Institution: Queen's University, Belfast

Unit of Assessment: 12

a. Overview

UoA12 membership comprises of 50 academic staff from two Schools: Mechanical & Aerospace Engineering, and Chemistry & Chemical Engineering. Both Schools have a strong track record in international research excellence. This highly successful unit has experienced expansion and significant internal and external investment in infrastructure, research facilities and staff since 2008. Investment by QUB of over £20M since 2008 has brought the unit to its current position of strength with solid output and excellent forward potential. Significant staff renewal has seen appointment of 26 staff, 21 of whom are early career, 3 experienced staff and 2 international leaders. The unit is now characterised by a vibrant young staff led by established career leaders.

The Unit's research teams are grouped into clusters, each led by a Director of Research (DR) who is an academic of international reputation. In this submission there are staff from three clusters within the School of Mechanical and Aerospace Engineering, namely: **Advanced Materials & Processing**, **Clean Energy** and **Aerospace & Manufacturing**; and from two clusters in the School of Chemical Engineering: **Innovative Molecular Materials** (IMM) cluster and the **Centre for the Theory and Application of Catalysis** (CenTACat). These clusters provide the critical mass in core capability and resources. The longstanding tradition of interdisciplinary research at QUB enhances collaboration across the clusters addressing challenges that have lead to significant impact. The work is grouped into three fundamental thematic areas:

Materials (currently 20 academic staff and 30 research students):
Biomaterials; Polymer Processing, Modelling and Simulation; Polymer Composites and Nanomaterials; Ionic Liquids; Super-hydrophobic Materials.

Energy (currently 15 academic staff and 16 research students):
Vehicle Performance Modelling, Exhaust After-Treatment, Microturbines, Waste Heat Recovery, Renewable Clean Energy, Catalytic Technologies.

Design & Manufacture (currently 15 academic staff and 26 research students):
Advanced Design Methods for Analysis and Manufacture**,** Aerodynamics**,** Value Driven Design**,** Manufacturing Automation & Robotics, Integration of Design and Manufacturing Processes

The research activities are associated with successful industrial research centres, which bring researchers together with commercially focussed areas and demonstrate delivery of both national and global impact. These centres are:

- Polymer Processing Research Centre (**PPRC**) – Long established self-sustaining centre of 20 years, cross-disciplinary with Mechanical Engineering, Chemical Engineering and Pharmacy.
- Centre for Theory and Application of Catalysis (**CenTACat**) – Established in 2003 with £7.5M – cross disciplinary with Mechanical Engineering and Chemistry & Chemical Engineering.
- Queen's University Ionic Liquids Laboratory (**QUILL**) – Established in 1999 to promote the industrial exploitation of ionic liquid technology, includes Chemistry & Chemical Engineering and Physics. Ionic solvents developed QUILL have been voted the **most important British innovation of the 21st century in 2013**
- The Queen's University Environmental Science and Technology (**QUESTOR**) Research Centre provides application focussed research and technology for local and global industry, includes Chemistry & Chemical Engineering and Civil Engineering.
- Centre of Excellence for Integrated Aerospace Technologies (**CEIAT**)- Established in 2003
- Northern Ireland Advanced Composites and Engineering Centre (**NIACE**) - £50M, 2013 cross-sector initiative, multi-institutional with Mechanical & Aerospace Engineering and University of Ulster, with an initial project portfolio of £5M.
- The Institute for a Sustainable World (**ISW**) – £10M, 2008 cross-disciplinary with engineering, science and social sciences.
- Centre for Advanced Sustainable Energy (**CASE**) - £10M, 2013 centre for industrially driven research

b. Research strategy

(i) Introduction

The 20 schools in Queen's have subdivisions called research clusters aimed at providing a flexible architecture and encourage cross-disciplinary research. These clusters have emerged to provide critical mass in key disciplinary areas and develop strategies to match national and international agendas from research councils, government and industry. Staff are attached to a single cluster for management purposes but are encouraged to collaborate across the university as is evidenced later in this document. The system provides a supportive structure for academics in their own discipline and opens opportunities for novel areas of research at disciplinary interfaces, such as sustainability, energy management in polymer production, biologically inspired materials and clean energy generation. This is evidenced by the number of collaborative papers in this submission.

(ii) Status at RAE 2008

In RAE 2008 the current UoA12 membership had forward plans (documented in submissions for UoA 18 & 28) as summarised here:

Materials

Environmentally sustainable polymers and advanced structural materials & processes formed the main thrust in polymers, with other substantial activity in nano-composites and biomaterials. International collaborations with University of Queensland and European partners were to focus on biodegradable polymers, supercritical fluid assisted processing and tooling and cooling concepts. The PPRC was to provide foundation & focus for cross-disciplinary and industrially relevant work.

Design & Manufacture

Continuing work in fundamental structures, aerodynamics and automated design processes and tools for analysis and manufacturing were key threads, supported by major initiatives including the Bombardier Royal Academy Chair in Composites. This was to be reinforced with cross-cutting work on value driven design methods with international collaborators in the USA and Europe. The strong industrial link with CEIAT was to provide a fulcrum for building integrated multi-disciplinary technologies, and developing virtual test beds for composite materials.

Energy

The main challenge was set around reducing emissions and developing after treatments for reduced environmental impact and fuel economy. Ageing of catalysts and continuing the strong industrially applied work with General Motors (GM) was to be a focus. Complementary research focused on turbomachinery, the fundamental principles that underpinned clean energy production, clean organic chemistry, and environmental protection.

