CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

Aerospace, Defence and Security

Contents

A world leading University

Cardiff University has an international reputation for excellence in teaching and research, recognised by our membership of the elite Russell Group, the UK's leading 24 research-led universities. Our world-leading research was ranked 5th amongst UK universities in the latest Research Excellence Framework for quality and 2nd for impact. We attract the best students and staff from around the globe and our commitment to deliver research-inspired teaching enables our graduates to be innovative individuals who push the boundaries of their disciplines. Teaching at the University was given the highest possible award in the last UK Government review.

As one of Wales anchor organisations and an institution of enterprise, research and learning, we have a strong track record of collaborative research with industrial partners, including those in the aerospace sector.

The aerospace industry is one of the most dynamic and successful sectors within the UK and Europe, creating millions of jobs and billions of pounds of turnover each year. Such levels of success have been achieved by meeting the continuously rising demands for lower costs, better service, seamless integration with other transport networks and the very highest safety and environmental standards. Previous requirements for "Higher, Further, and Faster" are now becoming "More Affordable, Safer, Cleaner and Quieter" reflecting the need to combine cost effectiveness with an uncompromising attachment to safety and environmental objectives.

Technology has a vital role to play in addressing these challenges and for over 30 years researchers at Cardiff University have been working hard to develop the innovations necessary.

This document outlines some of the opportunities from across the University that are of direct relevance to the aerospace sector. It is by no means exhaustive, but gives a flavour of some of the research and teaching activities undertaken and also potential areas for future collaboration.

Aerodynamics and Flow Control

Overview

The reduction of environmental impact of the aerospace industry is a key driver in the development of new aircraft and their aerodynamics can play a significant role in achieving such aims, through the control of laminar flow and reduction of drag.

Researchers at Cardiff University have made significant contributions within the aerodynamics field through the derivation of a new velocity-vorticity formulation of the Navier-Stokes equations. This formulation has proved to be particularly suitable for calculations of boundary layer disturbance evolution and control and has allowed researchers at Cardiff and around the world to study complex aerodynamic problems. Work under taken at Cardiff has demonstrated that compliant surfaces and MEMS devices can be utilised to delay the transition to turbulence in boundary layers, therefore reducing drag.

Projects

AEROMEMS I & II

Previously funded by the European Commission, the AEROMEMS projects assessed the viability of applying MEMS devices for boundary layer control on aircraft. The project undertook industrial scale wind-tunnel demonstrations and engineering integration assessments of MEMS flow separation control technology applied to improving the performance of wing high-lift systems, intake ducts and turbo-machinery components.

"Waggle Wings"

The discovery that waggling a wing section from side to side within a wind tunnel reduces drag friction led to an EPSRC funded project aiming to utilise the effect. The project demonstrated that causing the airflow to oscillate across a fixed surface had a similar effect. The new approach, which promises to dramatically reduce mid-flight drag, uses tiny air powered jets which redirect the air, making it flow sideways back and forth over the wing. Research has demonstrated that this micro-jet system could reduce skin friction drag by up to 40%, having a major impact on the aerodynamic design and fuel consumption of aircraft, as well as cars, boats and trains.

Oscillatory flow instability and laminar flow control

Fundamental studies have been undertaken to understand the behaviour of oscillatory flows adjacent to solid surfaces. This work was originally conducted as part of a joint project with researchers based at the University of Western Australia, which was fully funded by an Australian Research Council grant. Results obtained during the project suggested a new strategy for laminar flow control over aircraft wings. This work is currently being followed up by two Cardiff doctoral research students, with funding from the Engineering and Physical Sciences Research Council. Other aspects of laminar flow control have also been investigated, in collaboration with researchers based at Imperial College London, as part of the Laminar Flow Control UK project.

Airborne Systems

Overview

The airborne systems group is engaged in the development of compact, lightweight sensors, actuators and communication systems for a range of applications within the aerospace field including fixed wing, rotor and unmanned platforms.

Magnetoelastic and magnetostrictive materials are employed in the development of advanced stress sensors and actuators designed to reduce size, weight and cost for integration into micro-elecromechanical systems. At the same time improvements in spatial and temporal resolution and accuracy have been demonstrated as well as increased stress response and contactless operation.

Applications of this technology have included stress sensors for aerospace applications and for the space shuttle. Researchers also focus on the reduction in size and weight of wireless communication equipment, whilst reducing the energy consumption required for the generation of radio signals (from MHz to tens of GHz) for wireless communication and wireless detection/monitoring, e.g. RADAR and wireless signal jamming is essential for space based (satellite) and UAV based applications.

Facilities

Within this group facilities exist analysis of the structure and properties of magnetic materials. These include imaging facilities, bulk material characterisation and micro/nano material characterisation.

- **Fabrication capabilities** include amorphous wires fabrication, a rotating water quenched wires unit, a glass coated wires preparation unit and the ability to fabricate nanowires.
- **Performance characterisation** is carried out using a 3 phase transformer tester (characterisation of transformers - rating up to 15kVA), an instrument transformer test set, a wide range of dynamometers (maximum speed 24000 rpm, maximum rating of 24kW), electromagnetic emissions and immunity testing (including conducted, radiated, ESD, surges, interrupts, harmonics and flicker), a hemianechoic acoustic chamber and calibrated microphones.
- **Modelling and simulation** can also be performed using software including Vector Fields Opera and Infolytica Magnet for the simulation of 2D and 3D electromagnetic applications.

