Institution: Newcastle University

Unit of Assessment: 12

a. Overview

This submission is made from three academic units: (i) the School of Chemical Engineering and Advanced Materials (CEAM), (ii) the School of Mechanical and Systems Engineering (MSE), and (iii) marine technology researchers from the School of Marine Science and Technology (MAST). Research across the UoA is structured into nine research groups. The membership and principal research areas of the groups are briefly summarised below. Group leaders are shown in *italics*.

Advanced Materials (*Bull*, Frankel, Novakovic, Siller, Thomas). Nanomaterials; synthetic biology for materials development; porous materials for adsorption/gas separation.

Bioengineering (Bretcanu, Chen, Dalgarno, *Joyce*, Pancholi). Artificial joints; biomaterials; biofabrication; tissue engineering.

Design, Manufacture & Materials (*Dalgarno*, Franklin, Gibson, Robinson, Shaw). Mechanical power transmission; rail engineering; composites; additive manufacture.

Electrochemical Engineering Science (Metcalfe, *Roy*, Scott, Velasquez Orta). Electrodeposition, electrochemical surface structuring, fuel cells, batteries, wastewater treatment.

Fluid Dynamics & Thermal Systems (*Chakraborty*, Gan, Pancholi, Reeks, Roskilly, Sergeev, Swailes, Tian, Wang). Turbulence; combustion; multi-phase flow; sustainable power and energy.

Process Intensification & Catalysis (Boodhoo, *Harvey*, Metcalfe, Phan, Zivkovic). Membranes and biofuel cells, nanostructured foams, process intensification for sustainable energy systems.

Process Modelling & Optimisation (*Martin*, Montague, Willis, Wright, Zhang). Hybrid statistical and empirical modelling, high throughput technologies for chemical synthesis.

Marine Technology (Atlar, Benson, *Dow*, Tao, Yang). Ship design and hydrodynamics; sustainable shipping; offshore engineering; marine renewables.

MEMS & Sensors (Burdess, *Cumpson*, Gallacher, Hedley, Pozzi). Physical and biological micro-electro-mechanical-systems (MEMS); surface engineering; smart materials and devices.

b. Research strategy

b.i Vision

The aim of researchers across this UoA is to conduct internationally leading research which addresses the challenges of sustainability, an ageing population and industrial competitiveness. Our aim is closely aligned with University strategic objectives. In 2009/10 the University identified Sustainability and Ageing & Health as University wide Societal Challenge themes, and over this REF period these challenge themes have become a key element of our research strategy.

Alongside these themes we retain a responsibility and desire as engineers and scientists to develop and support the industrial base. In order to achieve our aim we have focussed through the REF period on establishing leadership in relation to the challenge themes, whilst continuing to undertake excellent scientific and engineering research which contributes to current and future industrial competitiveness. The mechanisms to deliver against this strategy include:

- Undertaking cutting edge research in areas of strength and realising new opportunities
- Recruiting and retaining high calibre academic and research staff
- Developing high quality PGR students to meet the needs of academia and industry
- Maintaining our vital and vibrant research community for staff and students
- Providing the necessary support and environment to enable and encourage academic staff to maintain a diverse portfolio of externally funded research projects
- Investing in new infrastructure to complement our existing world-class facilities and equipment
- Developing and supporting the industrial base by strengthening links with key stakeholders to shape our translational research capabilities and influence our research agenda
- Extending the reach and significance of research activities through our operations in Singapore

Specific steps and initiatives taken against each of the three challenges stated in the vision are outlined below, together with our future plans in those areas.

b.i.1 Sustainability

In 2010, Newcastle Institute for Research on Sustainability (NIReS) was launched to coordinate

sustainability research across discipline boundaries (Director of Research, Roskilly). Advanced Materials; Design, Manufacture & Materials; Electrochemical Engineering Science; Fluid Dynamics & Thermal Systems; Process Intensification & Catalysis; Process Modelling & Optimisation and Marine Technology groups make a significant contribution to its research, primarily based around energy and exemplified by:

