Institution: 10007822

Unit of Assessment: 12

a. Overview

Cranfield is a specialist university leading postgraduate education and translational research in applied science and engineering and management to support business, government and wider society. Fostering a distinctive blend of fundamental, strategic and more immediately applicable research, it aims to create and transform knowledge to solve real-world problems. Supporting that mission, the 161 academic staff in the submission to UoA12 are drawn from the School of Applied Sciences (SAS) and the School of Engineering (SoE), located on the main university campus, and from the School of Defence and Security (CDS) at Shrivenham. Research in UoA 12 is focussed on 6 research groupings (A) Aerospace Engineering, (B) Computational Science & Engineering, (C) Environmental Science & Technology, (D) Manufacturing & Materials, (E) Sensors & Measurement Science, (F) Structures & Machine Systems.

Major achievements since 2008 include the award of 6 EPSRC Centres for Innovative Manufacturing, 2 of which Cranfield leads (**Ultra Precision**, **Through Life Engineering Services**, Composites, Intelligent Automation, Industrial Sustainability, Laser Based Production Processes), the award of an EPSRC Manufacturing Fellowship, the award of 3 EPSRC Doctoral Training Centres, a second EPSRC Platform Grant in Engineering Photonics and significant successes from the Cranfield EPSRC IMRC (http://www.epsrc.ac.uk/research/centres/imrcs/completed2011/Pages/cranfieldimrc.aspx) and EPSRC Integrated Knowledge Centre (IKC) in Ultraprecision and Structured Surfaces (http://www.epsrc.ac.uk/innovation/business/schemes/Pages/ikcs.aspx). In addition, our research has resulted in the publication of over 5000 scientific and technical research papers, the graduation of over 585 doctoral students, training and support for over 23 early career researchers and research income in excess of £117M.

b. Research strategy

Cranfield's institutional strategy is to deliver our mission to enhance the economy, government policy and the third sector through a distinctive spectrum of research across the technology readiness levels, which blends curiosity-driven fundamental research with the co-creation of new knowledge through deep engagement with the strategic research agendas of our business partners. Our curiosity-driven research, funded principally by the Research Councils, plays a major role in delivering their strategic sub-themes in our chosen fields. For example, Cranfield's funding in each of EPSRC's Aerospace and Defence, Manufacturing, Water and Chemicals sub-themes is in the top 10 of UK institutions. This assures our future skills and competency as a research intensive university.

However, the centre of gravity of our research is associated with a profound engagement with business partners and the co-creation of new knowledge through engagement with their long-term strategic research agendas. This is a distinctive focus, with the scale of our engagement with business being proportionally more than four times greater than that of the sector average (29% of research income compared to a sector average of 6% - HESA Finances of Higher Education Institutions 2011/12).

The distinctive focus of this research strategy shapes key aspects of our institution including staffing, capital research investments, and our approach to impact and the transfer of our knowledge to the 'real world'. We achieve this by:

- Fostering a practical, research and innovation-led environment that inspires people to realise their full potential.
- Delivering educational programmes that transform the professional lives of our students.
- Working intimately in partnership with business, governments and others to deliver transformational benefit.

Following RAE2008, the Research Strategy of the UoA targeted the changing needs of society and industry as defined by HM Government, the Research Councils and our industrial partners; eg

sustainable air transport, aerospace composites, advanced scientific computing, nanotechnology, high value manufacturing and ultraprecision engineering; all to underpin UK industrial, economic and societal developments. The Research Strategy is based within a strong multi-disciplinary environment, which is exemplified by the many cross-School / pan-University research centres and research initiatives. This has also been facilitated by the establishment of Thematic Sectors, aimed at enabling researchers from across Cranfield University to develop a sustainable community of groups committed to collaborative activities in order to provide enhancements in the fields of Aerospace, Automotive, Bioscience, Health, Energy, Environment, Manufacturing, Defence and Security. Examples include the 6 EPSRC Centres for Innovative Manufacturing, the Boeing Centre for Integrated Vehicle Health Management (IVHM), the HEFCE funded Cranfield Centre for Competitive Creative Design and the EPSRC grant 'Bridging Applied Nano-Technologists (Bridging ANTs)' which enabled several groups across the UoA to collaborate in Applied Nanotechnology.

The Research Strategy has also been delivered through:

- Leading national and international developments through professional institutions and organisations such as the International Academy of Production Engineering (CIRP), the European Society of Precision Engineering and Nanotechnology (Euspen), the annual UK Manufacturing Debate.
- Building an electronic community to store and exchange technology-related-information, eg, the MBDA portal in connection with aerospace and defense companies. This also acts as one of the routes to interact with the wider community including industry and the general public.
- A series of seminars and informal forums to provide a time and place for researchers to meet on a regular basis to exchange ideas and develop collaborations.
- Creating strategic industrial collaborative partnerships to support industry and drive applied multidisciplinary/cross-sector collaborative research forward. Examples include strategic partnerships with BAE Systems, Airbus, Rolls-Royce, Boeing, Lockheed Martin, AWE, MBDA, Proctor and Gamble, Chemring, Unilever, Hexagon Metrology and the MoD.
- Running facilitated flagship workshop meetings where researchers can actively network to kick start collaborations; research projects that bring together designers and technologists in partnership, to develop novel ways to deliver and communicate technological solutions from a design perspective.
- Investment in large near-industrial scale facilities (Sec 5d) to provide the necessary experimental equipment and high performance computing resources.

Successful delivery of the Research Strategy is facilitated by the organisation of our research into 6 groupings:

(A) Aerospace Engineering. We are one of the largest academic centres in Western Europe for research within aerospace, working closely with partners including Research Councils, Regulatory Agencies, Governments, industry and other academic collaborators. Key to our research strategy are formal strategic partnerships with Airbus, Boeing, BAE Systems, ARA (Aircraft Research Association) and with Rolls-Royce through a UTC in Performance Engineering and a Rolls-Royce University Technology Partnership in Surface Engineering (discussed in (D)). Cranfield also hosts the Aerospace Technology Institute ATI http://www.ukaerodynamics.co.uk/about-us/aerospace-technology-institute-ati/ and the UK Aerodynamics Centre http://www.ukaerodynamics.co.uk/.

Our Aeronautical Systems research includes expertise in system design and testing for aircraft and unmanned aerial vehicles, including avionics, flight controls and guidance/navigation systems. Research in Aerospace Manufacturing is closely aligned to our Manufacturing and Materials theme, discussed in (D). Key areas relate to aerospace materials, assembly and automation. Airbus have established a Royal Academy of Engineering and Airbus Chair in Aero-structure Design and awarded Cranfield *Framework University* Status. Fatigue, fracture and damage tolerance research supports the design and optimisation of lighter, more durable and fuel efficient aircraft structures. Our research in future aero-engine systems addresses the challenges of reducing emissions and noise, novel cycles, propulsion architectures and systems, engine-airframe integration, analysis tools, reliability and costs. Within this context, we have developed a range of capabilities, including aero-engine performance, engine and turbomachinery aerodynamics,

component life assessment and techno-economic risk analysis. Expertise in autonomous systems covers all types of vehicles, including airborne, ground and marine. The research strategy related to Space Systems focuses on two themes, sustainable (clean) space, and radar Earth observation. We are developing expertise in spacecraft / atmosphere interactions and the related area of space debris mitigation / remediation using drag augmentation. In radar Earth observation we have a leading role in geosynchronous radar studies, with collaborations with other groups in Europe and China.

(B) Computational Science & Engineering. This grouping forms a key part of our research programmes. Our High Performance Computing (HPC) facility has supported a range of research. One example is multi-phase pipeline flows (e.g. oil, gas, water and sand transport); advanced models are developed and validated through our experimental facilities. The computational models are used to address the critical issue of how the flows behave at an industrial scale (i.e. in 24" and 48" diameter pipelines), sizes at which experimental work is completely uneconomic. This work is funded by BP, ConocoPhillips and Chevron. The HPC has also been used to support programmes involving multi-scale modelling, encompassing molecular dynamics through to engineering predictions of high energy explosions. The computational engineering programmes are also supported in two other ways. Firstly, through research into advanced computer architectures (e.g. large-scale, heterogeneous grid networks), where the major problems relate to efficient scheduling and resource allocation. The second is through research in software engineering methods, which include developments in archiving and automatic testing of complex engineering research codes.