Projects

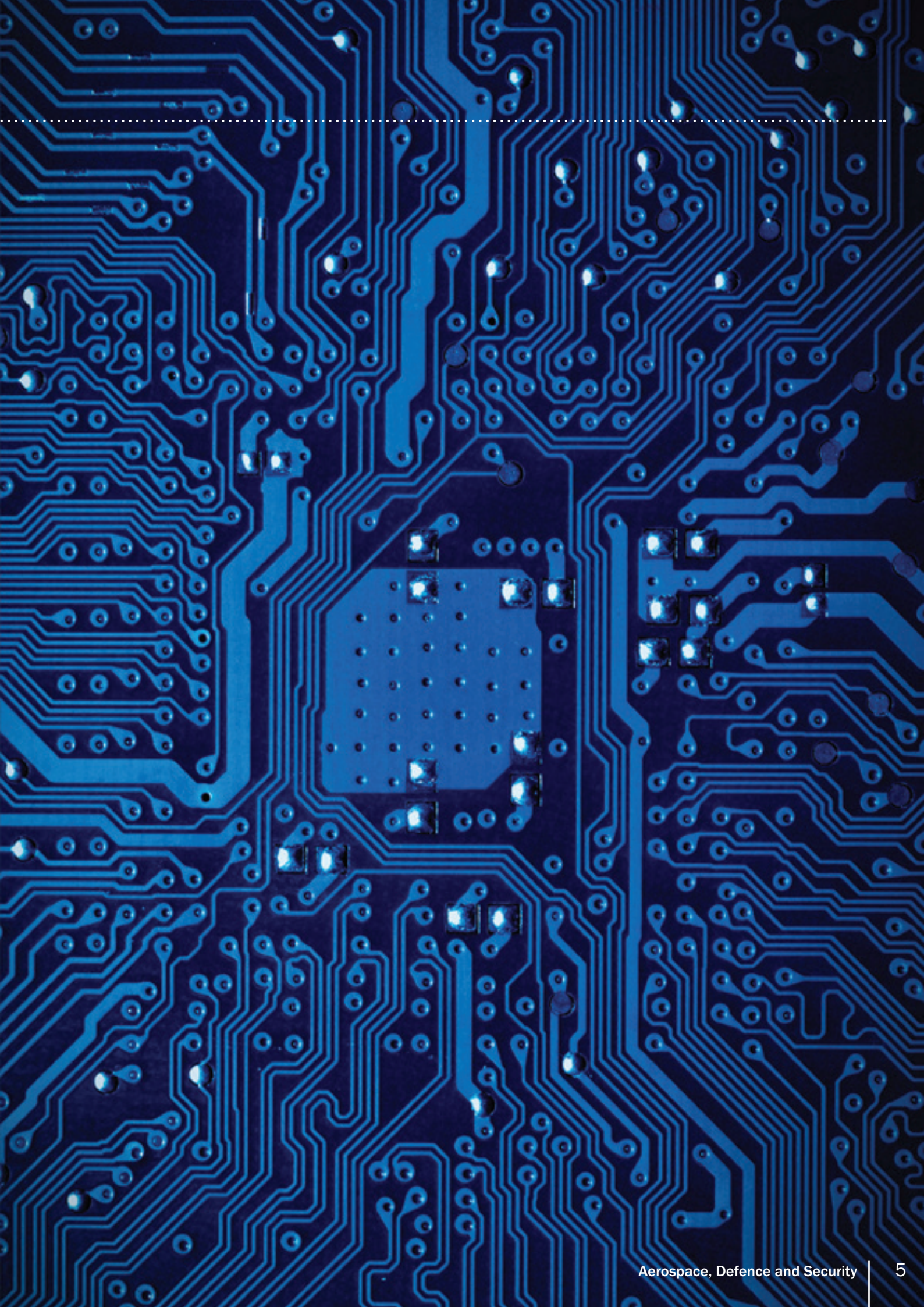
Magnetic Materials – Structural Health Monitoring of Helicopter Blades

This project aimed to develop a new method for evaluating mechanical stress using a magnetic non-destructive testing technique based on ‘Barkhausen noise’, to determine residual stresses on helicopter components following different types of machining. Magnetic properties, including magnetic Barkhausen noise depend on the mechanical condition of the material. Measurements of these properties can be used for surface and subsurface material evaluation.

Wireless Communication – Energy Efficient Electromagnetic Sensors for Airborne Systems

All airborne systems, both civil and military, incorporate electromagnetic sensors, e.g. radar systems, GPS, for numerous applications, i.e. safety and surveillance. Since in most cases energy budget is highly constrained, one of the key ways to get more functionality from these sensors systems is to improve their DC to RF energy conversion efficiency. This is the role played by the RF Power Amplifier.

The Centre for High Frequency Engineering is working jointly, on a number of projects, with QinetiQ and SELEX, to develop high efficiency X-band RF Power Amplifiers. This involves the extension, to high frequencies, of the techniques already developed by the Centre that have enabled the development of state-of-the- art high efficiency RF Power Amplifiers for the Mobile Communication Sector.



Human Factors

Overview

There are few examples of equipment, machinery or aircraft that do not require an operator to interact with some form of computer or data display. Understanding this interaction and the way in which data capture, processing and display can effect an operators decision making and stress levels can lead to improvements in safety and efficiency.

