Institution: University of Hertfordshire

Unit of Assessment: Panel B (15): General Engineering

a. Overview

This submission comprises research carried out by the School of Engineering and Technology, formed in 2009 through the merger of two former engineering schools. Since RAE 2008, substantial progress has been achieved in staff participation, PGR numbers, income, international research collaborations and publications.

The research activities are incorporated into the Centre for Engineering Research, one of four research centres within the university's Science and Technology Research Institute (STRI), a multidisciplinary research facility that provides 3,100 sq.m. of dedicated laboratories and accommodation for more than 180 research staff and research students from the schools of engineering, computer science and physics. The STRI's research infrastructure, which includes administrative support covering intellectual property, contract negotiation and grant financial management, fosters interdisciplinary research and has produced a vibrant research culture with close interaction between students, postdoctoral researchers and academic staff from the various disciplines. The Centre for Engineering Research comprises four research groups that make up this submission:

Microfluidics & Microengineering Research Group, which conducts research into microfabricated devices and associated systems, with particular emphasis on applications at the bioscience interface.

Materials & Structures Research Group, which conducts research into advanced materials and structures for applications in extreme environments such as aerospace engineering, high temperatures, fuel cells and the human body.

Sustainable Energy Technologies Research Group, which focuses on research into sustainable energy technologies relating to a variety of engineering applications within the automotive, aerospace and mechanical industries.

Digital Media Processing & Biometrics, a new group formed from longstanding research activities active in the previously separate engineering schools before the School of Engineering and Technology was formed. This group gained in terms of both critical mass and interdisciplinary research opportunities, and now focuses on research in areas of signal processing and processor architectures used for demanding multimedia data streams with such specific applications as image processing, automatic number plate recognition (ANPR) and electronic circuit design.

b. Research strategy

The university aims to carry out excellent research in targeted areas. Key elements of the current research strategy include creating a dynamic culture and environment; raising our international profile, increasing impact, exploitation and dissemination; and developing the next generation of researchers. In realising this overarching strategy, the research groups listed above have exploited the facilities, resources and multidisciplinary environment offered by the STRI to help them strengthen, providing a supportive and invigorating environment in which researchers can develop and continue the university's objective of engaging proactively with industry and business.

Achievement of 2008 strategy

Our 2008 strategy focused on enhancing working links with industry that would lead to collaborative grants, iCASE and other industry-funded studentships, and extend interdisciplinary research; capitalising on EU research opportunities; and providing strong leadership for knowledge exchange to industry. All these areas have seen improvement since 2008 and, as illustrated in the table below, the number of submitted staff has grown from 4 to 14.8.

Indicator	Cat. A fte	ECR %	BME %	Research income	KT projects
RAE 2008	4	0%	25%	£3.1 million	15 (£973,840)
REF 2014	14.8	40%	66%	£3.9 million	26 (£2.6 million)

In particular, the 2008 strategy identified the need to increase research through the development of younger researchers. There has been a marked improvement in early career researcher (ECR) numbers from none in 2008 to almost half of the current submission. The 2008 submission focused on the activities of just two research groups and the esteem of their staff. Through the recruitment of new staff since 2011 (**Bevilacqua, Cortes-Quiroz, Coudron, Dashti**, **Hertfatmanesh, Montalvao, Peng, Ren** and **Tian**), and support for increased research engagement amongst existing academic staff, this submission has benefited from growth not only in staff numbers but also in diversity and emerging talent. This growth has been supplemented by an increase in the numbers of postgraduate students by 20%. Specific achievements since RAE 2008 have been:

Microfluidics & Microengineering: Ongoing infrastructure and staffing investment, and the group now incorporates industry-standard microfabrication and microfluidics laboratories, a 25 sq.m. Class 100 clean-room, microengineering and systems engineering facilities, and experienced multidisciplinary staff. The group has exploited its specialised expertise in the research and development of novel sample-manipulation and processing technologies, from micropumps to multiplex antibody patterning; but, unusually for an academic group, it takes these considerably further by incorporating them into turn-key systems designed to tackle specific bioscience challenges. This ability has resulted in strengthened collaborations with bioscience and clinical organisations, most notably the Defence Science and Technology Laboratory (Dstl), Porton Down, for whom the Microfluidics group has been a longstanding supplier for over 15 years and from whom research contracts totalling more than £1.6 million have been received over the past five years. Further collaborations with bioscience researchers at UK HEIs, including UCL and KCL, and a recent EU FP7 award ('ENVIGUARD', to develop in situ sensors for man-made chemi- and biohazards: €5.2 million; the university's share, €600k) further endorse the group's capabilities at this topical engineering–bioscience interface.