Markers of Progress

Significant progress was made on several of the key areas as evidenced by:

- Appointment of the Bombardier-Royal Academy Chair in Composites
- Investment from General Motors in the Waste Heat Recovery lab
- Establishment of the NIACE Centre; ISW and CASE competence centres
- £1.2M funding for the DEL All-Island programme on sustainable transport.
- University of Massachusetts Lowell, Dublin City University, QUB memorandum of understanding for research in polymers.

Further examples of such success are throughout this document and the submission portfolio.

(iii) Strategic progress

Strategic research objectives are reviewed and updated annually by individual Schools and across Faculties. For example, recognition of the growing body of high quality work in sustainability related hot topics resulted in the establishment of the ISW, a £10M investment in cross-disciplinary research with Engineering, Science and Humanities. Since 2008 this process has been used to identify areas of focus, new research topics, resource requirements and objectives. In 2012 we announced major ambitions for our clusters focussing on global grand challenges: "**Energy: Clean Generation; Efficient Manufacturing; Sustainable Transport**". This further involved revision of clusters and expansion of membership to reflect this research commitment. The aims, challenges and achievements since 2008 for the three thematic areas are identified below:

Materials:

- ***Aim:*** To be globally leading in research having focussed and strongly integrated research areas concerned with polymer processing and process modelling, nanomaterials, biomaterials and ionic liquids.

- ***Grand challenges:***
  - Biomaterials: integrating the current research themes with mechanobiology and patient-specific and population-based implant biomechanics
  - Sustainable bioplastics and biocomposites to include incorporation of naturally sourced fibre additions.
  - Development of functional polymers and ionic liquid for novel applications
  - Multi-scale process modelling tools for advanced chemical product design
- ***Major developments:***
  - *Increased funding from EPSRC, EU FP7, TSB and directly from Industry combined with further investment in facilities has seen this develop into one of the largest groups in the field of polymer engineering in the UK.*
  - *Technology Transfer from the PPRC continues to be recognised internationally as excellent, evidenced by several awards and spin out companies.*
  - *Strategic recruitment staff in biomaterials, ionic liquids and nano materials*
  - *ASPEN-Plus flow-sheets incorporating ionic liquids relevant to commercial processes, industrial partners include Eastman Chemicals and Petronas*

Energy:

- ***Aim:*** To conduct high quality research in the area of clean-energy solutions for transport, power generation and manufacturing; and deliver world leading technologies to industry.
- ***Grand challenges:***
  - Efficient use of Energy Resources and Waste Heat Recovery
  - Alternative Energy Sources and Applications, including opportunity fuels
  - Novel technologies for the conversion and use of energy in reacting systems
- ***Major developments:***
  - *Strategic appointment of a Chair in Reactor & Process Engineering*
  - *Strategic recruitment of staff in turbomachinery and energy systems.*
  - *Establishment of the* Centre for Advanced Sustainable Energy *(CASE)*
  - *Change in research focus from engines and towards total vehicle efficiency, renewable energy sources, delivery of key elements of the hybrid drive for the New Bus for London.*
  - *A new catalytic dehydrogenation process was developed in partnership with Robinson Brother's, and subsequently commercialised.*
  - *Key enabling research developed for conversion of target batch processes to continuous flow in collaboration with Johnson Matthey and Robinson Brothers.*
  - *University spin out company (Vykson) established to commercialise patented small gas turbine system for low grade methane gas, backed by £1M of private investment funds.*

Design & Manufacture

- ***Aim:*** Developing paradigm shifting technologies and processes for sustainable manufacturing. Application areas range from integrated design and visual analytics, to manufacturing automation and life-cycle costing for advanced composites, multi-functional materials systems and advanced alloys.
- ***Grand challenges:***
  - Sustainable aviation from manufacture to end-of-life and re-life
  - A fully automated and integrated multi-disciplinary design cycle with manufacturing process considerations embedded
  - Integrated design and manufacturing process for advanced composites.
- ***Major developments:***
  - *Strategic appointment of the Bombardier-Royal Academy Chair in Composites (Prof Brian Falzon; with associated CNT manufacturing capability via Prof Stephen Hawkins)*
  - *Strategic appointments in CFD, aeroelasticity, visual analytics, digital manufacturing, automation and composites.*
  - *Re-emphasis of some of the cluster activity towards manufacturing*
  - *Technology transfer through KTS secondments into industry*
  - *Establishment of NIACE, an international focal point for advanced engineering R&D*

Future strategic aims and goals:

In the next six years the clusters will address the topical grand challenges in their respective engineering fields, building on existing and developing new international collaborations. Financial support to meet these challenges will be acquired though both internal University initiatives (for

enhanced infrastructure and facilities) and external funding from government grants, charities and direct industrial support. Research will address both health and energy; exploring extremes and defining new limits. To achieve critical mass and international impact at least ten academics will work within each theme, complimented by appropriate technical staff, research staff and PhD students. This is outlined below, in association with each research theme.