(C) Environmental Science &Technology. Our research strategy in this grouping concerns the application of engineering science and technology to the water, waste, offshore, automotive and energy sectors. Since RAE2008, research has been consolidated into 3 themes. *Energy and Resource technology*: research is focussed on energy conversion from wastes, bioaerosol releases from engineered composting facilities, metal recovery from contaminated soils, materials developments and performance in advanced gas turbines, CO_2 capture, gasification, pyrolysis and anaerobic digestion of biogenic wastes, biomass co-firing and materials development for ultra-supercritical coal power generation plants. *Water Science*: research is undertaken from source, through treatment and distribution to the consumers tap. Much of the growth in this research activity since 2008 has been delivered through strategic partnerships with Yorkshire Water, Severn Trent and Anglian Water. Development of the sector's future engineers is co-ordinated by Cranfield through the EPSRC/industry-funded STREAM Industrial Doctoral Centre, which won the "People Initiative of the Year" (UK Water Industry Achievement Awards, 2011). We have influenced the research agenda through managing EPSRC/industry funded networks in potable water treatment, energy efficiency for water utilities and wastewater treatment. Industrial scale demonstrators now exist for anaerobic wastewater and sludge treatment, low energy treatment and membrane bioreactors funded by EPSRC, EU, ERDF, UK water utility and US technology suppliers. Advances in water treatment include contributions on particle characterisation, scaling mechanisms, disinfection by-product formation, pathogen monitoring and advanced oxidation. *Environmental Risks and Futures Centre*: capitalising on a strategic partnership funded at Cranfield (2008-2011) between Defra, EPSRC, NERC and ESRC, the Centre now hosts Defra's horizon scanning activity and has undertaken research for government and its agencies (Defra, Environment Agency, WRAP, Scotland and Northern Ireland Forum for Environmental Research) on environmental policy development and better regulatory design.

(D) Manufacturing & Materials. Our research strategy in this grouping aims to build on the strong synergy between manufacturing, materials science, design and management. To this end we have continued to grow the areas of manufacturing technology and materials processing, providing state-of-the-art facilities that can support industrial scale research and development through funding in excess of £50m from EPSRC and industry under the umbrella of the Innovative Manufacturing Research Centre and the Integrated Knowledge Centre in Ultraprecision and Structured Surfaces. The IMRC strategy has been to focus on key areas of expertise within Manufacturing Technology (composites, welding and laser processing, precision engineering) and Product-Service Systems (PSS - the trend for many manufacturing companies to provide services linked to their products to enhance value and the impact this has on their business) to support the

Government's High Value Manufacturing agenda. The PSS research has brought together a critical mass of multidisciplinary researchers from Engineering and Management, working together to establish a new and timely research area. To date over 250 companies have bought into the research programme. The IMRC and IKC research has more recently transformed into 6 new EPSRC Centres for Innovative Manufacturing and the expansion of two pan-university Centres of Excellence, the Centre for Competitive Creative Design (C4D) and the Integrated Vehicle Health Management (IVHM) Centre which together with the new EPSRC CIM in Through Life Engineering Services forms the Through Life Engineering Services Institute (http://www.cranfield.ac.uk/about/people-and-resources/schools-and-departments/school-of-applied-sciences/groups-institutes-and-centres/throughlife-engineering-services-institute.html). We also manage the National High Temperature Surface Engineering Centre, which is supported by major power generation companies and SMEs and also incorporates the Rolls-Royce University Technology Partnership in Surface Engineering.

(E) Sensors & Measurement Science. Our research strategy aims to support the development and application of advanced measurement techniques to solve engineering measurement problems, and underpins much of the research within the other themes of the UoA. As a result, the research is inherently interdisciplinary in nature. The interdisciplinarity has been embedded through the support of two EPSRC Platform Grants over the REF period, (GR/T09149/01**,** GR/H02252X), which have investigators drawn from this grouping and from other groupings such as (B) and (D), and is reflected in the wide range of national and international academic and industrial partners with whom work is undertaken. The developed instrumentation and sensing platforms has been used in areas as diverse as superconducting magnets, building foundation piles, post-harvest crop quality monitoring, point-of-care diagnostics, biosensors and bomb detection. Our research is targeting new applications ranging from automotive components and prosthetic implants to archaeomaterials and new avenues of research have developed in bone mineral analysis, breast cancer calcifications and explosives. Research into the protection of sensors and detectors from laser sensor damage weapons is also being undertaken using a new high power laser facility.

(F) Structures & Machine Systems. Our research strategy in Structures and Machine Systems has been developed around our expertise in Energy, Automotive and Structural Health Monitoring. Our research in Energy examines new technologies and services related to low carbon energy and power generation for affordable power, heat and transport global industries, for wealth-creating exports or for reducing the impacts of energy poverty in less developed countries. We are also developing electric power conversion as an 'enabler' to green energy technologies and are studying the integrity management of energy assets such as offshore turbines and oil platforms as this is a critical activity for both conventional and renewable energy providers and manufacturers. In parallel, we work with industry and Government on energy policy and regulation and, through collaboration with research grouping (C), we look to minimise the environmental impact of energy production, generation and consumption through research into the control of emissions, cleaner fuels and renewable energy. Our research in renewable energy technologies encompasses wind, wave, tidal, solar, biofuels and biomass with a particular focus on the research, design and development, and techno-economic analysis of devices. Our work with the automotive industry is developing vehicles that are more fuel efficient with lower emissions based around electric and hybrid powertrains. Lightweighting, Crashworthiness and Physical Testing are also being undertaken using off-road and on-road testing facilities and our FIA approved crash testing capability. This research is complemented by our capability for theoretical, numerical and experimental investigation of the static and dynamic behaviour of materials and structures. We also lead the transition in the area of bio-sourced composites to be used in structural applications in vehicles. Our research at the engineering – psychology interface examines how humans interact with machines and is especially linked to manufacturing in research grouping (D) and aerospace issues (A) such as cabin evacuation and driver behaviour. An area of research that has seen considerable expansion over the last 5 years is structural health monitoring and vehicle health management. Key developments have been the Boeing IVHM Centre, the EPSRC CIM in Through Life Engineering Services and the Product-Service Systems theme within the IMRC.

c. People, including:

i. Staffing strategy and staff development

The implementation of Cranfield's Institutional Research Strategy requires distinctive staff. With no compromise on their research excellence, our people also need to engage directly with business, to recognise its strategic research agendas in co-creating new knowledge, to understand the commercial issues associated with partnering and to deliver to standards associated with modern business life. We are a research-intensive postgraduate institution. The University's strategy supports trans-disciplinary teams and relationships by grouping staff according to relevant societal challenges (Cranfield's strategic themes). UoA 12 maps onto several of these themes and our research offerings are presented through the six research groupings outlined above. Each of these research groupings is supported by staff from across the University. This breadth of research requires an interdisciplinary approach and is supported through a mix of income streams including RCUK, Europe and industry. This balance of income generation has been essential to fulfil our ambition of working at the leading edge of fundamental, strategic and applied research in our selected niche areas whilst being able to sustain a critical mass of permanent researchers.

Our staffing strategy complements this research funding strategy, delivering a set of fundamental and applied research staff that secures the required mix of income streams. The staffing strategy has included an extensive recruitment programme combined with sustained investments in infrastructure and equipment, aimed at:

- Enhancing Cranfield's strengths in working closely with industry, using appropriate modes of research ranging from fundamental through to strategic applied research with well-defined objectives.
- Establishing a substantial critical mass of research staff to carry out curiosity-driven research.

We frequently recruit from applied research institutes and from industry. Since 2008, 53 appointments of high quality academic staff have been made in strategically important fields including aerospace, automotive, nanotechnology, energy, electric propulsion, manufacturing, structures, sensors and welding and laser processing, creating a vibrant research culture with a sustainable age profile. 34% of the category A staff submitted are under 40 years old and 52% are in the mid-career age range of 40 to 55. The UoA has also invested heavily in a younger generation of high quality staff; for example Aspden, Asproulis, Balleri, Hargreaves, Jude, Kolios, Longo, Patchigolla, Sher, Shin, Skordos.