Materials & Structures: Further strengthened its primary areas of activity, i.e. materials processing; C-C composites and joining techniques of importance to the automotive, aerospace and cutting tool industries; metal–ceramic joining technologies; antibacterial and antiviral materials; impact and fatigue in aircraft structures; aero-elasticity; and non-linear dynamics. More recently, it has become active in the emerging themes of biomaterials and natural fibre composites. Through these activities, the group has developed strong collaborative links with leading research groups in China, Germany, India, Italy, Ukraine and Poland, including the Polytechnic of Torino, Nankai University, and the AGH University of Science and Technology, Krakow. The group is also a member of the KMM-VIN Virtual Institute on Knowledge-based Multifunctional Materials, in which it leads the Working Group in Metal-Ceramic Materials, giving access to resources across 100 institutions throughout Europe. The group currently hosts an EU-FP7 Marie Curie Fellow.

Sustainable Energy Technologies: Built on its original research strengths of hydrogen and nano-materials to expand into fuel cells, wind turbines, tribology, biofuels, electric vehicles and, recently, novel transportation schemes and renewable energy generation. New staff recruitment has enabled the group to broaden its areas of work into fuel injection, engine performance and phase change materials. Two EU FP7 projects have allowed new research fellows to be recruited to strengthen the team in areas of mathematical modelling and simulation.

Digital Media Processing & Biometrics: Further strengthened longstanding collaborative links with industrial partners such as TTi, SONY CEE, and Sedgewall Communications, whilst research in advanced ANPR is undertaken in collaboration with the Home Office and the National ANPR Countermeasures Group, together with CitySync Ltd. The group also specialises in architectural innovations (e.g. DSP Algorithms and H/W architectures) with prototypes on FPGA and system-on-chip solutions for applications such as for ANPR. Further activities involve research in advanced

wireless communications systems and electronic circuit design, stereoscopic-3D visualisation and augmented reality, each supported by industry and academic collaboration and staff exchange.

Future Strategic Plans

Within the context of the university's research strategy, our focus is on embedding the achievements of the past five years whilst strengthening our core research through a mixture of organic and targeted growth. We aim to achieve this through:

1. Expanding membership of the existing four research groups whilst strengthening the research culture both within groups and across the engineering discipline as a whole.
2. Targeted new staff appointments and, at the same time, increasing participation within the existing research population, which will allow groups to grow.
3. Raising our international profile through collaboration, consortium funding and international partnerships. Both internal and external funding will be dedicated to support this.
4. Further exploiting our business connections to generate routes to impact and dissemination of our research in the UK, Europe and globally.
5. Increasing the proportion of funding from RCUK and TSB sources, initially through partnerships with other HEIs, leading to securing a DTC or other form of Centre of Excellence recognition.
6. Further strategic capital and infrastructure investments in laboratory and specialist equipment resources. This will facilitate and accelerate the transition of our basic research outputs through to their implementation and exploitation in industry-relevant fields of endeavour.

Specific objectives for the individual research groups to achieve these aims over the coming period include:

Microfluidics & Microengineering will focus research into further refinement of the advanced microfabrication and microfluidics techniques that allow them to efficiently deliver vertically integrated technology solutions to commercial and governmental sponsors and collaborators. In addition, the group will significantly expand the number of PhD students to both reinforce the dynamic environment in which they work and strengthen the foundations for long-term sustainability of the group's basic and applied research. A major aim is to capitalise on the strength and outcomes of the major collaborations with sponsors such as Dstl to enable diversification in the group's funding base and a collaborative partner portfolio in areas of biomedical and clinical healthcare diagnostics.

