging challenges of later life, including accidental falls, cardiovascular events, cognitive impairment, frailty and social exclusion.
- The Biomedical & Biological Systems Lab undertakes multi-disciplinary research work for innovative theoretical studies and applications to a wide range of problems in biomedicine, biology and pharmacokinetics.
- Stochastic and Complex Systems Lab works in three main areas: neural coding and speech processing applied to cochlear implants and hearing aids, optimal information processing in noisy systems and systems identification techniques applied to complex systems.
- The primary focus of the Trace Metals in Medicine Lab is imaging and quantifying transition metal ion distribution in the human brain, supporting progress in early detection and diagnosis for neurodegenerative disorders.

Our members also work with the Warwick Integrative Synthetic Biology Centre which delivers an integrated, internationally leading programme of research, innovation and training for synthetic biology.

warwick.ac.uk/bioeng



Information Engineering

Issues around global and personal security, healthcare for the 21st century, and optimisation of wireless communications drive our Information Engineering research; developing fundamental theory and applications relating to the generation, distribution, analysis and use of information in image and video, bioinformatics, health informatics, and optical and wireless communication.

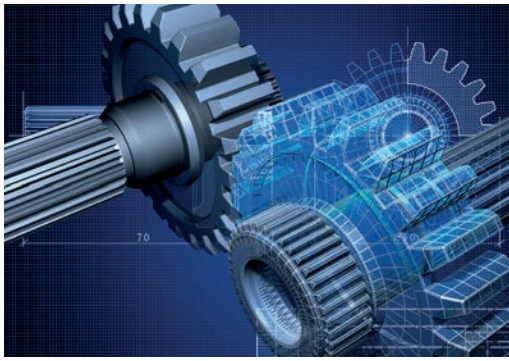
The group focuses on the development of computational models and algorithms, the analysis of signal, image and other data, and machine learning.

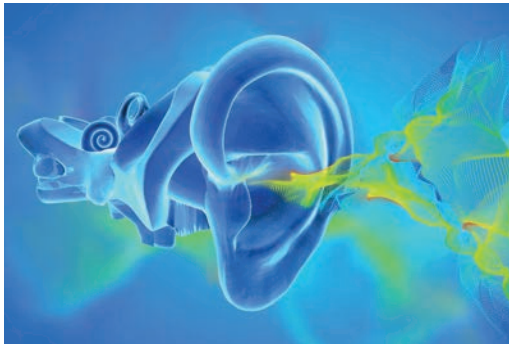
Five distinct research laboratories make up the group:

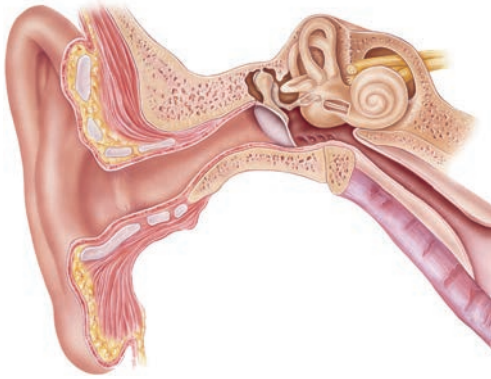
- Image Processing and Expert Systems performs a wide range of image/video processing research with diverse application areas including video enhancement and scene reconstruction for 3D object modelling and autonomous vehicle navigation.
- Applied Biomedical Signal Processing and Intelligent eHealth focuses on applications of information engineering theory and methods to practical health problems, in which eHealth, healthcare technology and information communication technology can give significant contributions.
- Biolab works on techniques to extract information out of omics datasets to enable improved predictive models and on how such information can be useful in synthesizing synthetic biological systems.
- Communications Systems leads on evolutionary optimisation of communication systems, wireless system design and analysis, energy harvesting techniques, wireless relaying and sensing, and cognitive radios.
- Communication Networks covers underwater optical communications to achieve high data rates and nanoscale communications to enable very small devices to form networks.

warwick.ac.uk/infoeng

Systems Modelling and Control







Systems, systems-of-systems and sub-systems are ubiquitous in both the natural and the engineered.