- Hosting the Sir Joseph Swan Centre for Energy Research (Director, Roskilly) with over 130 academic staff and an average of more than £6M research funding per annum.
- Significant engagement with the EPSRC's Supergen programme, the UK's primary delivery mechanism for sustainable energy research. This involved leading both the Delivery of Sustainable Hydrogen (Metcalfe) and the Fuel Cell (Scott) consortia, and UoA staff currently hold key roles within the Biological Fuel Cells consortium; the Energy Storage consortium; the Hydrogen and Fuel Cell Hub; and the Bioenergy Hub (Harvey, Metcalfe, Scott).
- A wide ranging portfolio of research addressing the efficient use of conventional and novel fuels (relevant outputs: *Chakraborty*1-4; *Harvey*2,4; *Phan*1,3-4; *Roskilly*2,3; *Tian*1-3; *Wang*1-4).

NIReS will focus on delivering excellent interdisciplinary research by supporting the development of new research projects, and through the development of three large scale research sites:

- The Neptune National Centre for Sub-Sea and Offshore Engineering will be established in 2015 at Neptune Park, on the north bank of the Tyne. The £7M Centre will be supported by a £3M HEFCE Catalyst Fund Award, a £2M investment from the University and £2M from industry. It will lead on collaborative research with industry in energy from offshore sources.
- Science Central is a 24-acre site in Newcastle city centre, on which the University and Newcastle City Council will jointly create an educational, business and residential development, built to high environmental standards, to serve as an exemplar for urban sustainability. The University has committed £50M to the first phase of the project with the completion of the Sustainable Urban Research and Engagement (SURE) building scheduled for 2017. Energy, Power and Transport is one of eight research themes within SURE; with a £2M planned investment in large scale facilities which will support future UoA research.
- The University's Cockle Park Farm will support research on rural sustainability, for example renewable energy from agricultural residues and energy crops. Over £1M (University & RDP fund) has recently been used to establish a state of the art anaerobic digestion research and demonstration facility and further investment of £2.5M (University and industry) has been committed to consolidate plant based research and also provide a test bed for smart-grid and energy storage technologies.

b.i.2 Ageing and Health

Bioengineering; Design, Manufacture & Materials; and MEMS & Sensor research groups will contribute to this strategic theme. The University has recently invested (£380K) in establishing *A Cross Faculty Translational Approach to Musculoskeletal Disease and Therapy*, to foster collaboration, build research capacity, and develop research proposals and projects, with a focus on tissue engineering and regenerative medicine. This has resulted in close collaboration between the UoA research groups and the Institute for Cellular Medicine in the Faculty of Medical Sciences. The cross-faculty collaboration has resulted in the Bioengineering research group playing a leading role in three major research projects: as the biomaterials and biofabrication hub of the £5.5M *Arthritis Research UK Tissue Engineering Centre*, a five year programme established in 2011; through co-ordinating the €4M FP7 project RESTORATION (*Resorbable Ceramic Biocomposites for Orthopaedic and Maxillofacial Applications*), a four year programme which started in 2012; and leading research into *Processes for In-clinic Manufacture* and *Minimally Invasive Implantation of Bioactive Materials* as part of the £6M *EPSRC Centre for Innovative Manufacture in Medical Devices*, a five year programme which started in 2013. This recent activity builds on biomaterials and biofabrication expertise (*Bretcanu1-4; Dalgarno2*) and adds to on-going high profile research in bioMEMS (MEMS and Sensors; *Hedley1-3; Burdess2*); joint replacement (Bioengineering; *Joyce1-4*), synthetic biology (Advanced Materials; *Frankel1-4*), and biopharmaceutical process development (Process Measurement and Optimisation; *Martin4; Montague1-4; Wright1,4*).