The human factors group study many aspects of human communication and interaction, in particular focussing on interaction with computers, decision making and interpretation of data and information. The Human Factors Technology Lab at Cardiff University ensures a truly interdisciplinary approach to this research area, bringing together staff and facilities from the Schools of Psychology, Engineering and Computer Science.

Facilities

Approximately 300 m2 of space in the School of Engineering has been refurbished to accommodate researchers, research leaders and visiting researchers, supported by a connection to the GRID, individual study areas, a local area network, a human performance laboratory, three interconnected booths, a rapid prototyping facility for proof-of-concept hardware and software systems, and general-purpose laboratory bench space.

The human performance laboratory aims to investigate many aspects of human communication and interaction through imaging, video, audio, and motion capture.

Projects

Designing Data Fusion Displays for Situation Awareness

The battlefield is typically a highly dynamic environment and the proliferation of information sources has meant that operators find themselves "swamped with data and starved of information" and in short, operators have poor situation awareness. This project sought to investigate the relationship between fused displays and situation awareness in order to provide feedback to developers concerning the effective and efficient design of fused displays.

Situation awareness broadly refers to the operators' understanding of the environment. Whilst data fusion seeks to improve operators' performance by reducing their workload, we have to ensure that fused data supports directly the operators' cognitive processes during task performance. It is not inevitable that fusion technologies will achieve this. In this work the relationship between fused displays and situation awareness was investigated.

Problem Solving with Information Access Cost in Mind

Problem solving is often conducted within the context of an external display. However, the time, physical effort and mental effort associated with accessing information from such displays may vary. This work was focused on the assessment of the extent to which problem solving search strategies would be sensitive to changes in Information Access Cost and would influence planning behaviour.

Lightning Protection

Overview

The effects of lightning strikes are a major concern for a number of different industries including aerospace, power distribution, wind turbine manufacturers and the construction industry. The issue is most clearly highlighted in the aerospace industry, where a commercial aircraft would expect to be struck on average once every 10,000 flight hours, or approximately one strike per aircraft per year.

Advances in materials technology within the aerospace industry have heightened the importance of lightning protection. The new generation of commercial aircraft has seen increased use of composite materials in the pursuit of weight reduction and fuel efficiency. While traditional Aluminium airframes offer reliable lightning protection, achieving the same level of immunity using composite materials requires careful design.

This must be achieved in a manner optimised for cost, weight, manufacturing and maintenance, whilst maintaining the required levels of safety.

The Advanced High Voltage Engineering Research Centre have been working for many years to understand the fundamental factors controlling the effects of lightning strikes on composite and metallic structures, influencing material selection and product design.

Key areas of interest include the development of novel methods of lightning protection, improved methods for the test and verification of lightning protection, developing new diagnostic techniques for the harsh high current test environment, and simulation of electrical field distribution for improved design of critical aircraft components. In 2011, the Morgan-Botti Lightning Laboratory was established to further focus.

Facilities

- **The Morgan-Botti Lightning Laboratory**

  The Morgan-Botti Lightning Laboratory has been established, with support from Airbus and the Welsh Government. This facility is unique within the university sector and one of only a handful of lightning direct-effects facilities worldwide.

  The laboratory provides a research and test capability for understanding and enhancing the science of lightning protection. The laboratory has four generators that produce a suite of current component waveforms ('A' - 200kA, 'B' - 2kA, 'C' - 400A and 'D' - 100kA) as defined in EUROCAE ED84-A/SAE ARP5412. These impulse currents are used for standardised testing both Carbon Fibre Reinforced Plastic (CFRP) and aluminium materials and components.

  Diagnostic capabilities currently include a 550mm x 550mm coaxial rig for flat panel testing, multi-channel fast response current and voltage monitoring, digital stills photography, high speed photography up to 775kfps with infrared laser illumination, high resolution thermal imaging up to 3kfps, fast wideband transient light intensity measurement and visible/near-infrared spectrograph systems. The lab facilities also include sample preparation equipment for sectioning, mounting and surface preparation of samples prior to analysis using software-driven optical microscopes and a benchtop scanning electron microscope.

  The development of advanced, novel and improved measurement capabilities forms an integral part of the laboratory's ongoing research activities.

Projects

Protection of Structures from Lightning Strikes- PROTEST- (ATI/InnovateUK)

A collaborative research project with Airbus Group, Airbus Operations, Hexcel and the National Composites Centre aimed at developing a better understanding of the phenomena and physics involved in aircraft carbon-composite joints. The project addresses two main aspects: the derivation and collation of specific data on the impact of lightning strike on key elements of the structure of an aircraft, and the integration of this information and existing models into predictive tools applicable to the design process.

Dynamic capacitive sensor for the measurement of millimetre-displacement of carbon composite panels (Sêr Cymru NRN)

The direct attachment of lightning to an aircraft exerts enormous forces on the structure, due primarily to the magnetic field interaction between the arc channel and the current flowing in the aircraft skin. This project aims to better understand the extent of mechanical deflection exhibited by carbon composite panels under high current conditions through the development of a novel high speed displacement sensor applicable to the harsh high-field environment of the test chamber.