The design and control of system behaviour is therefore a chief challenge where people, technology and the environment interact. In order to address the emergent behaviour of multiple systems, the functional and non-functional interactions between subsystems must be analysed and understood, which involves modelling of the system and therefore identification and estimation of parameters. Together, the members of this group aim to develop the techniques used in the modelling, analysis, design, validation and control of dynamic, multi-domain physical, and other, systems. The aims of the theme incorporate techniques and computer tools for modelling, predicting and analysing the behaviour of dynamic systems; and the techniques employed in feedback control system design and system validation.

Three core areas make up the work of the group:

- **Identification of complex engineering systems:** mathematical models of physical processes invariably include unknown parameters, which need to be estimated from real data. Theoretical techniques exist for ascertaining whether such unknown parameters can be identified from perfect (noise-free) system observations, and we have longstanding research interest in this field of identifiability analysis.

- **System-of-systems in applications to automotive vehicles:** a major field of research concerns the application of systems engineering approaches in the design, development and validation of systems within automotive vehicles.

- **Chaotic systems - interplay between noise and chaos:** many low-dimensional nonlinear systems exhibit the complex behaviour known as deterministic chaos. Although chaos is observed in many engineering objects, the chaotic regime is undesirable and it is avoided in systems' design. In many cases it leads to strong limitations in use of engineering systems.

warwick.ac.uk/systemsmodelling

Ground Engineering

Global expenditure on energy and transport continues to increase as nations race to improve economic performance.

Much of the UK's energy and transport infrastructure will have to be built on unavoidably problematic soils, such as the soft estuarine clays or London Clay; as available space for new development becomes scarce. Due to the UK's weather conditions, there tend to be frequent instances of serious slope failure or landslides every year. With the development of new vehicular transportation technology, the increasing vehicle speeds place increased demand on embankment stability and reliability. New excavation methods are also required for renewable energy development.

This group focuses not only on the core aspects in geotechnical engineering, but also on wider cross-disciplinary aspects in geotechnical engineering. Examples of research include:

- Numerical and experimental modelling of the initiation of landslides and subsequent debris flows under various climatic conditions.
- DEM numerical investigation of the behaviour of sands and cemented soils for constitutive modelling purposes and of engineering problems such as tunnelling in jointed rock masses and the stability of rock slopes.
- Hazard assessment of landslides based on geotechnical modelling and its integration with remote sensing.
- Determination of optimal slope shapes for engineered slopes and open cast mines via analytical modelling and experimentation.

Our research projects are directly linked to current railway development in the UK, including high-speed train embankment stabilisation techniques, long-term performance prediction, vibration and noise reduction techniques and the railway line health monitor techniques, which are currently conducted by numerical simulations, advanced lab tests and field tests.

warwick.ac.uk/groundengineering

Structural Engineering

Construction materials and structures have an important role to play in sustainable and resilient development through efficient application, smart structural design, energy performance and durability.

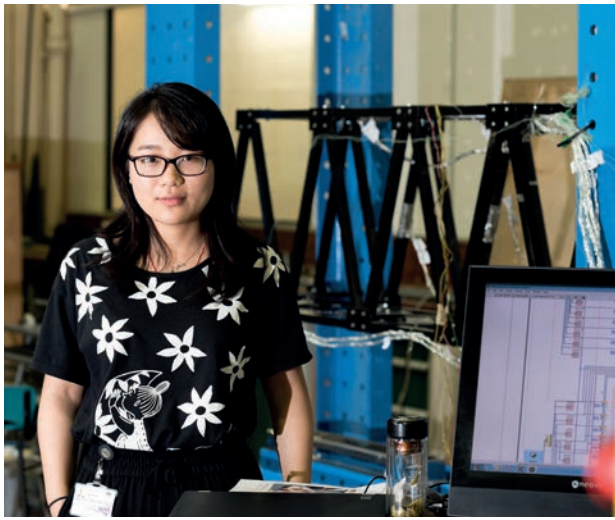
Developing new and modifying existing materials and structures is one approach to achieving a more sustainable and resilient building environment. Good design is synonymous with sustainable construction and this requires materials and structures research. Current activities within the group focus on the characterisation of components, joints and whole structures of new or traditional materials, and/or of innovative or unusual forms.