Materials & Structures will target the continued development of advanced materials and structures for applications in extreme or critical environments, such as aerospace engineering, high temperatures, fuel cells and the human body. The group will foster the development of key emerging research areas, including simulation of the mechanical performance of composites and endodontic materials, anti-viral and anti-bacterial functional materials, and natural fibre composites. Additional resources will be deployed to exploit the significant potential benefits of a materials processing technology – the use of electromagnetic fields for enhancement of materials properties such as corrosion resistance – that is already attracting substantial industrial interest.

Digital Media Processing & Biometrics will focus efforts on pioneering work and industrial collaboration in fields relating to 3D visualisation and augmented reality, wireless communications systems, intelligent co-operative processor-in-memory architectures for improved core-to-core performance, RF communication circuits and advanced signal processing for ANPR in adverse viewing conditions. A priority will be to grow research capacity through creating more postgraduate researcher opportunities and increased dedicated research time of academic staff. An emphasis on attracting external funding, whilst capitalising on existing research strengths, will enable new research avenues to be followed in biomedical sensors, personal tracking and localised service applications. These will support application areas within systems integration, intelligent healthcare management and future city technologies.

Sustainable Energy Technologies: will exploit its recent growth in new research staff numbers to target specific energy technologies that offer rapid application in industry, especially involving

advanced fuel cells, novel wind energy and energy harvesting, integrated energy management, electric vehicles and biofuels. The group will also seek to exploit its intellectual property through the establishment of new collaborative links with industrial partners both in the UK and internationally. These will facilitate further growth and consolidation in postgraduate and postdoctoral research staff.

c. People, including:

Staffing strategy and staff development

The university has provided researcher (staff and student) development for over 20 years through a wide-ranging centrally organised programme of development implemented at research institute and UoA level. The university launched the Concordat to Support the Career Development of Researchers in April 2010, which is implemented by mapping our researcher development provision to the Researcher Development Framework (RDF). Ours was one of the first universities to receive the European Council HR Excellence in Research Award; the Award was extended for a period of two years in 2013. The university participated in the 2010, 2011 and 2013 Careers in Research Online Survey (CROS). The 2013 results show that in 12 out of 18 categories University of Hertfordshire responses are above or more positive than the national average. The survey provides valuable feedback to the unit on its staff development strategy. The university has both research student and staff fora at university, research institute and UoA level to engage the research community in their developmental needs. Research staff development is provided by the HR Development team, who work closely with the Research Grants team and the University Researcher Development Working Group. Research staff can access academic staff development as well as the Generic Training for Researchers (GTR) Programme. There are 126 staff development sessions relevant to research staff. Examples of courses available include CPD courses in career management, leadership and management, personal effectiveness, specialist research skills and techniques, doctoral student supervision and public engagement. Additionally, the School supports research staff within the UoA by providing funding support for conference attendance, research networking and technical training.

Development for ECR staff includes: a one-stop web page for researcher development, enabling centralised access to all researcher development resources across the institution, and the opportunity to organise and participate and take a lead in School activities. Research staff organise an annual programme of research seminars, run master classes in laboratories, help organise career development events and take part in commercial consultancy work. Two engineering research staff have recently taken advantage of a new university leadership development programme for researchers.

A coaching and mentoring scheme is available for researchers, and all research staff have an opportunity for career development through limited teaching in engineering and attendance at the university's Academic CPD PGCert Programme. A researcher-led initiative permitted researchers to take responsibility for personal, professional and career development. This £10,000 fund allowed research staff to request support on any aspect of their own development.

At the research centre level, a Research Focus Group (RFG) of senior research staff will continue to direct, sustain and promote the vitality and esteem of the engineering research groups. The RFG has successfully introduced a workload management system, providing staff with dedicated time to undertake research each year. This includes protected research time for new staff, as well as secondment applications, unpaid leave or sabbaticals, and industrial secondments in pursuit of research goals. The RFG offers research staff and students the opportunity for UK and international conference attendance and networking through a specific policy for wider engagement by researchers. These processes, together with targeted deployment of ECR and new staff recruited into engineering, continue to underpin the building of larger and more sustainable research groups with strong foundations and inherent research culture. They also encourage staff to engage in international collaboration, exploit opportunities for researcher mobility, and provide a personal, professional and career development framework to enhance staff and researcher potential by enabling researcher responsibility for their own development needs.