3D Electrical Field Simulation around an Aircraft Radome

Theoretical and experimental simulations have been carried out in order to understand the physical processes and mechanisms of direct lightning strikes to aircraft. Electric field calculations have been conducted to determine the field distributions around the radome of the aircraft. 3D electric field and potential distributions inside and outside the aircraft radome placed in a uniform external electric field, but with different aircraft inclinations, were analysed using the finite element method. It has been shown that the shielding effect increases with the length and number of solid strips, and that segmented strips do not produce significant lightning shielding effects in the absence of a discharge.

A new design of segmented diverter strip is under development. This makes use of nonlinear ZnO to provide the required conductivity to lightning currents whilst minimising the adverse effect on the radar antenna pattern which can occur with conventional solid strips.

Manufacturing

Overview

Aircraft are incredibly complex machines assembled from millions of individual parts, manufactured by several tiers of suppliers.

Such a complex process can be improved in many ways; whether through cost savings for an individual component or more effective management of the supply chain process. Meeting such manufacturing challenges often requires a highly interdisciplinary, holistic systems-based approach. Cardiff University has a long and successful track record in working collaboratively with industry, from SMEs to large multi-national firms, bringing together expertise from across the University with access to state-of the-art engineering facilities to incorporate technological innovation with operations management and process improvement. We are able to bring to bear experts from a wide range of fields, including; advanced manufacturing technologies such as additive manufacturing, robotics and autonomous systems, micro- and nano-scale manufacturing and digital manufacturing, coupled with the latest business thinking in areas such as supply chain management, sustainable procurement, re-manufacturing, the circular economy, forecasting and inventory control.

Dedicated research groups including the School of Engineering's High Value Manufacturing research group, the Panalpina centre for Manufacturing and Logistics Research, based in Cardiff Business school and the interdisciplinary Centre for Advanced Manufacturing Systems at Cardiff (CAMSAC) work closely together and with a wide range of industry partners in the aerospace, security and defence sectors throughout Wales, the UK and worldwide on a wide range of fundamental and applied research projects and knowledge exchange activities aimed at facilitating the long term, sustainable development of these sectors.

Facilities

- **The Additive Manufacturing (AM) Laboratory** – has a strong track record of regional, national and international collaborative research with recognised leading funding bodies and research organisations such as the EPSRC, TNO in the Netherlands and the Technical University of Denmark (DTU), while also having excellent collaborative links with industry including internationally leading firms such as BAE Systems, Qioptiq and Renishaw.

  Our partners directly benefit from our unique research and technical expertise, developed over the last 20 years and have access to an extensive range of state-of-the-art equipment including an industrial fleet of three resin based machines (Stereolithography and Digital light processing), three polymer and one metal powder based machines (Selective Laser Sintering (SLS) and Selective Laser Melting (SLM)) for the production of plastic prototypes, patterns, tools and low volume production parts up to a volume of 1m3.

  Current additive manufacturing research includes the development of new materials and metal matrix composites for SLM, the development of improved functional geometries for increased shock or vibration absorption and work on AM process improvement including; process control, laser surface finishing, acoustic emission monitoring, use of microwaves technology for metal powder particle size monitoring, surface characterisation and powder heating applications.

- **Our micro and nano manufacturing facilities** – can support aerospace applications by enabling the direct machining or replication of features ranging from a few hundred micrometres to a few tens of nanometres. Our facilities include two laser systems (from pico- to nano-second pulsed irradiation), a micro EDM machine (with capability for on-the-machine micro tool preparation) and a micro injection moulding machine. These are complemented by a suite of advanced micro- and sub-micrometre characterisation equipment for dimensional inspections (optical microscopes, white light interferometer, scanning electron microscope), for material characterisation and/or for nano-manufacturing operations (atomic force microscope, focussed ion beam).

- **Our Robotics and Autonomous Systems laboratory** – provides cutting-edge robotic facilities, including two LBR iiwa robots and three Kuka mobile robots, which support a broad range of research activities. Current research in this area includes; enabling direct and safe human-robot collaboration to accomplish difficult tasks that lie beyond individual human capabilities (such as assembly, lifting heavy objects and logistics) and endowing a higher level of autonomy to unmanned systems, providing capabilities of efficient situation awareness, collision avoidance, path planning, and multiple robot task allocation.

- **Our Digital Manufacturing group's research activities** – include the deployment of advanced ICT solutions to integrate complex design information and user-generated data in the design of innovative products, systems and services. The through-life management and support of such systems is also a key activity. The use of state of the art ICT technology also enables advanced data analytics to improve manufacturing intelligence. This supports increases in manufacturing efficiency and provides decision support to boost innovation and the engineering of more sustainable technologies. Current research has successfully linked machines and sensors for networking and information sharing, offering the potential for prognostic condition-based maintenance.

Projects

Bombardier Metal Bond Flow Project

An industry funded project to implement a Manufacturing Flow System, based on Lean and Theory of Constraints, in a unit that manufactures panels and nacelles for the assembly of jet aircraft to ensure that the constraints were utilised effectively and efficiently to meet upstream demand.