Our research involves evaluation of results from both full-sized static and dynamic testing in our structures laboratories and advanced computational modelling. Research on resilience focuses on: damage-free, seismic-resistant, self-centring steel and steel-concrete composite frames; smart, fully replaceable and demountable steel connections; passive (metallic, viscous, elastomeric) dampers; and multi-hazard (seismic, wind, blast) resistant design procedures.

Research into vibration pollution and human-structure interaction is ongoing. Structural health monitoring is another area of research explored within the group. It involves damage detection, measurement and structural identification.

We have links with other research groups focussing on smart structures. Smart structures use integrated communication and sensor systems to monitor and manage performance, and within buildings to support the lifestyle choices of the occupants. The transfer of academic results into the drafting of standards, industry manuals and codes of practice is also undertaken and this ensures there are strong and synergetic links with end user groups.

warwick.ac.uk/structuraleng



Water Engineering

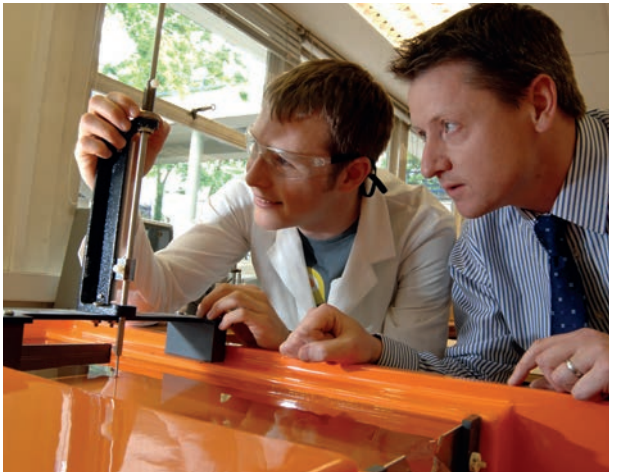
This group undertakes research into aspects of water engineering, the environment and sustainability.

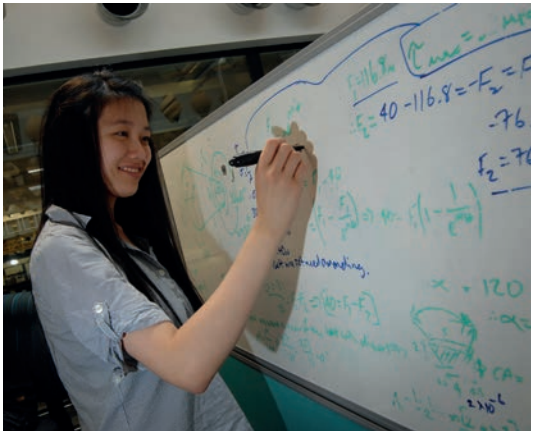
More frequent storms, increased development and improved environmental legislation all necessitate an enhanced understanding of mixing and transport in urban drainage systems. The research assesses how urban drainage structures (manholes, storage tanks, combined sewer overflows, ponds and wetlands) influence these processes. It focuses on identifying and quantifying the fate of soluble pollutants and contaminated fine sediments within rivers, urban drainage systems and the coastal environment.

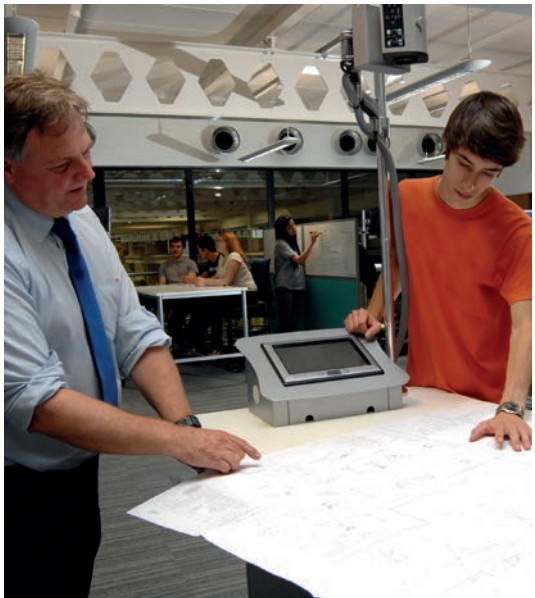
Our recent projects include work on the accumulation and dispersal of suspended solids in watercourses. Vehicles and highway maintenance activities produce a number of environmental contaminants which can enter watercourses during rainfall events. Field monitoring has quantified this load and investigated the effects of highway derived contaminants over a number of years at field sites across the UK. Results have been linked directly to the impact on receiving water ecology. Laboratory and field-based studies have been performed to elucidate hyporheic exchanges and transient storage in rivers.