Materials (external funding target for next 6 years: £20m)

- **Develop a new range of materials and processes to meet global needs**
  - Energy and material usage: Process optimisation using predictive and experimental approaches
  - Functionally graded systems: New or improved composite, packaging, and additive manufacturing technologies for high performance applications
  - Advanced material design: for separation processes, pharmaceutical formulations and sustainability
  - Innovative solutions for health: Combination drug delivery systems and surgical technologies for improved patient outcome

Energy (external funding target for next 6 years: £15m)

- **Deliver a step change in efficiency and performance of energy generation systems**
  - Thermodynamic systems and whole vehicle modelling
  - Engine boosting technologies for a new generation of down-sized engines
  - Renewable Clean Energy: biomass, biofuels, wind, storage, supercritical water oxidation
  - Development of sensor technology for control of oil and gas processes
  - Catalytic technologies: including, catalyst ageing, fast lightoff catalysis, reaction kinetics and novel reactor development for catalytic processes

Design & Manufacture (external funding target for next 6 years: £15m)

- **Shaping the future of design and manufacturing for step change in productivity and sustainability.**
  - Manufacturing productivity: from assembling materials to aircraft (innovative materials & processing technologies, flexible manufacturing automation, virtual utility in manufacturing, through-life human factors and ergonomics, the intelligent lean factory).
  - Design productivity: competitive advantage in engineering (capturing design and simulation intent, geometry handling, meshing and integration for future CAE systems, economics in design (Value Driven Design, cost and supply chain modelling)).
  - Sustainable & innovative aerospace solutions (aeroelastic design, laminar flow control, cabin thermal comfort, composite technologies, multifunctional materials and structures, multi-physics and high-fidelity simulations fit for design, virtual testing).

c. People, including:

i. Staffing strategy and staff development

All staff engage in research relevant to their cluster, which is aligned with specific School's and overall University strategy. These all directly reflect the national agendas as set by RCUK, and the European Commission, as well as the needs of our major industrial strategic partners. Each school produces an annual plan to which each cluster contributes, with its own localised strategy, which is matched to the higher objectives of the School. Clusters develop their research strategy considering two key factors: Novel research concepts which are high risk, and current industrial challenges provided by our strategic partners. This dual approach provides focus for impact of research and a long term view to develop tomorrow's technologies. To accommodate new areas of research and new staff the University continues to support development of the infrastructure.

As the research agenda evolves and staff progress through their career, forward planning accounts for new collaboration potential and for leadership succession. The result has been that several key staff have been promoted to leadership positions, and these have been supported by transformational Chair appointments in Composites (the Bombardier-Royal Academy Chair, Prof Falzon) and Reactor and Process Engineering (Prof Rebrov). Furthermore, Honorary Professorship appointments have been made to **Mr David Beverland**, an internationally leading orthopaedic surgeon and to **Dr Steve Myers**, Director of Accelerators and Technology at CERN. **Dr John Hsu** a senior systems engineer at Boeing, and former chair of INCOSE USA, was appointed as a **Royal-Academy Visiting Professor** in Systems Integration and has continued engagement being appointed as an Honorary Professor on completion of the RAEng scheme.

Additionally a cohort of young staff has recently joined to help build new areas of research. All the

new academic staff appointments have been from globally leading institutions.

Career development

All new staff undergo an academic probationary period typically lasting three years. During this time, a mentor is assigned to guide the probationer on the operations of the university and provides guidance on career planning. Additionally a probation committee is established which consists of the mentor, the Head of School (HoS) and the appropriate Director of Research (DR). The committee meets the probationer twice per year to monitor progress and provide general guidance on their career. Each new staff member is provided with a cash start-up package of £12k to enable early career opportunities for travel/general support and infrastructure.

The University has been awarded the **European Commission's HR Excellence in Research Award** for its efforts in improving the working conditions and career development opportunities of its researchers. This links to implementation of the **Concordat for the Career Development of Researchers** covering key principles relating to topics such as recruitment, retention, diversity and equality. Furthermore there is an active appraisal scheme in which all staff participate. This is a supportive process in which staff reflect on their activities and progress over the year and how this relates to their objectives and those of the School and University. Additionally each cluster maintains a reporting system in which outputs and productivity are regularly and openly reported, and success celebrated. Staff seen to be performing well and exceeding expectations received discretionary pay awards and are encouraged to apply for promotion. Staff are normally appraised by their Director of Research (DR). The Head of School (HoS) appraises the DRs and the Dean appraises HoS.

QUB was recently named as the lead university in the United Kingdom for **tackling the unequal representation of women in science and engineering** and is the first university to hold an Institutional SWAN Silver Award, 2012. The unit prides itself in having an inclusive ethos and provides a welcoming and supportive environment for female students and staff. As a result we have a well above **average cohort of female engineers, and have appointed 8 female academics since 2008.** In line with our own aims to encourage females to take up this exciting and rewarding profession. Both the School of Mechanical & Aerospace Engineering and Chemistry & Chemical Engineering currently hold **Silver Athena SWAN Awards**.

The Staff Training and Development Unit of QUB (STDU) provide a number of excellent courses for staff at all levels for personal career development. This includes a compulsory course on **equality and diversity**, which all established staff in the unit have successfully completed. Training records are maintained and used by staff. Moreover, in engineering many staff are members of professional institutions and follow their standard CPD processes. Of particular note is the leadership development course which is aimed at DRs and staff of a similar grade (SL & Chair) to help develop leadership capability.

Staff are encouraged to take sabbatical leave and a flexible approach to both research and education has provided greater opportunity in the last 5 years. The target is to increase uptake of such opportunities from currently one person per semester to three per semester. Staff are encouraged and supported in applications for prestigious fellowships and travel awards to take sabbaticals internationally and in world leading institutions (e.g. Price- Georgia Tech USA; Rooney- Beijing Institute of Technology China, Walsh- Northwestern USA; Goel- Kieo University, Japan).