Next Generation Composite Wing Design for Lean Manufacture

An Innovate UK funded scoping study as part of the Airbus/NGCW project, this work developed a framework of Design for New Aircraft (DNA) that involved a Design for Lean (DfL) at the outset, rather than a retrospective Lean improvement programme that have typically been applied to manufacturing designs in the aerospace sector. Precision Concept Design Model of Manufacture for Competitive Advantage (PreMade) An Innovate UK (BIS) funded project PreMade aimed to develop an integrated tool that validates the manufacturability of a design and gives a precise cost breakdown. A digital engineering model utilises design geometry to simulate the assembly process and also model cost as well as cycle time as key decision criteria. The project focussed on aerospace but is relevant across many industries.

Resilient remanufacturing networks: Forecasting, informatics and holons (ReRuN)

ReRuN a major new interdisciplinary research project funded through the EPSRC's Circular Economy programme which focuses on forecasting for remanufacturing operations, specifically investigating returns forecasting and how such forecasts can be integrated in a systemic way with inventory and production optimisation procedures.

The project is executed in close collaboration with a several relevant industrial partners (Brother, BT, MCT Reman, Panalpina and, from the defence sector, Qioptiq). Other contributors include the Waste & Resources Action Programme (WRAP) and the European Remanufacturing Council.

Managing product design change through-life

Current research in collaboration with Ministry of Defence, Rolls-Royce, Boeing, Cummings, Airbus and Bombardier Transportation is considering the whole-life support for high-value, long-life aerospace products. This aims to enable better coordinate the management of changes to product designs across an integrated supply chain.

The work supports the improvement of through-life design change management processes by enhancing the support that current and future information and communication technology can provide. In particular it is focussing on the provision of more accurate and detailed product change related information so that it more accurately reflects the current configured status of the products. The aim is to enable and support enhanced product maintenance, effectiveness and utilisation.

Aerospace Defence Security Space (ADS) Environmental Working Group

The School of Engineering is working with the ADS Sustainability Group to help understand how environmental issues may impact on businesses.

Materials and Structure

Overview

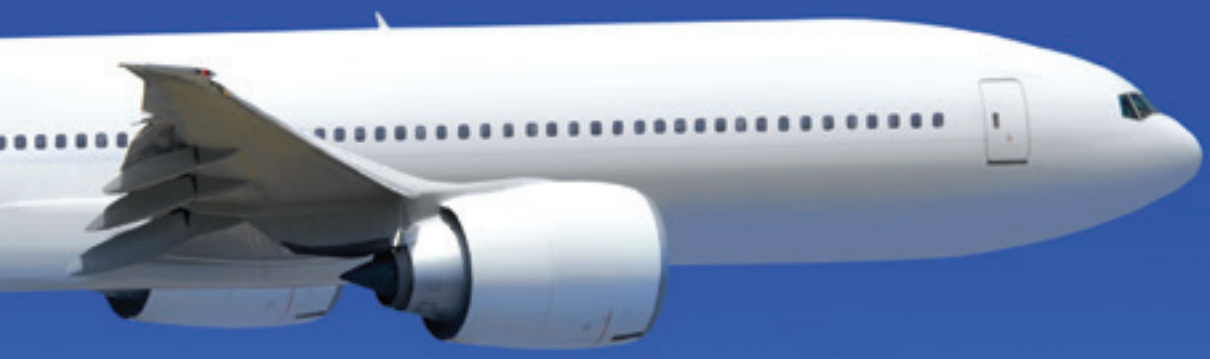
Our materials and structures research works to enable the design of lightweight, robust aerospace assemblies capable of meeting todays demanding criteria for lower financial and environmental costs.

Functionally graded materials allow the design of radomes with reduced mass and enhanced protection against birdstrike. Fast and efficient analysis and optimum design software for stiffened wing and fuselage panels enable the numerous scenarios considered during preliminary design to be analysed within seconds. Specialised, state of the art, industrially relevant simulation software is used to investigate post buckling performance, damage initiation and growth, uncertainty due to manufacturing tolerances, and dynamic behaviour and impact. Modelling is enhanced by extensive manufacture and testing capability, allowing the manufacture of both metallic and composite components for test under static, fatigue and dynamic loading, under ambient or hostile conditions.

The implementation of optimised, lightweight structures will lead to savings in fuel and hence environmental emissions. However, these new structural designs will need advanced monitoring solutions to detect damage at a much earlier stage, creating safer, greener aircraft. Therefore one area of research focusses on the development of low power, lightweight, wireless structural health monitoring (SHM) systems. The use of Acoustic Emission (AE) and Acousto-Ultrasonics (AU) is fundamental to this research, due to its sensitivity and applicability to energy harvesting techniques. The research is supported by a range of further experimental techniques including strain gauging, Digital Image Correlation (DIC), Video Strain Gauging (VSG), 3D Scanning Laser Vibrometry, and ultrasonic scanning.

Facilities

- **Manufacturing** – facilities are available for the manufacture of metallic, composite and polymer specimens and prototypes, including an autoclave for the manufacture of composites up to 1.5 x 2.5m at temperatures and pressures of up to 250ºC and 10bar.
- **Structural Testing** – a variety of load machines and actuators are available for both static and dynamic loading. Universal test machines which can apply loads from 2.5N to 2000kN for static and 5kN to 500kN for dynamic loading. A flexible grillage system is available for be-spoke loading of structures. A drop weight impact test system for impacts up to 1.5kJ and a centrifuge for acceleration testing from 1.5 to 100g.