We have also had substantive success through home-grown talent, with good examples of Cranfield-mentored staff progressing to senior levels (e.g. Alcock, Cullen, Dorey, Horsfall I, James, Jefferson, Jeffrey, Mba, Tiwari A). Research teams are also sustained through judicious Professorial recruitment in strategic areas (e.g. Assadian, Gu, Jolly, Manovic, Starr, Tomiyama, Webb) and from below through our Academic Fellow scheme (e.g. Dotro, Jarvis, McAdam, Parker, Soares), and through early career lectureships (e.g. Carr, Ganguly, Rocks).

Career Development Support

Staff development needs are identified through a number of mechanisms, including the annual performance and development review (PDR) of all staff, in which action plans are identified and managed through line manager interactions. Where more general development needs are identified, these are filtered up through School-level reviews and links with the HR manager network, who discuss emerging patterns with the University's Learning and Development Team. New staff are helped in developing research careers through short courses, e.g. research grant writing and supervision skills; through mentoring, e.g. assignment of a Professor as mentor and of second, 'mentoring' supervisors for research student supervision.

Since 2003 the University has also developed a PGCert in Learning, Teaching and Assessment in Higher Education (PGCLTAHE) for all academic and research staff. Over the last four years this has been transformed into a PGCert in Academic Practice (PGAP) which looks at the role of an academic practitioner more widely than just as a teacher and supervisor and has been tailored to the needs of Cranfield as a research intensive postgraduate University. The PGAP incorporates the development of staff research capabilities together with modules in Business Skills, Leadership

and Management. Completion of the course enables staff to gain Fellowship of the Higher Education Academy (FHEA).

Implementation of Concordat to Support Career Development
The Cranfield Researcher Development Programme (RDP) is based on the National Researcher Development Framework in which there are the following four domains: *Knowledge and Intellectual Abilities*, *Personal Effectiveness*, *Research Governance and Organisation*, *Engagement Influence and Impact*. Full details of the Cranfield programme together with how these domains map onto the training offered are provided on the Cranfield intranet. To support research staff development, the training programme used to enhance the academic career prospects of the Cranfield Academic Fellows and other post-doctoral/early career researchers in Science and Engineering has been extended over recent years. The University's Learning and Development Team assists in the delivery of a series of courses under the Cranfield Modern Academic Programme.

The University participates in the East of England Vitae and collaborates with other Universities to develop training material. The RDP is recorded on the Database of Practice at www.vitae.ac.uk/dop.

Personal Research Fellowships
During this REF period we have been awarded two AWE William Penny Fellowship Awards, (**Vignjevic, Drikakis**) and a Daphne Jackson Fellowship sponsored by the Royal Academy of Engineering, (**Tiwari D**) and have also been successful in winning an EPSRC Manufacturing Fellowship for a new Chair in Composites (**Foote,** recruited from BAE Systems). We also have the Royal Academy of Engineering chair in Aero-structure Design **(Webb)** and the CAA chair in Damage Tolerance **(Irving)**.

International Staff Appointments and Visiting Scholars
Assadian, Professor in Automotive Engineering, previously Ford Germany; **Anthony**, Reader in Energy, previously with Natural Resources Canada; **Suau-Sanchez,** Lecturer in Air Transport, previously with Autonomous University of Barcelona; **Manovic**, Professor in Carbon Systems Engineering, previously with Natural Resources Canada; **Salonitis**, Lecturer in Manufacturing Systems, previously University of Patras; **Tomiyama**, Professor of Life-Cycle Engineering, previously University of Delft and Tokyo University; **Zourob**, Reader in Biosensors, previously University of Quebec, Canada.

During the assessment period we have hosted two RAEng visiting Professors, **Daniel Steenstra** Professor in Medical Innovation and **Paul Tasker** Professor in Integrated System Design. Numerous visiting scholars have worked with us over the last 5 years, some notable examples being; **Prof Jay Lee**, director of the NSF Industry/University Cooperative Research Centre on Intelligent Maintenance Systems, University of Cincinnati – collaboration on Product-Service systems research within the IMRC; **Prof J H Wu,** Beihang University; **Professor Peter Sandborne**, University of Maryland, **Professor John Mo**, RMIT, Australia; **Dr Andrew Levers**, Technical Director, Survitec; **Professor Madhusudan Chakraborty**, The Director, Indian Institute of Technology (IIT), Bhubaneswar.

Equality and Diversity
Cranfield has demonstrated its commitment to Equality & Diversity for over a decade and it informs our activities; in the professional development of staff, in their promotion, in the management of our research and teaching environment, and in external processes such as REF. The University is an active member of Opportunity Now and the Higher Education Equal Opportunities Network. Equality & Diversity is led across the institution by an Executive Board Champion, who is currently the Deputy Vice-Chancellor, assisted by a Diversity Manager and our Professional Development Team. They implement and review our diversity objectives, ensuring that the University provides equality of opportunity for all, and preventing unlawful discrimination. Our Council plays a pro-active role in ensuring delivery of our Equality & Diversity agenda and the diversity team monitors on their behalf the University's approach to diversity and equality across all the characteristics protected by the Equality Act 2010. The University has equality-proofed all of its processes for

recruitment and promotion and for selection for external exercises such as REF, and has monitored and demonstrated their inclusivity. We have formally demonstrated equality in pay and reward and in the selection for REF at UoA level, including our University-wide independent process for cases of exceptional circumstances.

We carefully benchmark our equality and diversity performance against external demographics. In terms of key diversity strands, Cranfield's researcher community is ethnically diverse at around 12% of our staff, reflecting our cultural diversity and our international recruitment strategy. Our proportion of staff with declared disability varies across the institution between 1-3%; slightly below the sector average of around 3%, and the proportion of female academic staff reflects our narrow discipline mix focussed on STEM, being close to the sector benchmarks of 8% for female engineers in the UK, 19% for UK PhDs in Engineering and Manufacturing, and 42% for female undergraduates studying Science and Computing. As a public body, we recognise the challenge in gender representation in the professional engineering domains in which we work and our positive duties under the Equality Act 2010.

We are working closely with others within the Sector on the long-term need to improve the level of female representation. As a University we have a range of family friendly policies. Our staff contribute to mentoring and act as role models within local schools, lead projects aimed at improving gender representation in the pipeline to engineering, such as the Schools Aerospace Challenge. Members of staff also contribute to major national projects such as the CIHE (now The National Centre for Universities and Business) "Great Expectations" work on "Top Manufacturing and Engineering Talent 2030, which has now been transformed by BIS / HEFCE funding into a major project to increase the number of female engineers.

ii. Research students

Our research student experience is strongly influenced by our direct engagement with business. Our research students are typically recruited to work on specific research projects, often linked to industrial, research council or government contracts and often as part of a larger research team. The postgraduate research-led environment and excellent links with end-users (as sponsors of research, or as members of our many industry research clubs) provide students with an opportunity to develop both their research and transferable skills, constituting an excellent preparation for a career in industry. A 'CASE-style' funding arrangement is often used, with a strong focus on delivery. Research students enjoy high staff: student ratios and access near-industrial scale facilities. We recruit for organisational fit and an aptitude for independence and insist on high levels of delegated responsibility, providing stipends above the sector average. Researchers typically manage their sponsor-project interface, progress meetings with our partners, portions of experimental budgets and arrange periodic PhD reviews. They often raise income for conference attendance from professional and learned societies, and are called upon to present to industrialists and government scientists visiting Cranfield. Research students experience the full technology train or policy development cycle, from fundamental enquiry, to prototype, commercial or practical solutions for industry and government. They learn to manage real world constraints, such as budgets and sponsors' expectations, preparing them for life post graduation. They are expected to deliver excellent science, publish in international journals and present at national and international conferences.