Research students

A comprehensive programme of Generic Training for Researchers (GTR) with over 60 sessions covering the spectrum of the Researcher Development Framework is available to staff and PGRs. This underpins staff and students' research work by providing knowledge and transferable skills that help them progress through their research degrees and careers. The programme, commended in the 2009 QAA institutional audit, covers a variety of areas of supporting studies including, for example, the process of research degrees, personal development, career skills, employability and information technology. The university and the School participated in the 2009, 2011 and 2013 Postgraduate Research Experience Survey (PRES). The 2011 and 2013 results both show the UoA performing above the national average. PRES 2013 results show improvements from 2011 on 25/30 main indictors, with 27 of the 30 being above the national average. The PRES indicated areas for action, and led in 2011–12 to improved computing resources for PGRs, including new PC provision for all PGRs and better access to high performance computing. The result was a 60% improvement in PRES 2013 for this indicator. Improvement to our research seminar programme following PRES 2011 resulted in a 10% improvement to 2013, and a 30% improvement has been achieved in our research environment stimulating PGR work. Research students, working with their supervisors, carry out a development needs assessment and compile a personal development plan on an annual basis. This plan can use the GTR programme, the increasing number of HR research specific programmes, School or Research Institute development events or, increasingly, attendance at professional institution events. The Centre for Engineering Research organises a monthly research seminar programme to promote a research ethos that supports PGR development. This provides training in presentation, and improves communication skills. Specialist technical training is offered in MatLab, CFD, CAD and CAM software, specialist electronics software, equipment use and programming languages, as well as in relevant Health and Safety issues.

PGRs benefit from helping to organise events and activities within the centre, acting as representatives on STRI fora and university committees. For example, the career development event for researchers in 2012 was planned, organised, project-managed, budgeted and hosted by research students from across the research institute, with 31 researchers attending the event. PGRs have benefited from public engagement activities, including a three-day STRI research showcase in 2008, annual project displays in June each year, and participation in the university research photography competition in 2012. Over 30 research students have benefited from international travel to conferences and to work in the research laboratories of other universities or research organisations, gaining valuable international and technical experience. Plans for the future include making better use of research alumni to support and mentor PGRs. Completion rates are in line with that of the whole university, which itself outperforms national average rates.

d. Income, infrastructure and facilities

The UoA has been successful in attracting industry, KT and EU funding totalling £5.8 million since RAE 2008. KT funding has increased from £974k to £2.6 million, with 26 standard KTP and shorter KT projects in the REF period. EU grant income increased from £521k (RAE 2008) to £795k by the end of 2012. Since 2008, we have secured direct industry funding of over £2 million from, for example, Dstl, MoD and MBDA. Our commitment to developing underpinning research, enhanced with new staff appointments, coupled with industrial collaboration and international academic partnerships has borne fruit in Europe with £208k SHEL (Hydrogen JTI), £280k MAAT (Novel transportation schemes) and €280k Marie Curie (Electromagnetic Fields). KT projects have been used as vehicles to deliver impact and iCASE awards have provided underpinning research for the benefit of industry partners and the academic community. This is illustrated by five iCASE awards with Heales Enterprises, Gigasat, CitySync, Euro Energy Solutions Ltd and BAE Systems, and 26 KTP/KEEP/K4B projects totalling £2.6 million that have included Secomak (£123k), Powertrain (£137k), Fluorocarbon (£150k), C4 Carbides (£157k), Merit Plastic Mouldings Ltd (£158k), TTi (£252k), ITM Power (£372k) and Coopers Bearings (£120k). Looking ahead, the EU Horizon 2020 vision of funding activities with an integrated theme of research and innovation aligns well with our research portfolio and approach and will be an increased focus of future funding applications. The UoA has also developed research partnership agreements with local and regional organisations,

such the Building Research Establishment, which facilitates clear research objectives in key areas of need.