Projects have been conducted in both the nearshore and estuarine environments. The nearshore zone experiences pollutant loading through both the shoreline and seaward boundaries. From the seaward boundary, pollutant loading is transported landward towards surfzone wave activity, whilst from the shoreline boundary, run-off pollution, which can contain faecal indicator bacteria and human viruses, can drain into the surfzone. The long term aim of the research is to improve the knowledge of fundamental mixing processes, quantify their relative magnitude and enhance the predictive capacity of models describing the transport, mixing and fate of pollutants and fine sediments within the water environment.

warwick.ac.uk/waterengineering







Engineering Education Research Group

This group was founded in 2016. The Teaching Excellence Framework will provide a mechanism for the monitoring and assessment of teaching quality in UK universities.

It creates an opportunity for universities to demonstrate teaching excellence with key performance indicators to include: employability; student satisfaction and value for money. We are therefore challenged to contribute to pedagogy by undertaking robust projects which are effective and can be implemented across sector. We must define what we want the academic experience to be and how we can measure it to ensure continuous monitoring and improvement for students, teachers and stakeholders. As an integrated School of Engineering we are in a unique position to create an evidence-based approach to support our common foundation as well as to exploit the interdisciplinary nature of our degree.

Our group's vision is to prepare a syllabus and learning environment that: engages the students and teachers; develops transferrable skills and technical competence; and builds on Warwick's systems approach to Engineering philosophy. The core objectives are to: be involved in a range of innovative research projects in Engineering Education and Pedagogy; ensure the highest quality and most relevant Engineering Education for students in the School of Engineering; develop the understanding that will enable colleagues across the sector to introduce innovative and relevant learning and teaching practice that addresses the needs of industry whilst engaging students in their learning.

The group has received funding for a variety of research studies into teaching practices.

warwick.ac.uk/eerg

Industrial Links

The School of Engineering is proud to collaborate with companies based in the UK and internationally.

Current collaborators include:

- Advanced Bionics
- Alphasense UK
- Alstom
- AstraZeneca (Sweden)
- AVL Powertrain UK
- Baxter
- BTS Holdings plc
- CK Solar
- Cochlear Corporation
- CooperWalsh
- Dynex Semiconductors
- Dyson
- Eltek Semiconductors
- E.ON
- FTI Communication Systems
- GE Energy
- GE Power
- Hyundai
- IBM
- Jaguar Land Rover
- La Vision
- National Grid
- Norgine
- Owlstone UK
- Premier EDA Solutions
- Qinetiq
- Rolls Royce
- Severn Trent Water
- Smart Manufacturing Technology
- Thales Alenia Space UK
- Thales Research
- The Binding Site Group
- TVS Motor
- UNPS
- Williams F1

We collaborate with our partners to produce research results that impact the wider society. The next pages feature case studies of how our research has produced lasting impact.

CASE STUDY 1

Improving the lives of patients with kidney disorders

Through the mathematical modelling of biomedical processes, outcomes for patients with multiple myeloma (a form of bone cancer that can lead to kidney failure) have been vastly improved, with the result that dialysis treatment may no longer be necessary alongside their myeloma treatment.

Regaining kidney function for these patients improves quality of life and results in significant cost savings for the NHS. Research into the modelling of the kinetics of whole antibodies produced by multiple myeloma patients (and others) has also had an impact on patient outcomes and clinical decisions, as well as economic benefits for a global medical technology company.