The community of research students is supported and encouraged through our Doctoral Training Centres (DTCs). Seven DTCs have been established: Aerospace, Defence & Security, Engineering, Environment & Natural Resources, Health & Biosciences, Management, and Manufacturing & Materials. The DTCs provide training, information, networking, events and advice to research students across the University to ensure the best and most consistent student experience and research training. Our approach is to manage generic training across DTCs, with specialist training within or between DTCs. Doctoral training is rooted in a postgraduate researcher Core Skills training programme which maps onto the four domains of the VITAE National Researcher Development Framework. The Core Skills programme uses a blended learning approach which includes lectures and workshops from both internal and external contributors supplemented by e-learning material (some of which is internally produced and some purchased

externally). Over and above the Core Skills programme, individual DTCs also host their own special interest training and events, which may be purely for their students or open to students from other DTCs. Part-time students are regarded as full members of their DTC, alongside their full-time colleagues, and receive access to their virtual learning environment and to research training, as well as invitations to participate in DTC activities.

Whilst the main activity of DTCs relates to doctoral training, they also provide a forum for the exchange of good practice regarding student supervision and progress monitoring and the induction of doctoral supervisors. Team supervision of doctoral students (providing a better student experience and also supporting less experienced supervisors by mentoring by an experienced supervisor) is encouraged. All doctoral students undergo regular formal and informal progress monitoring. Supervisors are expected to hold frequent meetings with their students. In addition, formal monitoring occurs annually with a panel chaired by an independent academic, a process that is overseen by the Dean of Faculty. A final year assessment is made to ensure that the student is on track to submit their thesis. At each formal panel review the student is offered the opportunity to discuss any supervision issues in private with the panel Chair, and students concerned about any aspect of their supervision may approach the programme director or manager at any time. The University's approach to research student progress monitoring was commended by the QAA during its last Institutional Audit in 2010. During the review period, over 583 doctoral students have graduated from UoA 12.

d. Income, infrastructure and facilities

Academic and research staff are expected to demonstrate a capability for winning intellectually challenging, exciting and commercially-viable work, and to deliver to our research partners' satisfaction. Where appropriate, we work to maximise commercial returns from intellectual property rights (IPR). Unique experimental facilities (examples below) are maintained and enhanced, taking every opportunity to access external capital funds to maintain buildings and experimental facilities to high standards. We upgrade experimental facilities through the re-investment of research-generated margin. In pursuit of leading edge capabilities for our niche areas, we invest continuously to secure peer-reviewed research income (mainly RCUK and EU) as the hub around which other projects and activities are supported. We purposefully seek a mixed platform of financial support for curiosity-driven science (RCUK), strategic and applied science supporting long term policy design and delivery (e.g. EU, Environment Agency, TSB) and near market product and service development (industry). These components are mutually supporting, so that research gaps identified by a piece of policy analysis are fed back as fundamental research questions in the next Research Council proposal; while EU and other research income is sought for the implementation of challenges raised by theoretical enquiry. On-going industrial research, more immediate in its delivery objectives, acts as a reality check on the practicability of theoretical insights.

This deliberate blend of research income makes for a rich landscape across the technology readiness levels, ensuring the progression of science and engineering fundamental to the disciplines, its relevance to end users, timeliness for policy design and industrial application, and utility for the practical implementation of research insights. Our proximity to government and industry continually challenges the relevance of our work and, combined with the strategic management of the overall income mix, ensures the long term financial sustainability of our research. Our scholarship over the assessment period, therefore, has been supported by research income secured from Research Council grants (£37.7M); grants from Research Foundations and Charities (£4.1M); from government departments (£18.5M); from the European Commission £15M); and funding from Industry (£45.6M), totaling £117.3M.

At a high level in support of UoA12 research activities we have: made international appointments to strengthen existing areas (e.g. **Tomiyama**, manufacturing; **Anthony**, **Manovic**, Energy); invested significantly in equipment and laboratories for globally-significant growth areas, notably High Value Manufacturing (**Shore, Webb, Williams**),Through Life Engineering Services (**Irving, Roy, Starr, Zhu**); promoted high-performing early career staff to positions of responsibility (e.g. **Dorey**, **Tiwari A**); assembled staff in larger groupings of critical mass (e.g. the Department of

Manufacturing and Materials, bringing together expertise in manufacturing technology, manufacturing management, engineering materials and materials science, much of which supports 6 EPSRC Centres in Innovative Manufacturing).

As a consequence of our strategy to carry out research across the spectrum of technology readiness levels, we invest in a distinctive range of facilities at or near industrial scale to create a proxy industrial research environment. These enable us to create new knowledge across the spectrum from fundamental enquiry-driven research to the co-creation of knowledge with our strategic industrial partners. We hold and develop many of these facilities on behalf of the Higher Education and also key business sectors in the wider economy. The critical mass of such facilities has created an innovation habitat around the University which includes other national assets ranging from the Aircraft Research Association, the UK's Aerospace Technology Institute & Aerodynamics Centre, to the NERC Met Office Facility for Airborne Atmospheric Measurement at Cranfield's own airfield. Our research infrastructure has been enhanced through significant investments since 2008 from both internal and external sources. Examples include:

(A) Aerospace Engineering - wind tunnel development; unmanned aerial vehicles, modifications to the Cranfield Bulldog aircraft as a flight test platform, **(£1M)**.

(B) Computational Science & Engineering - new high performance computing facility, **(£0.6M).**

(C) Environmental Science & Technology - equipment for algae/bio-fuels, carbon sequestration and other CO_2 capture approaches **(£0.3M).**

(D) Manufacturing & Materials - RAEng/Airbus aerostructures assembly laboratory, expansion of the Precision Engineering laboratories, including new machine tools, reactive atom plasma technology and large-scale metrology capability, IKC Structured Surfaces Laboratory, laser welding facilities and large scale (4mx3m) metal additive manufacturing capability; refurbished ballistics testing capability, establishment of Constrained Rapid Induction Melted Single shot Up-Casting Process (CRIMSON Lab); Through-life Engineering Services Studio (Thermography system, Environmental chamber, VR facility), **(£5.5M).**

(E) Sensors and Measurement Science – New analytical facilities, CT, XRF, LA-ICPMS, Raman microscopy, IR microscopy, confocal microscope, optical microscopy and a 3D laser scanner, reloading of the JJT Cobalt 60 gamma ray source, hyperspectral and multispectral imaging facility, high-resolution optical spectrometers and laser facilities, **(£3M).**

(F) Structures and Machine Systems – New Structural Integrity Laboratory, Ocean Systems Laboratory, Microalgae Pilot Plant, 50kW Wind Turbine Test Bed and Electrical Machines & Power Laboratory, **(£4M)**.

These investments have enhanced and augmented our existing suite of facilities which include:

The world's highest pressure (250 bar) hyperbaric chamber for deep (~2500m) weld simulations; Newly refurbished industrial-scale Energy Technology Centre; FIA approved Cranfield Impact Centre for vehicle crash research; Off-Road Dynamics Facility, unique in the UK, which includes a whole vehicle moisture-controlled soil lane; The National High Temperature Surface Engineering Centre including the only facilities for the deposition of EB-PVD thermal barrier coatings onto production turbine blades at a European University; Water Science facilities that include the University's own sewage treatment facility and pilot plant hall; Flight Simulator; Aero-structure Assembly and Systems Installation Laboratory; Icing Tunnel; Structural Integrity Laboratory; Accident Investigation Laboratory; Aircraft Cabin Simulators; Multiphase Flow Laboratory; Engineering Photonics Laboratories; National Flying Laboratory Centre which owns and operates a Jetstream 31 – BAE Systems Flying Test Bed and 3 further aircraft used for research; Ocean Systems Laboratory; Wind Turbine Test Facility.

e. Collaboration or contribution to the discipline or research base

A summary is provided in the table. (Note: the statistics for FREngs, Fellowships and contributions to papers and publications refer **only to Category A staff**; and, for publications, does not distinguish between cases where there are multiple internal or external co-authors because of the difficulties in allocating fractional authorships).