Personal Fellowships

A number of prestigious personal fellowships have been awarded. Of the 29 established staff 10 have won, in competition, recognised fellowships or other awards. Most notably: Fellow of the Royal Academy of Engineering (Harkin-Jones), two Royal Academy of Engineering/Leverhulme Trust Senior Research Fellowships (Walker, Dunne) and ERC starting investigator (Rebrov). Other notable awards include: Orthopaedic Research Society/British Orthopaedic Research Society Travel Fellowship (Dunne), Climate Change Research Programme Research Fellowship (Foley), Marie Curie Fellowship (Walsh). Visiting fellowships include Australian Institute for Bioengineering & Nanotechnology (Dunne), Royal Academy of Engineering Global Research Award (Price), Visiting Professor in China (Harkin-Jones), Honorary Doctorate degree from UCTM, Sofia Bulgaria (Allen); Visiting Professor in Ecole de Mines Nantes, France under Erasmus Mundus ME3 Programme (Walker)

International staff appointments

The unit has an internationally outward looking ethos and has appointed a number of international staff in the last period (<name>, <origin>, <preceding institution>):

- **2009:** Dr Y Jin, China, Nanyan TU
- **2010:** Dr D Soban, USA, Georgia Tech; Prof. E Rebrov, Russia, Eindhoven UT
- **2011:** Dr A Foley, Ireland, Univ. College Cork; Dr S Marques, Portugal, Univ of Liverpool; Dr A Lennon, Ireland, Trinity College Dublin
- **2012:** Dr. J. Jacquemin, France, UBP Clermont-Ferrand; Dr G Abdellal, Egypt, Univ of Liverpool; Dr A Hamilton, USA, Aalborg Univ Denmark;
- **2013:** Dr B Smyth, Ireland, Univ College Dublin; Dr D Poulidi, Greece, Univ of Newcastle; Dr CW Chan, Hong Kong, HK Polytechnic Institute; Dr S Kim, Korea, Univ of Toronto; Dr M Geron, Italy, Univ College Galway; Dr E Ghassemieh, Iran, Univ of Sheffield; Dr A Marzano, Italy, Univ of Nottingham; Dr S Goel, India, Heriot Watt Univ; Prof S Hawkins, Australia, CSIRO; Dr E Themistou, Cyprus, Univ of Sheffield; Dr H Manyar, India, Univ Mumbai; Dr V Degirmenci, Turkey, Eindhoven UT; Dr C Mangwandi, Zimbabwe, Univ Sheffield; Prof B. Falzon, Australia, Monash

A typical strategy was to attract international staff already collaborating with existing staff members and clearly brought complimentary skill and research track record which synergised with ongoing research and met future ambitions (e.g. Soban – Visual Analytics and Value Driven Design; Lennon – computational modelling in biomaterials; Rebrov – Reactor and Process Engineering).

Outgoing staff have gone to take up international leadership positions. For example, Curran is now Chair of Aerospace Operations at TU Delft, Robinson has joined Rolls Royce Germany to establish a MDO unit, and Ou is now a Reader in Nottingham. McNally now holds a Chair in Nanocomposites at the University of Warwick.

Visiting scholars

Staff have hosted a large number of incoming international scholars who have spent at least a month at QUB.

In Materials, experts have participated in projects on biomaterials, nanocomposites and metals. For example: Dr Mark Staiger, University of Canterbury, New Zealand, 2009, Professor Don Paul, University Texas 2010, Professor Peter Halley, University Queensland, Australia, 2011, Professor Richard Wool, University Delaware 2011, Professor Steve McCarthy, UMass Lowell, 2010.

In Design and Manufacture examples include: Dr Krishnan Suresh, University of Wisconsin-Madison, 2009; Prof Vadim Shapiro 2010, Prof. Tian Huang, Warwick Univ. 2010, Dr Elena Garcia Georgia Tech 2013 Royal Academy Visiting Scholar in Design, Prof John Hsu Boeing Royal Academy Visiting Professor in Systems, Dr Qingxuan Gao Mechanical Engineering of Chongqing University China.

ii. Research students

Students are recruited annually in late Autumn. A series of events to publicise research are held to inform the main undergraduate body, and scholarships and projects are advertised nationally and internationally. Some scholarships are provided by the University as strategic investments and for internationalisation, and the unit has successfully used these to explore new research opportunities. International scholarships are additionally supported by Schools to include travel, training and consumables by reinvesting investigator funds such as FEC funds from research councils. Further, Queens is an active participant in the Chinese CSC scheme, and has taken a number of top Chinese students through this. In addition, due to the unit's strong industrial connections an increasing number of projects include scholarships provided by industrial partners.

Students have two supervisors, one primary, the main driver, and a support supervisor. Students meet their supervisors at least once a week, though many meet daily.

All PG students take a number of training courses, organised by the Staff Training and Development Unit on time management, planning, computing etc. In addition students are sent on specific training courses relevant to their research, and all attend at least one major international conference during their PhD. A Post Graduate Staff Student Consultative Committee is in place to help students provide feedback on the system and engage with the school in the general management of PhDs. The process is coordinated and administered by a senior academic with the role of post-graduate coordinator. In the first year of a PhD each student undergoes a three month review to ensure that the project has kicked off to a satisfactory standard, and then goes through differentiation at the end of month 9, where progress is assessed very strictly via a submitted report and interview. Subsequently an annual review is carried out until final submission.