Infrastructure and Facilities

The centre has already benefited from a major infrastructure development and investment programme. Future funding will be aimed at widening the scope and capability of research groups within the context of the university's 10-year estates strategy and redevelopment of the present campus buildings. The current laboratory space total for the Centre for Engineering Research total is ~800m^2, and this will be increased substantially in the coming decade under the university's new Estates Plan.

Existing Facilities: The **Microfluidics & Microengineering** group is very well equipped for rapid turn-key product development with microfabrication and microfluidics laboratories, a 25m^2 Class 100 microfabrication clean room, plastics microfabrication, Suss MJB4 photolithography, resist spinners, microscopy, metal deposition and plasma ashing, UV- surface treatment, laser plastics cutting, precision CAD-CAM-CNC, flow cytometry, fluorescence microscopy with cooled CCD camera, and an optical surface profiler. The **Materials & Structures** group has a range of laboratories including a structures lab, composites lab, electromagnetic processing lab, high-temperature materials lab and a materials characterisation lab. The **Sustainable Energy** group operates within the dedicated Sustainable Energy Technology Centre, which incorporates a fuel cell laboratory, hydrogen delivery infrastructure, an industry-funded production drying 'centre' with data acquisition and interpretation, a nano-tester laboratory and a tribology suite. The **Digital Media Processing & Biometrics** group is supported by dedicated biometrics, signal processing, and system-on-chip, RF testing, wireless and electronics and ANPR laboratories. Software for communications and network simulation such as OPNET are also available.

Recent investments: Strategic investment in the centre from university capital funds and other sources has totalled £1.35 million, plus a further £2.42 million of in-kind hardware support from industrial partners. This has benefited areas of **Microfluidics/Microengineeering**: TWI particle measurement equipment (£110k), a 9m^3 aerosol exposure chamber, cooled camera and microwave test equipment (£78k), laboratory development including clean room, new microfabrication facilities, CFD modelling software and ANSYS Workbench (£400k). **Materials**: £195k for a nanoindenter, two Differential Scanning Calorimeters, a potentiodynamic corrosion rig, two high-temperature furnaces, tensile test equipment with an environmental chamber unit, and a new scanning electron microscope (£160k). In late 2013, a further £220k will be invested in a Materials laboratory upgrade. **Digital Media Processing and Biometrics**: £102k to support research into biometrics through the development of platforms for speaker recognition and 3D face recognition, and a FPGA and ANPR system, £2.1 million 'in-kind' donation of nanoboard hardware and software from Altium, a 3D visualisation and analysis facility with stereoscopic-3D displays, a head mounted display wall and high-precision optical tracking cameras. This has been supplemented by mobile communications signalling testing units, donated by Anritsu. Funding (£310k) from QR, CapEX and GH budgets has provided a SmartLAB, atomic force microscope, universal vibration rig, new natural fibre composites laboratory, flow cytometer and, for the **Sustainable Energy** group, specialist energy harvesting instrumentation.

e. Collaboration or contribution to the discipline or research base

One of the centre's strongest long-term links is through Dstl Porton Down and generally through the **Microfluidics and Microengineering** group (**Tracey** and **Coudron**). This has led to £1.1m of funded projects, and we are one of the suppliers of choice to Dstl. **Chrysanthou** has developed an EngD scheme with MBDA and Ford, whilst MBDA have supported iCASE studentships in aircraft structures. KT work with C4 Carbides KTP, Meggitt Aircraft Braking Systems, ITM Power Ltd, Secomak Ltd, Coopers Bearings, and TTi; and our iCASE awards with BAE Systems, CitySync, BRE and Euro Energy Solutions Ltd, have all proved useful collaborative activities. In the field of antiviral and antibacterial nanoparticles, **Ren** has collaborations with QinetiQ Nanomaterials Ltd, Retroscreen Virology Ltd, Sun Chemicals (UK), Pall Aerospace Europe, and three UK HEIs. The EPSRC Supergen IV Wind Consortium, of which **Ren** is a partner, includes ten universities as well

research organisations such as the STFC Materials Group, and 16 companies, including E-on and EDF Energy. **Peng** has international collaborative research with the global automotive company AVL and with Tianjin Yiqi Auto Company (China), which has improved their engine fuel economy by 3–5% and reduced emissions. **Hertfatmanesh** is working on fuel injection characterisation with Delphi Diesel Systems. The DMPBRG has collaborated with TTi, Segdewall Communications and CitySync, whilst the group also works in collaboration with the Home Office CAST and the National ANPR Countermeasures Group through two sponsored EngD programmes (**Sotudeh**). **Xu** has funding from MBDA and Airbus for their work on stability of non-linear structures and structural integrity analysis for damage-tolerant design and structural health monitoring.