Contribution Indicator	Number
Fellows of the Royal Academy of Engineering	4
Fellowships of Professional Bodies	61
Members of EPSRC Peer-Review Colleges	27
Prize-Winning Publications	36
Editorships/Editorial Boards	23/56
Refereed Journal Papers	2480
Conference Papers	1930
Patents	19
Keynote/Plenary and Invited Lectures	155/265
Conference Chairs	36
Research Funding*	£137.6M
Project Awards with a value over £ 250k/£1M	110/12
Collaborative EU Awards with a value over £100k	48
New Spin-Out Companies	2
Number of Industrial Research Partners	260
Number of Formal Strategic Research Partnerships	26
Research Doctorates Awarded	583
Average Number of FTE Research-Students Registered per Year	425
Research Fellows/ Assistants	427

* includes research income, research income in-kind and SRIF funding

Examples of leadership with industry in major research projects for each research grouping are provided below:

(A): The Cranfield UTC in Performance Engineering together with an EPSRC Platform grant **(Rolls-Royce, EPSRC)**. EU projects VITAL, NEWAC, LEMCOTEC, DREAM **(all with Rolls-Royce).** The Clean Sky Joint Technology Initiative **(DLR, NLR, ONERA and CIRA Aerospace Research Establishments, Airbus, Rolls-Royce, Safran, Thales, AugustaWestland and Eurocopter.)** Project SAMULET **(EPSRC, Rolls-Royce)**, Project DEAP **(TSB)**, Virtual Aeronautical Collaborative Enterprise **(Airbus),** CREON, CRESCENDO, VIVACE and TOICA **(EU projects),** Propulsion System Life Estimation **(Boeing),** Gas Turbine Maintenance **(Alstom Power, BP),** Demon UAV **(EPSRC/BAE Systems);** Novel bio-inspired micro aerial vehicles **(EPSRC, MoD, Boeing, the Defence Technology Centre on Data and Information Fusion and the Centre for Defence Enterprise).**

(B) Multiscale Modelling of Meso and Nano Scale Interfacial Dynamics Phenomena, Computational and Theoretical Modelling of Shock-Induced Instability and Mixing across Material Interfaces **(MBDA, BAE Systems, Lockheed Martin, MoD/DSTL, UKAEA);** 11 **EU** funded consortia DINAMICS, CHANGE, ESTOLAS, FRIEDCOPTER, GOAHEAD, FUSENET, ERANET, URBAN-NET, iComFluid, ECOFUEL, IPACTS, SIMUSPRAY; Unmanned Aerial Vehicles (UAVs) and micro UAVs **(US Air Force, ESPRC, TSB, MBDA); Aeroengine Aeroacoustic Interactions, (EPSRC); High Resolution Mosaicing, (EPSRC); Optics for Local Zoom and Beam Steer, (Sagem); Path Planning Planetary Rovers, (European Space Agency);** Two William Penny Fellowships **(AWE)**.

(C) Wastewater Research Framework Partnership **(Severn Trent)**, The National AMP5 (Asset Management Plan 2010-2015) programme (**UK Water Industry Research**); RBCs of the Future, effects of chemical dosing on reed beds; indirect potable reuse programme, **(Thames Water)**; MBR technology development programme, **(The Dow Chemical Company)** Enhanced

oxygenation of MBR at high MLSS, **(Praxair Inc)**; Nano-membrane toilet, **(Bill and Melinda Gates Foundation)**; Anaerobic MBR III, **(Thames Water/Severn Trent Water/EPSRC);** Siloxane removal from biogas, **(Severn Trent Water/EPSRC);** Dissolved methane recovery from water, **(Anglian Water, Severn Trent Water, Northumbrian Water and Yorkshire Water, EPSRC)**; **Collaborative Centre of Excellence in Understanding and Managing Natural and Environmental Risks (EPSRC/ESRC/NERC/Defra);** Provision of an horizon scanning and futures function, **(Defra Network and other partners)**; Strategic risk management for sustainability, **(Yorkshire Water)**; UK energy futures: mapping uncertainties and risks, **(NERC (UKERC))**; International Centre for Infrastructure Futures **(EPSRC/ UCL lead);** US/UK EPA/NERC Environmental Nanoscience Initiative (**CEH, Rothamsted Institute, Duke University, Carnegie Mellon University); AMP5 framework agreement, 2010-2015, (Yorkshire Water); Delivering low carbon anaerobic wastewater treatment and renewable energy production (EPSRC, Anglian Water, United Utilities, Yorkshire Water, Thames Water, Severn Trent, EON, Paques).**

(D) EPSRC Centre for Innovative Manufacturing in Through-life Engineering Services, **(ADS Group, Aerospace and Defence KTN, ARM Ltd, BAE Systems, Bombardier Transportation, East of England Energy Group, EnginSoft UK, GOM UK, Imperial Innovations, Knowledge Transfer Networks KTN, KTN - Energy Generation and Supply, MoD, Northrop Grumman Sperry Marine, PRICE Systems International, Rolls-Royce, Say One Media, Siemens, UK Council for Electronic Business);** EPSRC Centre for Innovative Manufacturing in Ultra Precision, **(Cinetic Landis (Fives Group), Gooch and Housego, Hexagon Metrology, M-Solv, Microsharp Corporation, National Physical Laboratory, SPI Lasers);** EPSRC Centre for Innovative Manufacturing in Intelligent Automation, **(Aero Engine Controls , Airbus, Ford Motor Company, Manufacturing Technology Centre, Rolls-Royce);** Royal Academy of Engineering Chair in Aero-structure Design **(Airbus);** High Deposition Rate Additive Manufacture of Complex Metal Parts, **(BAE Systems);** Robustness-performance optimisation for automated composites manufacture, **(Coriolis Composites, ESI UK);** SAMULET Project 1 - High Efficiency Turbomachinery, **(Rolls-Royce);** oxidation and hot corrosion of industrial gas turbine materials, **(Rolls Royce, Siemens (USA and Germany));** Ultraprecision machining of optics, **(NASA, European Southern Observatory, Thales, Contour Fine Tooling);** Thermal Barrier Coatings, **(Rolls-Royce).** In addition the IMRC has so far worked with over 250 industry and academic partners.

(E) Sensor research, **(Alphasense, Geotechnical Instruments, Oxford Instruments and Casella, Chemring, Biomet and BAE Systems)**; Optical sensing techniques for aerospace, from design through manufacture to flight testing, **(DLR, NLR, Airbus and Piaggio)**; EU FP7 ADVITAC, **(Daher Aerospace, Technalia, Coriolis, Embraer and NLR)**; EU FP7 EU FP7 PMnIDEAs; **(Tata Steel and Stagecoach)**; Foundation pile monitoring, **(Arup Geotechnical, BRE Stent and an EPSRC Challenging Engineering award)**; Point-of care-instrument to detect C Difficile, **(Cascade Technologies, Bedford NHS hospital trust and TSB)**; **Point-of-Care High Accuracy Fracture Risk Prediction, (HALO X-ray Technologies Ltd, Radius Diagnostics);** Low cost tuneable laser source for gas sensing applications, **(University of Southampton and EPSRC)**; New fibre optic chemical sensing capabilities, **(Kitakyushu University, Japan)**; Image based sensing approaches, **(Alberta University, Canada)**; Interrogation techniques for fibre optic sensors, **(INOA-CNR, Italy)**; EU FP7 AIM - Advanced In-flight Measurements, EU FP7 program AIM2, flight testing a gas sensing system, **(EPSRC, BAE Systems, Airbus, DSTL/MoD);** SMARTER: Smart Multifunctional Architecture & Technology for Energy aware wireless sensors, **(EPSRC).**

(F) Nova - the feasibility of large vertical axis wind turbines sited offshore, **(Energy Technology Institute (ETI), University of Strathclyde, Sheffield University, James Ingram & Associates, CEFAS, QinetiQ, Wind Power and OTM Consulting)**; AUTONOM: Integrated through-life support for high-value systems, **(EPSRC);** Revolutionary Electric Vehicle Battery, **(EPSRC);** Light Weighting of off-road Engineering Vehicles, **(EPSRC);** Analysis of Shock Transit in Composite Lay-Ups, **(AWE).**

Interdisciplinary Research
Interdisciplinary working is stimulated through academics from different disciplines being co-located, representative examples being engineers, economists and psychologists in (A) Aerospace Engineering; biologists, physicists, engineers and social scientists in (C) Environmental Science and Technology; mechanical, production and materials engineers, physicists, chemists and economists in (D) Manufacturing and Materials, physicists, engineers and chemists in (E) Sensors and Measurement Science, and engineers, physicists, materials scientists and social scientists in (F) Structures and Machine Systems. Co-operation, within the UoA is enhanced by sector groups using eight 'themes' under which to group our expertise – Aerospace, Automotive, Energy, Environment, Health, Management, Manufacturing and Security and Defence. To help customise our multi-disciplinary work more closely to the needs of our research partners, each theme is assigned a 'champion' to coordinate the pan-university activities. The approach has proved to be very successful in stimulating collaborations across the University and has also assisted in the establishment of major centres such as the EPSRC funded IMRC and IKC, centres such as IVHM and most recently the new EPSRC Centres for Innovative Manufacturing.