- **Inspection** – we monitor and inspect structures using a variety of techniques. A range of non-contact measurement techniques are available for determining deformation and strain. Ultrasonic C-scanning, and phased array scanning are available for detecting flaws within structures up to 1.4m x 0.5m, and a variety of acoustic emission acquisitions system and sensors for non-destructive evaluation of structures and materials are available. An audible acoustic measurement system is being used to detect and locate damage within composite structures.
- **Modelling** – Capability exists for performing a range of dynamic and structural analyses using exact strip software developed in house for vibration and instability analysis. A variety of commercial finite element packages are also available for nonlinear and dynamic analysis as well as Topology, shape and topography optimisation.

Projects

Development of SHM systems has been funded through Innovate UK projects. This research has led to an ultra-light weight, low power, wireless system that is capable of detecting damage from a central node. Projects with Micro-Semi Ltd and Airbus have created novel approaches to energy harvesting and power management approaches. A topology optimisation tool has been developed to maximise the power harvested during typical flight scenarios. This work has been validated using experimental testing.

A further project with BAE systems and Airbus, amongst others has developed a sensor node, capable of retrofitting to existing aircraft, that will wirelessly transmit the location of impact or damage within a radius of 700mm in aerospace materials. The node has been trialled successfully on an Airbus A350 composite wing structure.

These two projects in combination have led to the development of a wireless damage detection node that is powered by ambient aircraft energy that will be capable reducing costs whilst lowering global emissions.

Surface Science Group (Cardiff Catalysis Institute)

The Surface Science Group is part of the Cardiff Catalysis Institute (CCI), a recognised global leader in the development of catalysis for economic and environmentally sustainable manufacturing processes.
The CCI has a successful track record of working with a range of businesses, including leading aerospace companies.

The Surface Science Group specialises in the study of interfaces and surface processes with experience in areas of surface modification, protection, adhesion and corrosion. The group has state of the art analytical facilities with a particular expertise in x-ray photoelectron spectroscopy (XPS) but also TEM, SEM, atomic force microscopy (AFM) and surface vibrational spectroscopy including FTIR and Raman.

Propulsion and Transmission

Overview

The propulsion and transmission group brings together a multidisciplinary group of academics encompassing Mechanical and Chemical Engineers, Mathematicians and Physicists.

With the University's unique Gas Turbine Research Centre (GTRC) researchers are able to study, model and validate many facets of the combustion process at different pressures; including combustion strategies, advanced cooling and particulate emissions.

To transmit the high power generated by such gas turbine engines a transmission system must operate in a very demanding environment, whilst still remaining light weight. Researchers at the university have focussed on understanding of failure mechanisms and predicting failure and remaining life in high power transmissions systems indicative of aerospace applications.

Facilities

- **Propulsion - Gas Turbine Research Centre (GTRC)**

  The Gas Turbine Research Centre (GTRC) consists of two major combustion rigs each designed for detailed investigation of combustion and emissions in gas turbines. The rigs are designed for the study of different facets of the combustion process and are operated at different pressures. A wide array of measurement techniques is available to investigate multiple aspects of the combustion process.

  The Sector Combustion Rig (SCR) is primarily used for internal gas sampling within combustor sectors at variable operating conditions (airflow <5kg/s, pressure <10bar and temperature <900k). Gas samples are analysed for combustion and emissions species.

  The High Pressure Combustion Rig (HPCR) (pressure <16 bar) is a multipurpose combustion facility for combustor fundamentals research. State-of-the-art measurement sections are available, some unique, each with a different capability and predominately non-intrusive.

  Multiple fuels and fuel mixtures – single and two-phase - can be fired, with an on-line exhaust gas analysis suite which includes the European reference systems for Particulate Matter emissions which was designed and built at Cardiff on behalf of EASA.

- **Transmission - Twin Disk Test Rigs** – a range of test rigs are available, suitable for studying scuffing, micropitting, contact conditions, lubricant thermal and rheological behaviour, mixed lubrication and the effects of surface finishes and coatings. Each rig features two crowned rollers of 76mm diameter, loaded under rolling/sliding conditions giving an elliptical contact avoiding edge effects. The rigs can replicate the behaviour of real gear contacts, with maximum sliding speeds of 20 m/s and maximum Hertzian contact pressure of 2.0 GPa.

- **Gear Testing Rigs** – two rigs are available. One is a back-to-back power recirculating gear testing rig, using gears of around 2-3mm module. These can be used for fatigue, micropitting or scuffing tests, together with condition monitoring work on damaged gears.

  A further rig accurately measures tooth sliding friction, and may be used to investigate the effects of surface finish.

- **Other equipment** – other experimental rigs are used to investigate ball bearing behaviour, and to study elastohydrodynamic lubrication using optical interferometry. Additionally, a Talysurf surface profilometer is available for the study of three dimensional surface geometry to a resolution of 19 nm.

- **Modelling** – bespoke Elastohydrodynamic Lubrication modelling software is used to investigate a range of lubrication conditions. It is capable of modelling the thermal and non-Newtonian behaviour of lubricants, and can simulate the contact of real rough surfaces. Additional software allows fatigue life prediction due to micropitting under high cycle multiaxial loading.