Warwick researchers, led by Dr Mike Chappell, modelled the prevalence of free light chains in patients with multiple myeloma, and the effect of these light chains on kidney function on the outcome of certain forms of chemotherapy. Patients with multiple myeloma and severely-reduced kidney function or kidney failure can become dependent on dialysis, which is an additional burden on their quality of life as well as being costly from an economic perspective. In order to improve the quality of life of such patients, a key objective is to remove the greatly increased amounts of the free light chains produced, permitting recovery of kidney function and hence a release from dialysis dependence.

This modelling work prompted a series of local clinical trials between 2006-8, in which multiple myeloma patients with kidney failure were treated using larger filters than previously used and over extended dialysis sessions, being up to 12 hours daily for a few weeks compared to the previous treatment of 3-4 hours three times per week potentially indefinitely.

The results of these trials were extremely encouraging, with 85% of patients recovering kidney function and no longer requiring dialysis treatment.

The promising results obtained from these trials led to a Europe-wide series of clinical trials. The modelling has also been applied to the treatment of other medical conditions such as rhabdomyolysis. A two compartment model has been developed by Warwick to treat rhabdomyolysis patients undergoing dialysis for the removal of myoglobin. The application of the modelling removes myoglobin more effectively without the removal of other larger essential molecules.

This modelling work is now being extended to consider the impact of antibodies as novel biomarkers in the treatment of multiple myeloma with Warwick Impact Fund/EPSRC funding to support this research.

CASE STUDY 2

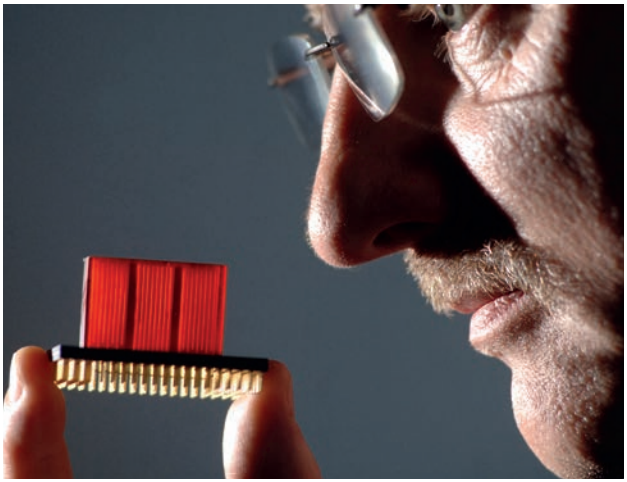
Sniffing out disease and bacteria

The first commercial electronic nose (aka e-nose) instruments were designed, developed and built by researchers in Warwick's School of Engineering in the 1990s for commercialisation.

Warwick's patents in chemical sensing also led in 2008 to the creation of a spin-out company, Cambridge CMOS Sensors Ltd (CCS), which provides low-cost low-power gas-sensing technology and is already established in the gas-sensing market.

The smart sensors and instrumentation developed as a result of the pioneering research in artificial olfaction and chemical sensing have led to economic impact across a wide range of sectors, in particular in food quality, healthcare and consumer electronics. Thousands of e-nose instruments have been sold to help quality assurance of foods, beverages and are also now being deployed in hospitals for bacterial detection.

The measurement of smell is critical to industries worth billions of pounds, such as agri-food, drinks, air quality, security (drugs) and cosmetics. Furthermore, malodour can be an indicator of bacterial infection and diseases so important for healthcare. Human (organoleptic) panels are routinely used to measure smell but are costly, slow and subjective hence the desire for an e-nose that can detect smell. To classify odours, the human olfactory system uses hundreds of different olfactory receptors and a specialized neural architecture. The functionality of such a complex system can be mimicked by an artificial system that uses electronic sensor arrays and pattern recognition algorithms.



Building on the concept of an artificial nose (first proposed by two Warwick biochemists) Professor Julian Gardner designed, developed and built the first commercial e-nose instruments in 1993 with the company AlphaMOS (France).