How Collaborations Have Informed Research Activities and Strategy
Section 5b outlined examples of the strategic partnerships that have been established with industry and, together with our internal sector groups using eight research themes, we are able to act both in a proactive and reactive way to support our research partners. A typical example is the research of the IMRC, which has been guided by a supervisory board composed of leading figures from business, industry and government bodies, working alongside the Cranfield academics. This steering group represents many strands of influence: large companies, the SME sector, international expertise, and government and industry associations. Their input has been vital in helping the Cranfield IMRC to set itself ambitious targets of international industrial relevance and as individuals the board members have been very much involved in the overall direction of the IMRC and the various projects. A similar approach is being adopted by other centres such as the IKC, IVHM and the EPSRC Centres for Innovative Manufacturing.

We also have input into future national and international research priorities through a range of mechanisms, including membership of various advisory groups as listed below, and by promoting debate through national and international discussion. Examples include hosting the annual National Manufacturing Debate, organizing research meetings at the Royal Society and Royal Academy of Engineering, membership of an EPSRC Strategic Advisory Team**,** initiating and chairing working groups within professional institutions such as CIRP and the Association of Industrial Laser Users.

Advisory Board Membership
(A) Braithwaite, International Society of Air Safety Investigators, Industrial Advisory Board for the Singapore Aviation Academy, International Air Cargo Association, Human Factors Group of the Royal Aeronautical Society; **Hobbs**, ISO committee TC20 / SC 14 Space Systems and Operations WG1; **Mason**, Global Business Travel Association Project ICARUS Global Advisory Board and European Committee, British Chamber of Commerce and RAC Foundation Business Travel Research Study Group.

(B) Drikakis, Final Panel member in EU FP7 Aeronautics Programme, Expert Evaluator in the European Research Council, Fluid Dynamics Committee of the American Institute of Aeronautics and Astronautics, Annual Osborne Reynolds Awards Scientific Committee; **Jenkins,** Chair, UK Consortium on Computational Combustion for Engineering Applications, 2009 – 2012.

(C) Anthony, Chair of Expert Review Committee for Canada Foundation and Innovation; **Cartmell,** WRAP Environmental Transformation Fund Anaerobic Digestion Demonstration Programme Panel Assessor, invited Task Force member and report author for "Water and Energy" for WssTP (European Commission Water supply and sanitation Technology Platform), Wessex Water Sustainability Panel, Public Utilities Board, Singapore Technical Expert; **Oakey,** Member of MatUK, Energy Materials Working Group, Independent Expert for EC Energy Research Programme, Member of the Advanced Power Generation Technology Forum, Advisor to DECC on EU SET Plan

Priorities in CCS and Bioenergy; **Pollard,** Member, Review Panel for the Institute for Animal Health, Pirbright, Beringer Report, BBSRC, HMT Infrastructure UK Engineering and Interdependency Expert Group; **Rocks,** Member, Hazardous Substances Advisory Committee (HSAC, previously ACHS); **Simms,** Member, National Physical Laboratory Industrial Advisory Committee on Lifetime Performance of Materials; **Tyrrel,** Member, BSI EH/2 committee on Air Quality and UK principal expert to the CEN working group CEN/TC 264/WG 28, "Measurement of airborne microorganisms in ambient air".

(D) Carr, British Standard committees: BSI PH/3/9 Protective clothing and equipment for motorcyclists, BSI PH/3/11 Protective clothing and equipment for sports, BSI PH/3/12 Protective clothing and equipment for use in violent situations.UK representative on the European Standards committee (CEN TC 162 WG 5 PG 5 Body armour); **Dorey,** Chair of UK Energy Harvesting Network Steering Board; **Nicholls,** Technical Expert in High Temperature Materials, Corrosion and Wear for NATO/RTO, Technical Expert for the European Commission on 'Materials and Coatings for Extreme Service Conditions'; **Shore,** RCUK Fusion Advisory Board; **Tomiyama,** Advisory Committee Member for IOP-IPCR (Innovation Oriented Program, Integrated Product Creation and Realization)**; Webb,** British Automation and Robotics Association Council, Board of the Academic Federation for Robotics, SAE Aerospace Automated Fastening Committee.

(E) Hodgkinson, Chair of MNT Gas Sensor Focus Group; **Richardson,** Expert Advisory Group - MOD/DSTL Weapons Technology Centre; **Rogers,** The International Centre for Diffraction Data advisory board; **Tatam,** Director of SPIE, Advisory Committee for SPIE's International Symposium on Optical Metrology.

(F) Brennan, DECC MEAD Advisory Panel Member, TSB Offshore Catapult Centre ORE-CAT, Member of Scientific Advisory Board; **Dorn,** member of the Parliamentary Advisory Council for Transport Safety, member of the EU HERMES expert panel representing road safety researchers from 12 European countries to develop driver coaching interventions; **Mba** International Standards Organisation Member, working group (ISO TC108 SC5 WG14); ISO Technical Committee ISO/TC 108 SC5; WEE/046 Non-destructive testing ISO/TC 135/SC 9/WG's 1 to 4, BSI committee member on 'Machine Vibration and Condition Monitoring', (ISO TC108 SC5 WG's 5 and 7), ISO working group for wind turbines (ISO/TC 108/SC 5 Advisory Group G); **Patel,** Member of International Technology Advisory Panel of Keppel Corporation, Singapore.

Industry
(A) Braithwaite, Non-executive member of Safety Review Board for Thomson Airways; **Lei,** Senior Adviser to Hainan Airlines Holdings.

(B) Breckon British Machine Vision Association and Society for Pattern Recognition (Executive Committee member + treasurer) http://www.bmva.org/executive_committee. London Technology Network Business Fellow (LTN); **Jenkins** Chairman of UK Consortium on Computational Combustion for Engineering Applications; **Savill,** Director Cambridge Flow Solutions Ltd.

(C) Cartmell, Director of WSUP (Water and Sanitation for the Urban Poor); **Coulon,** expert adviser on landfill issues to Viridor, Churngold Recycling Ltd, Hillingdon Borough Council, UKZN South Africa, BACTEST, Environment Agency of England and Wales, Abu Dhabi Water and Energy Academy (ADWEA), Environmental Sustainability Knowledge Transfer Network; **Judd,** Consultant, Centre for Environment, Fisheries and Aquaculture Science (Cefas), Marine Management Organisation and Seafish; **Oakey,** GDF Suez, Laborelec Technical Advisory Board, Director, Energy Materials Industrial Research Initiative and Vice Chair of Steering Committee; **Pollard,** Consultant to Defra (risk), DECC (hydraulic fracturing), Calgary Water, Yorkshire Water, EON, Environment Agency (including expert witness statement); State Veterinary Service (carcass disposal); **Stephenson,** Chairman, Technical Director of Water Innovate Limited, Chairman (2010-2012) and board Director of British Water, Board director of Water and Sanitation for the Urban Poor (WSUP).

(D) Nicholls, Director of Rolls Royce 'University Technology Partnership (UTP) in Surface

Engineering and Coating Technology, Non-executive Director of Sensor Coating Systems Ltd., Non-executive Director of Southside Thermal Sciences Ltd; **Shore,** Director Loxham Precision Ltd; **Webb,** Council Member of the British Robotics and Automation Association, SAE Automated Assembly and Fastening Committee.