Academic and international collaborations

Materials and Structures: Chrysanthou collaborates with Imperial College on TaC-HfC composite synthesis for hypersonic aircraft, chairs the European KMM-VIN working group on metal-ceramics, is working group leader for metal-ceramic composites, and executive committee member of CMA-UK 2012, on the Board of Governors of the international KMM-VIN, delivered invited lectures at CIMTEC 2010/CMA-UK 2012, and is on the editorial board of *Metallurgy and Adv. in Ceramics*. **Ren** collaborates with Nankai and Tianjin universities, the Institute of Metal Research and Sun-yat Sen University; is on a TSB-funded AMSCI project collaboration with Manchester, Imperial College London, Royal Holloway, Nottingham and Cranfield; and is editor for *J. of Ceramics*, *Adv. in Applied Ceramics* and *Acta Materiae Composites Sinica*. Group staff are reviewers for nine international journals and have visited the AGH University of Science and Technology, Krakow, for training on transmission electron microscopy. **Xu** collaborates with the Institute for Theoretical and Experimental Analysis of Aeronautical Structures in Romania, hosted an exchange programme in 2011 and staff exchanges in 2012 and 2013 with the Indian Institute of Technology. He works with Narvik University College, Norway, on the effects of ice accretion on the dynamic behavior of wind turbines and was a member of the scientific committee for the International Conference on Fracture and Damage Mechanics, 2012. The group has a longstanding exchange programme with multiple short-term visits from the Polytechnic of Torino; two from the Institute for Energetics and Interfaces, Milan; two from Nankai University, China; one from the NPL, India; and one from the Indian Institute of Technology, Guwahati. Montalvao collaborates with Technical University of Lisbon and Vrije Universiteit Brussel.

Microfluidics and Microengineering: Collaborations are predominantly with major industrial organisations, but in recent years there has been diversification into additional academic projects. The group now works with UCL on the Joint Synthetic Biology Initiative project, as well as with KCL in chip design and microfabrication for cancer diagnostics, and with TTZ Bremerhaven and the Food and Environment Research Agency. Staff exchange has taken place with the Technical University of Dresden, and joint work on micropump design and FEA modelling has been carried out with the Tokoyo Technical University.

Sustainable Energy Technology: Peng has jointly published and researched with staff from Tianjin University, Dalian University of Technology and Beihang University, China; held joint grants on Smart Control and Diagnosis for Economic and Clean Engines with HEI Lille and Univ. Picardie, France; a member of the PRC for IMechE; and a co-organiser of the 2008 SAE Fuel and Lubricant conference and the 2008, 2010, 2012 and 2014 international symposia on Jet Propulsion and Power Engineering. **Tian** is a member of the IEA Task 4224 experts panel, co-organised an international workshop on Solar Energy at Univ. Warwick and collaborates with research teams at the universities of Cambridge, Nottingham, Shanghai Jiaotong and Tongji, China.

Digital Media Processing & Biometrics: Sun's research was the basis for collaboration with 11 universities internationally, including in Singapore, China, Australia and UAE; works closely with Hunan University, China in analogue signal processing, fault diagnosis and automatic antenna tuning; is involved in a joint PhD programme with Dalian Maritime University (DMU); associate editor of *IEEE Trans. on Circuits and Systems-I*; editor of *ETRI Journal*; and lead guest editor of a special issue on Cooperative Wireless and Mobile Communications, *IET Communications*, 2013. **Sotudeh** has been visiting professor at Ryerson Polytechnic University, Toronto, since 1995. **Livatino** referees for *IEEE Transactions*; special-session chair, IEEE International Symposium on Industrial Electronics, Italy and IEEE International Conference on Multimedia and Expo, Spain.