Research projects and significant findings are presented every year by final year students in a series of seminars and events, typically used as a training ground prior to international meetings.

The international **Sir Bernard Crossland** competition is entered by all 2nd year PhD students. The top students are selected to represent QUB in the final. Students are also encouraged to enter international competitions e.g. the annual Institute of Materials, Minerals and Mining (IOM^3) worldwide competition (R O'Hara, winner, 2009)
The global successes and calibre of the research students is reflected in a significant number of major prizes won at international conferences (examples: Brown Bioceramics 2009, Davies ATIO 2010, Mullan ATOS 2011, Sivagnanasundaram HKIE 2010, Kusmanto ANTEC 2008, Abeykoon ICMIC 2008, Fee BINI 2013)

d. Income, infrastructure and facilities

Provision and operation of specialist infrastructure and facilities

There has been significant on-going investment in infrastructure and facilities. The Ashby and Keir Building, which house the clusters have been completely refurbished to the highest modern standard with an investment totalling £23M (Mechanical and Aerospace Engineering: £10m, Chemistry & Chemical Engineering: £13M). New equipment has been purchased under a number of individual programmes and major initiatives, such as the DEL Strengthening the All-Island Support Base £1.2M, the NIACE £50M, and the GM waste-recovery lab.

Evidence of investments (current and future) in infrastructure and facilities

- ***Materials***
  - Environmental SEM- shared with Chemistry/Civil/Pharmacy
  - Thermo-gravimetric Analyser
  - Thermo-Haake Twin-Screw Extruder and Batch Mixer
  - Laboratory refurbishment, including purpose-designed Advanced Materials testing and characterisation facility
- ***Energy***
  - New Waste-Heat-Recovery laboratory being prepared: funded by GM, TSB and Wrightbus.
  - New energy efficiency facilities planned through renewable energy centre (CASE)
  - Specialised turbocharger / small turbomachinery test lab
  - Suite of software for 3D mechanical and aerodynamic turbomachinery design
  - Enhanced catalyst aging facilities in collaboration with Catagen Ltd.
  - State-of-the-art thermal imaging equipment.
  - Magmasoft simulation software (£200k value)
- ***Design & Manufacturing***
  - Extensive suite of testing equipment such as digital image correlation for full field strain measurement, high speed cameras, and portable NDT kit for scanning composites.
  - NIACE - £50M investment in a major 3500m^2 facility
  - CNT web manufacturing facility
  - Portable virtual reality laboratory

Research funding portfolio, including future plans

The clusters have a current portfolio in excess of £10M covering a range from research council funding through to knowledge transfer and exploitation. The clusters in this submission have a distinguished reputation in industrially relevant research and this is exemplified with the high proportion of **direct industry funding** (80:20 public to private sector), and TSB projects. Over the REF period our **29 established staff** have generated an **average research income of £160k** per person per year and supervised **3 PhD students** over the same period.

- ***Materials***
  - ***Current funding:*** has been secured from a range of national and international agencies, including the EPSRC (e.g. Calcium Phosphate Cements (Buchanan and Dunne)); EU FP7 (e.g. Rotofast (Hornsby)); Industry (e.g. Total Petrochemicals); National Government Agencies and Institutions (e.g. Invest NI, Department of Health, Qatar NPRP).
  - ***Future funding (£20m target):*** Several strategic initiatives will be targeted for funding particularly towards the EPSRC and EU Horizon 2020. Industry funding will build on relationships with Bombardier, AstraZeneca, Exxon Mobil, Petronas, Saudi Arabia Basic Industries, BP Chemicals Limited)
- ***Energy***
  - ***Current funding:*** Industrial: General Motors, USA; Jaguar Land Rover, UK; NACCO Materials Handling, UK & USA; Wrightbus, Ricardo & Revolve, Johnson Matthey, Robinson Brothers, Bowman Energy Recovery, Cummins Turbo Technologies and Vykson. Non-UK

sources including King-Abdul Aziz University, ICSI, Germany, IHI Corp, Japan; UK Government Agencies (e.g. InvestNI, EPSRC, Carbon Trust).

- ***Future funding (target £15m):*** In addition to these sources of funding the energy staff will benefit from the £10M Centre for Advances in Sustainable Energy (CASE), 50% funded by InvestNI and a collaboration of 15 local companies. A major target will be EPSRC in the energy grand challenges.

- ***Design & Manufacturing***
  - ***Current funding:*** Sources range from EPSRC, EU FP7, TSB, local RDA (Invest NI) and Industry, with a current split between public and private sector being about 70:30. Exemplar projects include the TSB project Next Generation Composite Wing (NGCW), FP7-CRESCENDO and DEL Sustainable Transport.
  - ***Future funding (target £15m):*** In addition to continuing these sources of funding, the staff will benefit from the £5M NIACE project funding via Invest NI. The staff are also building a strong collaboration with the EPSRC Centre in Through Life Engineering Services at Cranfield, EPSRC Centre for Innovative Manufacturing in Composites and the National Composites Centre (NCC).