Professor Gardner (currently head of Warwick's Microsensors & Bioelectronics Laboratory, formerly known as the Sensors Research Laboratory) continues to push forward the research and development of electronic noses, in particular the optimization of instrumentation for a range of commercial applications, such as breath analysis for low-cost healthcare monitoring.

CASE STUDY 3

Setting the standards of European-wide construction

Research led by two members of the School of Engineering strongly influenced the planning, drafting and technical content of nearly all of Eurocode 4, one of ten European civil engineering standards. Eurocode 4 covers composite structures made of steel and concrete.

Since 2010 this standard has been in force in all countries of the European Union (EU) and the European Free Trade Area (EFTA). The Eurocodes are the only set of design rules for publicly-funded structures on land that satisfy national building regulations throughout the EU and EFTA. Their impact on structural engineering is wide-ranging and growing, the principles and methodology contained within these Eurocode 4 will be the basis of engineering design teaching for Chartered Engineers throughout the EU.

The rules of the EU and EFTA require that barriers to trade among member countries are removed, so it was necessary for the European Commission (EC) to generate a set of principles and rules for the design and construction of composite steel and concrete structures that would be accepted by each country and would satisfy their diverse national standards. To achieve this, research was needed to resolve differences in the meanings of units, symbols and so on and in the legal status of standards between nations. The new standards (Eurocodes) were based on the best available scientific evidence with uniform and consistent margins of safety and are designed to protect workers and the public and to save construction costs. The rules of Eurocode 4 were strongly influenced by research led by Professors Roger Johnson and David Anderson.

As conveners of the EU project teams they were actively engaged in all the technical aspects. This involved studying competing methods for design of composite structures (typically based on current national practice), calculations for evaluation and calibration, devising compromises and making proposals (often based on their own published research) that were adopted.

The timescale of the development of Eurocodes is long (it took over 30 years to develop them). However, the draft Eurocodes influenced the basis of structural design of a few international projects in the 1990s. Examples are the famous bridge over the Øresund between Denmark and Sweden (2000), and a novel structure for the Millennium Tower in Vienna (2000).

CASE STUDY 4

Improving the design of complex automotive systems

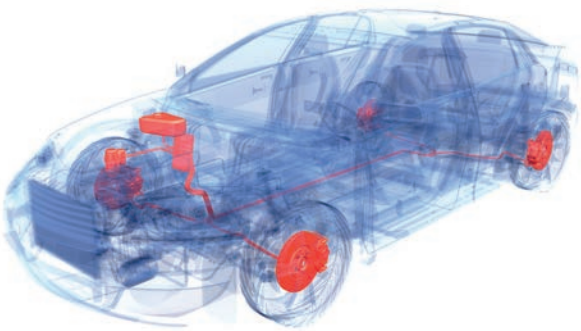
The vast majority of innovative features in modern automobiles are realised through the use of electronics and software.

This has resulted in automotive electronic systems becoming extremely complex. An associated challenge arises in testing and validating such complex systems of systems, in a way which is safe and efficient. Research performed in the School of Engineering in co-operation with researchers in WMG at Warwick, and in collaboration with industrial partners, has profoundly influenced the product development processes within key automotive companies and their supply chains. This research is centred on the work of Dr R. Peter Jones (Reader, now Emeritus Reader), beginning in the late 1990s with a very early investigation into the feasibility of applying emerging hardware-in-the-loop simulation technology to create robust approaches to validate the functionality of control systems.

Key research includes:

- Trialling an innovative, configurable hardware-in-the-loop simulation platform to be used in vehicle development programmes.
- Early research into novel methods for detecting and diagnosing failure conditions in a vehicle's distributed, embedded electronic systems.
- Concept and prototype development of an innovative vision-based system and test regime for automatic validation of vehicle infotainment systems.

Warwick has helped to implement a range of innovations within the automobile industry, leading to improved car functionality, significant company savings in product development time and costs, and more reliable electronic systems that deliver significant boosts to brand reputation. A range of Masters-level training modules for the automotive industry have also been developed as a result of this research.