Projects

Propulsion Study on Sampling and Measurement of Aircraft Particulate Emissions – SAMPLE

As part of a consortium led by the national German aerospace research centre DLR, Cardiff University's Gas Turbine Research Centre (GTRC) has been working on a project funded by the European Aviation Safety Authority (EASA) to better understand and characterise fine particulate matter from aircraft engines. The GTRC's 'Hot End Simulator' simulated conditions of a gas turbine engine during a range of cruise conditions, during which periods controlled, representative sampling of combustion species could be undertaken. Additionally its state-of-the art capability for continuous ('online') measurement of PM and other primary combustion species was used to compare against other technologies from around the EU and the USA.

Transmission Application of EHL modelling to health and usage monitoring of helicopter gears

This EC-funded project led by Eurocopter developed Elasto hydrodynamic lubrication models of gear tooth interaction alongside an experimental programme on vibration, acoustic emission and debris particle monitoring. These models were able to quantify variations in contact strain energy as a potential source of acoustic emission, and explore debris production in terms of surface fatigue analysis. The experimental programme examined the effects of introducing damage features to the test gears and monitoring the consequent changes in signal signatures.

New route to hydrogen peroxide (Cardiff Catalysis Institute)

The Cardiff Catalysis Institute (CCI) is recognised as a global leader in the development of catalysis for economic and environmentally sustainable manufacturing processes. It has a successful track record of working with a range of businesses, including leading aerospace companies. The institute has a range of state of the art equipment for materials synthesis and characterisation and a unique set of skills in the development of chemical processes, one example of which is the development of a new route to hydrogen peroxide, a potential rocket fuel. The University is also currently developing a research programme in the sustainable manufacture of jet fuel.

Security

Overview

Many computer systems exist to ensure the efficient daily operation of the aerospace industry. These systems help ensure the safe and reliable operation of the industry in the air and on the ground. The overarching network of these systems is very complex, with many interactions, dependencies and relationships between them. It is key that the network alongside individual systems are secure from failure and malicious attacks to ensure the safe running of the industry.

The security group brings together the research activities in computer science incorporating areas such as distributed and scientific computing, informatics and visual computing, to realise secure and safe aerospace system infrastructures.

The informatics team work on semantic technologies & human-agent systems for emergency response - data linking via ontologies, virtual organisations / coalitions – evidence based arguments including uncertain information, sensor information processing & delivery and user-level sensor tasking from mobile devices.

Visual Computing research looks into Transferable Belief Modelling (TBM) or more generally uncertain information fusion for tracking, identification and sensor modelling, behaviour modelling - using particle modelling to model crowds and behaviours, force models, attraction, personal space, flock behaviour, lamina flow and video analysis using background modelling and tracking.

Research Units and Projects

Crime & Security Research Institute / Data Analytics and Information Sciences (DAIS) Laboratory

The Cardiff University Crime and Security Research Institute hosts the Data Analytics and Information Sciences (DAIS) laboratory, part of a 10-year $80M US/UK Initiative in collaboration with IBM, Airbus, BAE Systems and other UK and US partners. The Data Analytics and Information Sciences International Technology Alliance aims to unlock the potential of "big data" in front line situations. The alliance has been established by the US Army Research Laboratory (ARL) and the UK Defence Science and Technology Laboratory (Dstl). The aim of the collaboration, called the Distributed Analytics and Information Science International Technology Alliance (DAIS ITA), is to perform fundamental research on how people and computing devices can work together in rapidly changing situations, such as major disasters, to make people safer.

In contrast to the typical view of big data in which collections of computer servers in huge data centres are accessed via the cloud, DAIS ITA is aiming to "turn the data centre inside out" by collecting and processing data near the edges of the network, for example in front-line situations when a major disaster occurs. The goal is to enable people and computing devices to work together to manage rapidly-changing situations by creating dynamic, virtual data centres surrounding teams of front line responders. Key research topics include machine learning that is explainable to human users, situational understanding among teams of humans and artificial intelligence agents, and effective techniques for modelling and predicting group behaviours.

Cardiff's Crime and Security Research Institute provides an interdisciplinary environment for the DAIS ITA work, in which academic research staff and PhD students work alongside external collaborators and stakeholders.

Airbus Centre of Excellence in Cyber Security Analytics

The University hosts the Airbus Centre of Excellence in Cyber Security Analytics. The centre works across industry, academia and government to provide a focus for cyber security analytics in the UK. The centre is the first of its kind in Europe and aims to strategically position the UK as a leader in cyber security analytics.

The centre addresses emerging challenges to cyber security by combining:

- computational and mathematical methods, drawing on our technical expertise in machine learning, artificial intelligence and big data analytics
- criminological expertise in cyber crime
- international relations expertise in communication and governance

Data Innovation Research Institute

Cardiff University is home to the Data Innovation Research Institute (DII), which draws on expertise from staff from across the University. The DII has been set up to conduct fundamental research into the aspects of managing, storing, analysing and interpreting massive volumes of textual and numerical information.

Researchers are engaged in a wide range of projects with applications across many sectors, including aerospace.

Using 3D Facial Motion for Biometric Identification

The aim of this project was to investigate the distinctiveness and durability of using facial actions as way of personal identification for biometric applications. Two dimensional face recognition techniques exist in both a commercial and forensic sense which use the human face as a physiological biometric. However it is often seen as a weak biometric as head poses, facial expressions and sensitivity to illumination, alongside ageing effects, make-up and facial hair allow for many different appearances. With the use of three dimensional imaging techniques some of the above problems can be overcome and allows for facial expression to be considered a biometric. The results obtained by this project showed the potential of facial expressions for biometric applications.