Consultancies

Staff are active in providing consultancy services to industry, including both local SMEs and multinationals. The university has an established consultancy team who manage business relationships and staff connected with appropriate companies to provide services when requested.

e. Collaboration or contribution to the discipline or research base

Exemplars of research collaborators

EU and International Project Collaborations

Many staff have been partners in major EU projects, including several prestigious Integrated Projects led by Airbus, Rolls-Royce, Eurocontrol etc. Examples include:

- FP6: VIVACE (**Armstrong, Robinson**); Episode 3 (**Price, Murphy**); DEEPWELD (**Price, Murphy**); DESYGN-IT (**McNally,** leaver 2013)
- FP7: CRESCENDO & TOICA (**Armstrong, Robinson**); RECREATE (**Early, Price**); Bandana (**Hornsby**); BIOGO (**Rebrov**); BIO-POLYTEC (**Buchanan, Dunne**)
- FP7: Marie Curie ITN project 316838 ATBEST, (**Rooney, Goguet, McCullough**; EU Marie Curie ITN project 238273 ATWARM, (**Walker, Allen**)
- ERC Starting investigator fellowship, European Research council 2011-2015 (**Rebrov**)
- US-Ireland Award (£900k, 2013-2016) DMR-1306741 / USI 044 funded by NSF, SFI and DEL NI (**Dunne**)

Research Council Grant Collaborations

- Professor Ruth Wilcox, EPSRC grant with University of Leeds 2007-2011- FE modelling, **EP/E022863/1** (**Buchanan, Dunne**)
- Professors Phil Coates (University of Bradford) and Paul Buckley (Oxford), Including period, 2008-11, **EPSRC** grants **EP/E040446/1 and EP/C006992/1**
- BAE Systems UK, Cambridge, Exeter, Cranfield– S4T Program 2008 – Digital manufacturing & Service support processes, EPSRC **EP/F038526/1** – QUB value £120k
- Dr Paul Rooney, NHS BT: injectable bioceramics-**EPSRC KTSS** funding (2011-2012)
- Ricardo Engineering Consultancy - **EPSRC** project and publications (Catalyst modelling).
- **EPSRC** programme mode grant (CASTech - £3M, 2009) involving University of Cambridge, Birmingham and Virginia
- **EPSRC** Systems Engineering Doctorate Centre; Loughborough (lead), Bath, QUB, Leicester, Strathclyde (2007-2015).
- **EPSRC** Intelligent Grid Interfaced Vehicle Eco-charging (iGIVE) EP/L001063/1, £855k, (2013-2016), with Professor Luk, Cranfield (**Foley**)

Industrial Research Collaborators

- Smith & Nephew (Mr David Farrar), £143k, 2008-2011, bioresorbable implants
- Wrightbus (Mr Brian Maybin, Tech Director) , £1.6m TSB project, £569k to QUB
- Vykson Ltd, UK (Mr James Oakley), combined with Carbon Trust, £380k, 2007-2011
- IHI Charging Systems, HD, Germany (Dr J Ehrhard) , Turbocharger technology, 2008-2012
- General Motors Tech Center, Detroit (Dr Gary Smyth, Exec Director of Research), £400k WHR project

- General Motors (Detroit) - Waste Heat Recovery project - industrial funding, 2010
- Jaguar Land Rover - Exhaust After treatment research, £206k, 2011-2013
- Rolls-Royce, funding through GHandI project for geometry and meshing, £350k, 2013
- Ryobi Aluminium Casting (UK) Ltd / INI Two projects: £1220k project to extend die life, 2006-2009 and £1541k project to minimising casting gate size, 2010-2013
- Constellium, Voreppe France, 2010-2013, funding of two PhDs
- NACCO UK Ltd, Counterbalanced Forklift Trucks, Modelling of Energy Consumption, Phase 2, £364k (committed), 2013
- Proctor & Gamble (Jim Shepherd, Senior Engineer) 2009-2013: £441,780
- The ionic liquids group has been awarded successive contracts from Petronas since 2008 to develop ionic liquid technology for the treatment of crude oil and natural gas.

Exemplars of interdisciplinary research

- Beaufort Biodiscovery- major Irish government funded project involving marine biologists, pharmacists and materials scientists
- CASTech – EPSRC/Industry funded project Chemistry and Physics, QUB
- Fast Response Temperature Measurement, with Electrical & Electronic Eng
- QUB Institute for a Sustainable World – Collaboration with Biological sciences, Politics, Law

How have research collaborations informed research activities and strategy?

Many of the major engineering grand challenges are multi-disciplinary in nature and the collaborations established by staff have been highly focused towards these. As the nature of collaborations has changed and evolved, the strategies in research have moved correspondingly. For example, in the late 1990s the aerospace work began to develop some manufacturing aspects and this has opened opportunity to address major challenges in aviation related to cost effective manufacturing in collaboration with Bombardier. There are similar examples in each research theme.

Within the Energy theme researchers have now utilised their skills in engine modelling and technology to look at energy generation and sustainability and as a consequence is moving its research strategy in this direction. For example, linkage with the aerospace researchers in developing models for energy usage in transport systems through the ISW and industrial collaborators. Energy in all forms has been a growing area of research with projects ranging from processing crude oils and renewable feed-stocks through to the design of catalytic renewable energy storage systems and more recently the investigation of new materials and reactors to improve energy coupling to the active catalytic site.

The MoU signed with Queensland in the last period has continued to strengthen relationships, with exchange of researchers and extended study visits from international leaders in materials. The success of this encouraged the team to sign a MoU with UMass Lowell, resulting in 3 joint conferences between Lowell, QUB and Dublin City University. Collaboration with University of Minnesota in dental biomaterials research, with exchange of researchers, industrial funding and publications continues.