CASE STUDY 5

Improving power electronics for performance and reliability

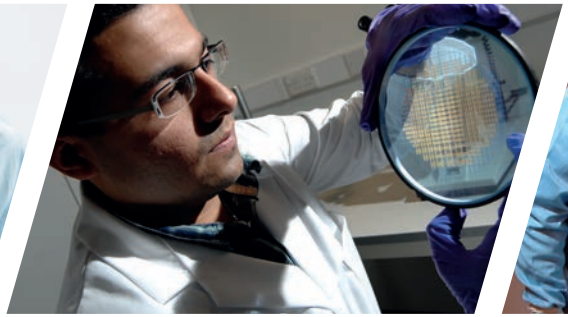
The control and conversion of electrical power is key to the efficient, safe and reliable use of electrical and electronic energy.

Power Electronics is a growing multi-billion dollar industry and is critical for the development of the automotive, aerospace, and power conversion industries. Professor Philip Mawby leads the Power Electronics Applications and Technology in Energy Research (PEATER) group which focusses on fundamental underpinning power-semiconductor work to support power electronics related industries.

Part of the research concerns the development of a silicon carbide based MOSFET technology. Silicon Metal-Oxide-Semiconductor-Field-Effect-Transistors (MOSFETs) are the building block of most modern power electronics systems. They can process power from a few milliWatts to hundreds of megaWatts. Silicon has proven to be an excellent material for this purpose; however, the technology has developed to such an extent now, that it is limited by the properties of the material they are fabricated from. The properties of silicon carbide (SiC) mean that it will be much better than silicon, allowing the performance for the basic building block to be vastly (at least 2 orders of magnitude) improved. The performance is measured in a number of ways; power density, efficiency, and system costs are probably the main measures.

Research by the PEATER group in this field of power electronics and silicon carbide (SiC) devices has led to wide-ranging impact. Firstly, significant improvements in performance, reliability, cost and weight in a major hybrid car model, which has produced over two million vehicles using the technology. Secondly, direct changes to the technology to be used within the next generation of aeroplanes produced by a major manufacturer; improving the electric power distribution methodology and potentially reducing costs in the sector.

The research also led to the formation of a spin-out company, Anvil Semiconductors, to support commercialisation of SiC in power devices. Professor Mawby led the automotive theme in the review of strategy for the future of UK power electronics commissioned by the Department for Business, Innovation, and Skills (now BEIS).



CASE STUDY 6

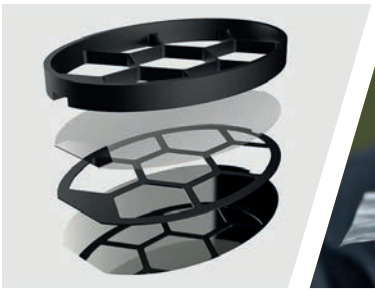
The invention of a super-thin, flexible loud speaker

Warwick Audio Technologies Ltd (WAT) is a spin-out company from the School of Engineering that was formed to exploit an invention: a flat, thin, flexible loudspeaker that operates on electrostatic principles.

The invention arose from work that the ultrasonic group had been performing on airborne ultrasound transducers, led by Dr Duncan Billson and Professor David Hutchins.

The loudspeakers are being manufactured in the UK, and sold through a distribution network under WAT's subsidiary company 'ZonarSound' to a commercial market. Discussions to introduce the loudspeaker into the mass market (in different consumer products) are at an advanced stage and the first production run has been completed. There is also interest from a wide range of sectors, including automotive, domestic electronics and public transport, which can benefit from utilising the technological advantages of the new loudspeakers. Key features of the technology include: highly directional capability; extremely light weight and thin products; relatively inexpensive to produce; and ultra-low power consumption. All this is achieved whilst retaining the highest quality sound output with a high level of discrimination.

WAT has also worked with its brand partner, Sonoma Acoustics to produce headphones with the ultimate clarity of sound. The Sonoma M1 Headphone System was launched at the Rocky Mountain international Audio Fest in October 2016 in Denver, Colorado. At the show, the HPEL (loudspeaker) technology won the prestigious Editor's Choice award from Innovation and Tech Magazine.



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