(E) Rogers, Chief Scientific Officer at Halo Xray Technologies Ltd; **Tatam,** Non-executive Director of AOS Technology Ltd.

(F) Patel Non-Executive Directorships of Keppel Offshore & Marine Ltd, Singapore, BMT Group Ltd, BPP Technical Services Ltd and BPP Cables Ltd.

Research Councils
27 members of staff are currently members of the EPSRC Peer Review College.
http://www.epsrc.ac.uk/SiteCollectionDocuments/other/CollegeMemberListbyOrganisation.pdf

(A) Tsourdos, Whidbourne, EPSRC Peer Review College

(B) Breckon, Drikakis, Savill EPSRC Peer Review College; **Breckon** member of STFC IPS Assessment Panel

(C) Cartmell, EPSRC Peer Review College, NERC Resource Recovery from Waste: Challenges for Health of the Environment Think Tank; **Coulon,** EPSRC Peer Review College, Member, the Georgian National Science Foundation Peer Review College, Member, National Research Foundation College, South Africa; **Judd,** EPSRC Peer Review College; **Oakey,** EPSRC Peer Review College; **Pollard,** EPSRC Peer Review College; EPSRC Process, Environment & Sustainability Strategy Board; EPSRC Sandpit Mentor 'Water for all'; EPSRC Engineering Panel, incl. Chair; EPSRC Sandpit Director 'Engineering solutions to resource efficiency'; NERC Programme Advisory Group 'Resource recovery from waste: challenges for the health of the environment; **Stephenson,** Chair of EPSRC Engineering Programme Grant Interview Panel, Author of Foreword for EPSRC 'Best Practice Guide to Managing Submissions'.

(D) Irving, Jolly, Roy, Shore, Tiwari, Williams, Zhang, Zioupos, EPSRC Peer Review College

(E) Higson, Hodgkinson, James, **Tatam,** EPSRC Peer Review College; **Tatam,** EPSRC Strategic Advisory Team for the Materials, Mechanical and Medical Engineering Programme; Chair, responsive mode ranking panel.

(F) Assadian, Brennan, Whidbourne, EPSRC Peer Review College.

Learned Societies/Professional Bodies
(A) Garry, Member of the ESDU Aerodynamics Committee. **Hobbs**, Co-chair of Synthetic Aperture Radar Special Interest Group (SARSIG) of Remote Sensing and Photogrammetry Society; **Mason**, Guild of Air Pilots and Air Navigators Environment Committee.

(B) Drikakis, Fluid Dynamics Committee of the AIAA, Annual Osborne Reynolds Awards Scientific Committee; **Tsourdos,** AAD KTN National Technical Committee on Autonomous Systems, Executive Committee IET Robotics and Mechatronics Professional Network. International Member of the Technical Committee of the IEEE Control Systems Society.

(C) Cartmell, Royal Society – DFID Africa Capacity Building Initiative Panel Member, RSC Water Science Forum Committee member; **Coulon,** executive committee member of the Society for Brownfield risk assessment (SoBRA), UK Standing Committee of Analysts on Total Petroleum Hydrocarbons; **Dotro,** Regional co-ordinator for IWA; **Jeffrey,** one of three subject leads for the European Water Supply & Sanitation Technology Platform task force report on water reuse; Project Oversight panel for ICE 'State of the Nation: Water' report; member of consultation body to update Environment Agency water demand scenarios to 2050; **Longhurst,** member of Her Majesty's Treasury Engineering Infrastructure Expert Group coordinated by the RAEng, Dept. of BIS and

Infrastructure UK; **Oakey,** Member of IOM3 Energy Materials Group; **Pollard,** The Institute of Risk Management Education Advisory Board; Panel judge, Lloyds 'Science of Risk' Prize; Submission to The Royal Society and the Royal Academy of Engineering on Shale gas extraction in the UK: a review of hydraulic fracturing; **Soares,** Institute of Chemical Engineers member of the Water Special Interest Group committee; **Stephenson,** Chair and member ACQUEAU EUREKA Cluster Scientific Committee, Edie Website Environment Industry Awards.

(D) Ball, Member of IET Design and Production Sector executive committee; **Dorey,** Chair of the Functional Materials Division of the Institute of Materials, Minerals and Mining; **Roy,** member of IET Manufacturing Policy Panel and the National Technical Committee on Advanced Design and Manufacturing; **Shore,** President of the European Society of Precision Engineering and Nanotechnology; **Tiwari,** Treasurer of the World Federation on Soft Computing (WFSC); **Webb**, Member of the Board of the Academic Federation for Robotics.

(E) Tatam: Institute of Physics representative to the Board of the European Optical Society.

(F) Brennan, IMechE Offshore Engineering Committee, BSI Fatigue Testing of Materials Committee; **Dorn,** Member of the Parliamentary Advisory Council for Transport Safety, member of expert panel on police-related road traffic incidents for Independent Police Complaints Commission and of the Home Office working party on the development of a police driving simulator; **Luk,** Chair, IEEE UK &RI Power Electronics Chapter, Electrical Machine Committee (EMC), IEEE Transactions on Industrial applications; **Mba**, British Institute of Non-Destructive Testing - Acoustic Emission Working Group' member; IMechE TRANSTAC (Transmissions Technical Activity Committee), British Gear Association council (2009 to 2011), COMADIT (Condition Monitoring and Diagnostic Technology Group), British Institute of Non-Destructive Testing; **Whidbourne**, Chair IEEE (UK &RI) Control Systems Chapter, Member IFAC Technical Committee on Aerospace, Member IFAC Technical Committee on Control Design, Member IFAC Technical Committee on Robust Control; **Zhang**, Royal Aeronautical Society's Structures & Materials Specialist Group.

Conference Programme Chairs
(A) Assadian, 50th IEEE Conf. on Decision and Control, European Control Conference, Orlando, USA, 2011; **Li,** ASME Turbo Expo 2012, 2013.

(B) Drikakis, 13th Int. Workshop for the Physics of Compressible Turbulent Mixing (IWPCTM13); **Cao** 19th Int. Conf. on Automation and Computing (ICAC'13), London, 2013; **Breckon** BMVA Symp. on Vision for Automotive Applications (2009); BMVA Symp. on Aerial Image Analysis and Classification (2010); BMVA Symp. on Using GPUs for Vision (2011) BMVA Symp. on Computer Vision in an Increasingly Mobile World (2013), Int. Conf. Advanced Video and Signal-Based Surveillance, 2013; **Tsourdos,** 2013 Int. Conf. on Unmanned Aircraft Systems, AIAA Guidance, Control and Navigation Conf., 2009, 2010, 2011, 2012,2013.

(C) Anthony, 62nd Canadian Chemical Engineering Conf. 2011, 2nd Int. Conf. Chemical Looping Combustion, Germany 2012, 16th SCEJ Symp. Fluidization and Particle Processing, Japan 2010, 61st Canadian Chemical Engineering Conf. 2010, 8th World Congress on Chemical Engineering 2009, 21st Int. Conf. FBC, Italy 2012; **Cartmell,** Barcelona Tech Water Technology Summer Sessions, 2008, Annual Anaerobic Digestion Research and Development Forum UK 2011, **Dotro**: 13th Int. Conf. Wetland Systems for Water Pollution Control 2012; **Soares,** Clean Water through Bio- and Nano-technology, Sweden 2012.

(D) Nicholls, Gordon Research Conf. on 'High Temperature Corrosion' 2009; **Roy,** 2nd EPSRC Manufacturing the Future Conference, 2013; **Shehab**, 11th Int. Conf. on Manufacturing Research, 2013; **Shore,** Euspen 12th Int.Conf., Stockholm,2012; Euspen 13th Int. Conf., Berlin, 2013.

(E) Rogers, Classified Infrared & Electro-Optics Conf. 2013; **Tatam**, Int. Advisory Board of Symposium B (SmartOptics) of CIMTEC, Italy, 2008; Advisory Committee for SPIE's Int. Symp. Optical Metrology, Germany, 2009.