National Software Academy

The National Software Academy (NSA) is a centre of excellence for software engineering which produces work ready graduates with industrial experience. Working in partnership with Welsh Government and industry leaders, the Academy is an innovative Cardiff University initiative to tackle a national shortage of skilled programming and software engineering graduates.

Based in Newport, the Academy delivers a degree focused on the knowledge and hands-on experience needed to work as a commercial software engineer. It developed its three-year BSc Applied Software Engineering course in collaboration with industry. Taught by academics and industrial practitioners, students deliver real software projects, teaming with other students and lecturers in a vibrant start-up atmosphere. The programme applies cloud, mobile and web technologies to real world projects in many sectors including aerospace.

Advanced Semiconductor Materials and Devices

Overview

The Compound Semiconductor Centre (CSC) is a joint venture between IQE plc and Cardiff University to underpin the creation of a unique capability for emerging technologies based on Compound Semiconductor materials. The CSC aims to build on research undertaken at Cardiff University's Institute for Compound Semiconductors to develop innovative new materials technologies that will enable a wide range of new photonic and micro-electronic applications.

The Institute and Centre provides a complete capability chain from high-end, Word-class research and development through product and process innovation to high value, large-scale manufacturing via IQEs global facilities. Our vision is to provide Europe's first prototyping facility dedicated to allowing businesses and academics to demonstrate new technologies based on Compound Semiconductor materials that will be production ready; allowing rapid routes to market entry for entrepreneurs and technology leaders. In addition, the Centre has a mission to facilitate a wide range of training and skills development to support a growing demand for Compound Semiconductor based technologies. The Centre and Institute are key elements in a broader vision to create the world's first Compound Semiconductor Technology Cluster in South Wales, which has gained an investment commitment in excess of £250M; including a Compound Semiconductor Applications Catapult, a large scale manufacturing Foundry, and a EPSRC funded Future Manufacturing Research Hub in Compound Semiconductor Technologies.

Projects

Gallium nitride (GaN)-on-diamond microwave technology

A five-year project, funded by EPSRC, to develop next generation microwave components to support tomorrow's 5G and 6G phone networks, Space and Defence communications and radar systems. The project aims to develop High-electron-mobility transistors. Energy flows in these can be as high as the heat flux on the surface of the sun. Researchers believe diamond – due to its ultra-high thermal conductivity – is the best material for handling the energy needed to drive 5G and 6G networks.

CS MAGIC: Compound Semiconductor MAGnetic Integrated Circuits

The global market for magnetic field sensors is expected to reach up to $2.9 billion by year 2020, with a wide range of uses in metrology, imaging and industrial, automotive and aerospace sensing. This project will explore the feasibility of producing highly miniaturised magnetic sensors which have the advantage of integrated ancillary electronics on a Compound Semiconductor millimetre-scale chip solution. Target applications include: current sensing, embedded cable detection, high resolution metrology and magneto-imaging for Medical, Security and Non-Destructive Testing.

Enhanced Performance of Integrated Concentrator Photovoltaics & Thermo-electrics

Compound Semiconductor (CS) Photovoltaic cells offer highly efficiency conversion of solar energy to electricity as a much improved alternative to current solar panel technologies, and are commonplace in Satellite and UAV applications. The small size of standard Concentrated CS PV cells (less than 1cm2) can lead to very low electricity costs but the cell temperature needs to be cooled to optimise power generation. This project will develop optimized theoretical designs and manufactured prototypes of novel CPV-Thermo-electric receivers, lowering costs of renewable energy generation and building the UK CPV supply chain via technical innovation.

Working with us

We work with businesses and organisations, of all sizes and sectors, and provide a range of mechanisms to enable partners to access to our knowledge, expertise and facilities.

Student Placements and Projects

As a Russell Group University, we attract top students from around the globe. Recruiting our students and graduates will supply your workforce with talented, enthusiastic and highly capable individuals, with a zest for learning and application. We offer a range of options for engaging with our students, from sponsored PhD studentships, to year in Industry and more short term opportunities.

Knowledge Exchange

Our key enabler for knowledge exchange is the Government-sponsored Knowledge Transfer Partnership (KTP) scheme. Via a KTP, you can access our academic expertise and employ graduates to work on projects of strategic need to your company, with the aim to improve competitiveness, productivity and performance. Cardiff has an excellent track record of applying, securing and managing KTP projects, with a greater than 90% success rate, delivering over 250 projects to date.

Research and Development Partnerships

Cardiff University prides itself on conducting curiosity driven research with impact and applications in real scenarios and businesses. Researchers are engaged in a diverse range of research collaborations with other research institutions and businesses, both in the UK and internationally, attracting significant funding.

Networking and events

The Cardiff University Innovation Network has been established for over 20 years. Through a series of free events throughout the year, covering topics on innovation, enterprise and entrepreneurship, the network aims to encourage innovation and collaboration between academia, business and government.

GW4 Alliance

Cardiff University is part of the GW4 Alliance which brings together four of the most research-intensive and ambitious universities in the UK; the universities of Bath, Bristol, Cardiff and Exeter. The universities anchor the regional economy through income, employment, knowledge exchange and collaborations with business.

Through the GW4 Alliance, organisations can access the combined expertise of all four universities in areas such as advanced engineering and digital innovation and forge collaborations at a globally competitive scale.

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