Constellium have invested significantly now in the development of advanced metallic technologies for aerospace manufacturing and this has supported continuing integrated approaches for design and manufacturing, supporting a flexible approach to manufacturing research.

Leading research in design modelling using efficient analysis methodologies and understanding of CAD geometries and their role in design has resulted in a continuous stream of funding from Rolls-Royce in the development of complex modelling tools in the aerospace domain.

The development of technology with potential for rapid impact in transport has seen effort redoubled in hybrid drive modelling and catalysis which has been supported by major investments from General Motors in Detroit and Wrightbus in Northern Ireland. The implementation of the technology helped win Wrightbus the new Bus for London which forms one of the unit's case studies.

Therefore our informed strategy is to create larger teams, tackling multidisciplinary problems with global impact and strong industrial links.

Exemplars of leadership in academic community

Every member of staff is actively encouraged to become a leader in their own field. At present each has an internationally recognised area of expertise with total inclusive volume for all staff evidenced below. This shows that, since 2008, of the **29 established staff 63%** have won an

international prize, **30%** have made keynote presentations, **50%** have been technical chair of an international conference, **50%** in the EPSRC college, **25%** on funding panels, **20%** hold major advisory board positions and **50%** have learned society or editorial board positions. Of the new early career staff **20%** come with international accolades such as prizes.

Details of awards, prizes

Prizes range from student papers through to prestigious awards such as the IMechE George Stephenson prize for published work (**Spence**, 2011) and OBE for services to Higher Education (**Harkin-Jones,** 2013): Best paper, 20th International Meshing Roundtable, Paris, Oct 2011 (**Armstrong, Robinson**); Best student presentation: Orla Brown, Bioceramics 22, South Korea 2009 (**Buchanan**); Best student presentation: Rochelle O'Hara IOM^3 World Lecturing Competition, S Africa, 2009 (**Dunne, Buchanan**); Best Oral Paper Award: Eoin Cunningham, UK Society of Biomaterials, Liverpool, UK, 2008 (**Buchanan, Dunne**); Best Biomaterials Paper, K Fee, BINI2013 (**Buchanan/Dunne**); Best student paper: HKIE Outstanding Paper Award for Young Engineers: Subenuka Sivagnasudurum (**Early**); Institute of Materials, Minerals & Mining, 2009 Composite Award for published work of particular merit in the field of composites .Plastics, Rubber & Composites; Macromolecular Engineering, 37, 113-123, 2008 (**Harkin-Jones**); Best student paper, Febe Kusmanto , ANTEC 2008, (**Hornsby**); Best paper presented at: Fourth International Conference on Multiscale Materials Modeling, 2008 (**Malinov**); 2011 Young Author Best Paper Award (to Chamil Abeykoon) International Conference on Modelling, Identification and Control (ICMIC 2011), Shanghai, China, June 2011 (**Martin**); Best Student Paper Award to Gary Davies ATIO 2010 (**Early**, **Price**); Best Student Paper Award to Claudia Mullan – ATOS 2011 (**Soban**, **Price**); **Certificate of Distinguished Service**, presented by AIAA (2008) (**Soban**); Best Presentation, Systems Engineering Doctorate Centre Annual Conference Oliver Bennett (**Armstrong**). IMechE Ken Harris Prize, 2011 (**Spence)**; Hong Kong Institute of Engineers, Outstanding Paper Award for Young Engineers/Researchers, 2010 (**Spence**). Hong Kong Institute of Engineers Environment prize 2009 (**Allen**); 2008, International Symposium on Agglomeration best student paper (**Walker**); India-UK Scientific Seminar award, 2012 (**Rebrov**); ADC Forum Australian Leadership Award 2009 (**Falzon**)

Invited Keynote Lectures

Keynote speaker at 19th International Meshing Roundtable, Chattanooga, Tennessee, USA, 2009 (**Armstrong**); Plenary Lecture, 1st International Symposium on Polymer modification with High Energy Electrons, Dresden, Germany, November, 2010 (**Buchanan**); Plenary speaker at the XT-12 conference, Moscow, Russia, March 18-23, 2012 (**Rebrov**). Key note speaker at the 1st Int. workshop on advanced nanostructured materials and thin films for industrial applications, Nottingham, U.K. November 10-13, 2008 (**Rebrov**). Keynote speaker at Jordan Energy conference 2011 (**Rooney**), Keynote speaker at Solution Chemistry conference, France 2011, (**Rooney**). Keynote 60th anniversary of Dalian Institute of Chemical Physics, China, 2009, (**Rooney**), Invited Plenary speaker ICEnv International conference in Malaysia 2011 (**Allen**), Keynote speaker at Bioceramics23, Istanbul, Turkey 2011 (**Dunne**), Keynote speaker at 4th International Conference-Biomaterials, Tissue Engineering & Medical Devices, Bucharest, Romania 2010 (**Dunne**), Keynote speaker at 19th Interdisciplinary Research Conference on Injectable Biomaterials/Biomechanics for Minimally Invasive Clinically Applications, Fort-de-France, Martinique 2009 (**Dunne**); Invited Keynote lecture at the 4th Global congress on Catalysis, Dalian, China, 2013 (**Rebrov**); Invited Plenary Speaker IMRP World Congress, Shanghai, 2013 (**Buchanan**); Keynote Presentation at Inaugural Workshop on Virtual Engineering, Liverpool Virtual Engineering Centre, Liverpool, Oct 2011 (**Price**).