(F) Dorn, Inte. Conf. on Driver Behaviour and Training, Sweden 2013; **Whidbourne,** UKACC Int. Conf. on Control (CONTROL 2014).

Invited Keynote Lectures
More than 155 Plenary and Keynote addresses have been given by Category A staff. Examples include:

(A) Li, Int. Conf. Condition Monitoring, Beijing 2008 and Lincoln NE 2009; **Guo,** Aeroelastic beneficial effects and challenges in MAV, UAV and aircraft wing design, RAeS UK, 2009; **Mason** Business Travel challenges and opportunities, 2012, Next in Corporate Travel Event 2011 and 2010, RAeS Hamburg, 2007.

(B) Drikakis Parallel CFD Conference at NASA Ames, 2009; Royal Society, London 2008.

(C) Anthony, 21st Int. Conf. Fluidised Bed Combustion, Italy 2012, 8th World Congress on Chemical Engineering, Canada 2009, 60th Canadian Chemical Engineering Conf., 2010, 16th SCEJ Symp. on Fluidization and Particle Processing, Japan 2010, 62nd Canadian Chemical Engineering Conf. 2011, 2nd Int. Conf. . Chemical Looping Combustion, Germany 2012; **Coulon,** 5th Int. Workshop on Chemical Bioavailability in the Environment, Cleanup 09, Australia, 2009; **Dotro,** IWA 13th Int.l Conf. Wetland Systems for Water Pollution Control, Australia 2012; **Jarvis,** International Water Association Young Water Professionals Benelux Conf. 2011; **Judd,** 2nd Gas Processing Symp., Qatar2012; **Oakey,** Materials for Power Engineering, Belgium, 2010; **Parker,** 12th Sanitation Community of Practice meeting, UK –, 2013; **Pollard,** International Water Association, Netherlands 2009; 3rd International Contaminated Site Remediation Conf., Australia 2009; **Rocks,** 4th International Contaminated Site Remediation Conf., Australia 2011; **Simms,** 8th Int. Symp. on High Temperature Corrosion, France 2012; Gordon Research Conference on High Temperature Corrosion, USA, 2010; Surface Stability of Materials in High-Temperature Aggressive Environments, USA, 2010;, EU Enlargement and Integration Workshop, Poland, 2009, 7th Int. Symp. on High Temperature Corrosion, France 2008; **Soares,** Clean water through Bio- and Nano-technology, Sweden 2012.

(D) Morantz, nanoMan 2012. **Nicholls,** Harold Moore Memorial Lecture (2011) of IoMMM. **Shore,** JSPE Spring Int. Conf., Japan 2011, Japanese Society of Precision Engineering Int. Conf., Japan 2008; **Tomiyama,** 13th Mechatronics Forum International Conference, EcoDesign 2009, CIRP General Assembly 2009, SDPS 2011; **Webb,** Composites UK Conf. 2011; **Williams,** 19th Machine Tool Congress 2013.

(E) Tatam, SPIE Smart Structures/NDE, 2010, USA; **Rogers,** UK Radiology Congress, 2010; **Chehura, James & Tatam,** Asia Pacific Optical Fiber Sensor Conf., China, 2013.

(F) Brennan, South American Conf. for Offshore Inspection & Maintenance, Colombia 2011, NTNU International Lecture, Norway 2012; **Vignevic,** Int. Conf. Mechanics, 2008, 9th New Models and Hydrocodes for Shock Wave Processes, 2012. IV SPHERIC, 2009; **Whidbourne,** Int. Conf. Mechanical Engineering, Robotics and Aerospace (ICMERA 2011); **Zhang,** 2nd Int. Symp. Aircraft Airworthiness, China 2011.

Election to Learned Societies
In total we have 119 memberships/fellowships of learned societies/professional institutions.
We have 4 Fellows of the **Royal Academy of Engineering**, Stephenson, Nicholls, Shore, Patel.

Journal Editorship
(A) Lei, Air Transport Studies (Assoc. Ed).

(B) Drikakis ASME Journal of Fluids Engineering, Journal of Computational and Theoretical Nanoscience, Encyclopedia of Aerospace Engineering, International Journal of Aviation Technology; **Tsourdos**, Proc. IMechE Part G (Assoc. Ed.); IEEE Transactions on Instrumentation and Measurement (Assoc. Ed.); **Cao** International Journal of Automation and Computing (Assoc.

Ed.); **Shin** Guest editor for a special issue of International Journal of Intelligent Computing and Cybernetics (IJICC) on UAVs 2011.

(C) Cartmell, Critical Reviews in Environmental Science Technology (Assoc. Ed); **Coulon,** J, Bioremediation and Biodegradation (Assoc. Ed); **Judd,** Desalination; **Oakey,** Power Plant Life Management and Performance Improvement 2011; **Pollard,** Science of the Total Environment (Assoc. Ed); Environment, Systems, and Decisions (Assoc. Ed); **Stephenson,** Editor-in-Chief Environment.

(D) Nicholls, Materials at High Temperature; **Tomiyama**, J. Advanced Eng. Informatics.

(E) James, Optics & Laser Technology; **Tatam**, Optical Engineering (Assoc. Ed.), Measurement Science & Technology (European Ed.); **Tatam**, Guest Editor for 3 special issues on Optical Fibre Sensors in Measurement Science & Technology (2009, 2010, 2013).

(F) Brennan, International Journal Fatigue and Fracture of Engineering Materials & Structures; **Luk,** Associate Editor of IEEE Transactions on Power Electronics; **Mba**, Machines.

Awards and Prizes

(A) Cranfield was awarded the 'Diamond Jubilee' Queen's Anniversary Prize for Higher and Further Education in 2010-12 for its *'world-leading work in aviation safety through research and training in air accident investigation*'. **Knowles,** IMechE Charles Sharpe Beecher prize, IMechE Kenneth Harris James prize, IMechE George Stephenson Gold Medal.

(B) Breckon, Royal Photographic Society (RPS) Selwyn Award for Early Career Contribution to Imaging Science (2011), IET Award for Innovation, "Selex Galileo – Stellar Team" (2009) R. J. Mitchell Trophy for Innovation, MoD Grand Challenge 1st Prize, Stellar Team (2008) Finmeccanica Group Innovation Award (2009); **Fei** IET Premium Award 2011; **Gu,** The UK Scopus Researcher Award in Engineering 2011; **Stillwell**, Sarah Ann Martin Award in Information Science, ARCS Foundation; **Tsourdos**, 2008 UK MoD Grand Challenge Winner: RJ Mitchell Trophy (Team Stellar - Sensing and Autonomous Tactical Urban Reconnaissance Network); IET Innovation Awards 2009: Team Award (Team Stellar - Sensing and Autonomous Tactical Urban Reconnaissance Network).

(C) Anthony, Team Merit Award from Natural Resources Canada for Oxy-Fuel CFBC Project (2008); **McAdam,** Sensors for Water Interest Group, Early Career Researcher Prize.

(D) Kirby, 4M2008 Best paper award, Science Foundation Ireland E.T.S Walton Visitor Award; **Nicholls**, 'Tom Bell Medal' for Surface Engineering Excellence (2009), ASME 'Best Technical Paper' (2008); **Shore**, NASA and ESA "Significant Achievement Awards" in recognition of its "extraordinary contributions to the James Webb Space Telescope mission" (2013); **Tiwari A,** IMechE Thatcher Bros Prize 2008/09 for the Best Journal Paper in Manufacturing.

(F) Assadian, Ford Motor Company 2008 Technical Achievement Award; **Patel,** Medal of Distinction of The Royal Institution of Naval Architects, 2010; **Luk,** 2011 IET Premium Award in Electric Power Applications, 2009 Award of Excellence by Knowledge Transfer Network; **Mba,** Ludwig Mond prize, 2010; **Campbell, Hughes** and **Vignjevic,** The 2009 Derek George Astridge Safety in Aerospace Award by IMechE; **Yeung,** Overseas distinguished scientist award of the BUAA (Beijing University of Aeronautics and Astronautics), 2012.