Conference programme chair or organisational role

All staff have participated in scientific organising committees for key conferences in their field. However, more notably several have been organising Chairs of major conferences, most of which are 500+ events. For example: 14th ESAFORM international conference held in Queen's University Belfast in April 2011 (**Martin, Menary**); Technical Committee Chair for the Joint Japanese and American Society of Automotive Engineers Small Engine Technology Conference Committee, Sapporo, Japan, November 2011 (**Kee**); PPS-24 International Polymer Processing Society Conference, Salerno, Italy June 2008 (**Harkin-Jones**); International Conference of Computational Methods in Sciences and Engineering, 2010 (ICCMSE 2010), Greece (**Malinov**); 9th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference, Hilton-Head, USA

(**Price**); 10th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference and 13th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference, 2010, Texas USA (**Soban**). UK-US Prime Minister's Initiative in Education (PMI2) International Workshop: "Magnetic nanoparticles: Synthesis and Applications" 14-15 July 2011, Belfast (**Rebrov**) 2008, 2010 and 2013 International Symposiums on Agglomeration and 4-6th International Granulation Workshops, Sheffield UK, Lausanne, Switzerland (**Walker**); Chairman of Advanced Symposium in Chemical Engineering Hong Kong 2012 (**Allen**); 13th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference, Los Angeles, USA, 2013 (**Butterfield**); RAMI Bioengineering in Ireland Conference, Belfast, 2012 (**Buchanan**); Irish Transport Research Network 2011 (ITRN2011), University College Cork (**Foley**); 9th World Biomaterials Congress, Chengdu, China, 2012 (**Dunne**). 4th Global congress on Catalysis (**Rebrov**); 9th World congress of Chemical Engineering (**Rebrov**); 15th Asian Pacific Confederation of Chemical Engineering Congress (**Rebrov**); IEEE International Conference on Environment & Electrical Engineering, 2013 (**Foley**); 6th International Granulation Workshop, 2013 (**Mangwandi**); Deputy Chair of the Australian Aerospace Congress and Chair of the Australian Aeronautical Conference, 2013 (**Falzon**)

It is notable that QUB personnel have been on the leadership team for the ATIO conference for the last 7 years playing a major role in the direction and growth of this flagship event in the AIAA calendar. This has led to the formation of a new international aviation forum called 'AVIATION 2014' to be held in Atlanta next year, and will merge 19 existing aviation-related conferences into one single Technical Forum (Chair: **Soban**). **Kee**, similarly has led the Small Engine conference as the technical chair for a number of years (SAE and JSAE).

Research Council Panel membership

A total of 15 staff are members of the EPSRC peer review college, but in addition 4 have served on several panels for EPSRC, another 4 on EU or other equivalent international panels.

National/international advisory board membership

Board Member Higher Education Authority (HEA), Ireland [ministerial appointment] (**Harkin-Jones**); REF2014 UoA12 Panel Member (**Harkin-Jones**); Virtual Engineering Centre International Advisory Board (**Price**); NSF Workshop on Complex Systems Design 2010 (**Price**); NUI Peer Review College 2010-date (**Walker**); New Zealand Research Assessment Exercise 2012 (**Harkin-Jones**), Australian Research Assessment Exercise (**Falzon**); International Advisory Board member for the Irish Research Council (**Early**); Member of the International Scientific committee of CHEMREACTOR conference (**Rebrov**); Member of the International Scientific committee of MNF conference (**Rebrov**); Member of International Advisory Committee for International Journal of Material Forming (**Menary**); Expert reviewer for Luxembourg Research Council (**Menary**); Expert reviewer for the Research Council of Norway (**Menary**)

Committee membership or position of responsibility in Learned Society

There are 16 staff involved in responsible positions in societies, some of note as Chairs are **Armstrong** on the NAFEMS CAD-FE committee, **Soban** as Chair of the AIAA Aircraft Design Technical Committee and **Spence** as Chair of the Turbomachinery committee and **Rebrov**, Elected Member of the Young Academy of Europe (YAE).

Journal editorial panel membership

International Journal of Nano and Biomaterials (**Dunne**), European Editor; Polymer Engineering & Science (**Harkin-Jones**); IMechE Journal of Process Mechanical Engineering (**Harkin-Jones**); International Journal of Polymers and Technologies (**Harkin-Jones**); Recent Patents on Chemical Engineering (**Harkin-Jones**); Plastics and Rubber Composites: Macromolecular Engineering (**Hornsby),** Associate Editor; ISRN Biomaterials (**Dunne**); BioMed Research International (**Dunne**); Journal of Nanomaterials (**McNally,** leaver 2013); International Journal of Aerospace Engineering (**Price**), Associate Editor; Journal Of Aerospace Operations (**Price**); Advances in Biomaterials (**Buchanan**); SAE Journal of Engines (**Kee**), Associate Editor; Chinese Journal of Engineering (**Rebrov**); The Aeronautical Journal (**Falzon**), Associate Editor; Editorial Board Member of the Applied Composites Materials Journal (**Falzon**); Journal of Aerospace Operations (**Soban**), Associate Editor; Chemical Engineering Research and Design (**Walker**), Associate Editor; Chemical Engineering Journal (**Walker**), Associate Editor; Periodica Polytechnica – Ser. Mechanical Engineering (**Walker**), Associate Editor.