The UoA will continue to grow healthcare research activity, aligned with this University theme, and have significant new awards: bioMEMS (*EPSRC Interdisciplinary Research Centre in Early-*

Warning Sensing Systems for Infectious Diseases, £11M, in collaboration with UCL, five year programme started 2013) and synthetic biology (*A new frontier in design: the simulation of open engineered biological systems*, £5.5M, five year EPSRC programme, started 2013).

b.i.3 Industrial Competitiveness

All research groups will contribute to this theme and the UoA will foster emerging and growing research areas, which will impact on current and future industrial competitiveness, through our interdisciplinary University Research Centres. Staff from within this UoA currently lead the *Biopharmaceutical and Bioprocessing Technology Centre* (Martin), the *Research Centre in Catalysis and Intensified Processing* (Metcalfe), the *Newcastle Centre for Railway Research* (Robinson), and the *Sir Joseph Swan Centre for Energy Research* (Roskilly), and play a significant role within the *Durham/Newcastle Joint Quantum Centre*, the *nanoLAB Research Centre*, and the *Centre for Synthetic Biology and Bioexploitation.* All of these will continue to shape our future interdisciplinary research directions.

All of the research groups in this UoA carry out domain specific research in collaboration with industry. The strategy for this research is decided at research group level and is increasingly being reinforced by our societal challenge themes. These links have allowed us to maintain direct industry funding at a level of ~20% of our total research funding over the REF period, with increasing funding from international industrial sources (up from 5% of total industry funding in 2008 to 26% in 2012).

b.ii Evaluation of Position Relative to RAE2008

In RAE2008 submissions were made to UoA 26 (Chemical Engineering) and UoA 28 (Mechanical, Aeronautical and Manufacturing Engineering). The UoA 26 submission described research centred on Chemical Engineering Science; Measurement & Analysis; Products & Processes; Natural Resources themes; and UoA 28 with research groups in Bioengineering; Sensors & MEMS; Design, Manufacture & Materials; Marine Technology; Multiphase Flow and Thermal Systems.

Following a strategic review taking into account future research challenges, new staff appointments and infrastructure investments, these themes and groups have now evolved into the group structure outlined in section a. The research groupings successfully build on the RAE2008 strategy to develop our research excellence in bioengineering (MEMS technology, biosensors & biomechanics), energy (renewable sources, fuel cells, alternative fuels & thermal systems), process intensification and process development and industrial competitiveness (product and materials development & numerical simulation). The structure provides critical mass in key areas of strength, as well as providing strong research leadership and a mechanism for support and mentoring. Research encompasses the full spectrum of engineering, from fundamental research (e.g. the physics of fluid flow at low temperatures and the structure and chemistry of surfaces) through to applied research focussed in a number of industry sectors including the process industries (food, chemical, petrochemical, home and personal care), energy, health and transport.

Both RAE2008 submissions identified continued and expanded collaboration with the industrial base to be of strategic importance. Our commitment to industrial competitiveness over the REF period has resulted in research in collaboration with industry and addressing the increasing importance of "impact" (see REF3a).

c. People, including:

i. Staffing strategy and staff development

c.i.1 Staffing Strategy

Our staffing strategy is to recruit and retain excellent staff. Recruitment over the REF period has been driven by the desire to concentrate on areas of strength in sustainability, ageing and health and industrial competitiveness and also to readdress the balance of senior staff. These drivers have defined where the UoA has recruited, with all academic appointments then made on the basis of individual excellence. Sixteen new appointments (7 ECRs, *italics*) have been made to the following research groups. Bioengineering; **Bretcanu**, ***Chen***, **Pancholi**: Design, Manufacture & Materials; **Franklin**: Electrochemical Engineering Science; ***Velasquez-Orta***: Fluid Dynamics & Thermal Systems; **Chakraborty** [Chair], ***Gan***,***Tian***, **Wang**: Process Intensification & Catalysis;

Boodhoo, **Phan**, ***Zivkovic***: Marine Technology; ***Benson***, **Tao** [Chair]: MEMS & Sensors: **Cumpson** [Chair], ***Pozzi***.

Retaining internationally leading academic staff is critical to maintaining a vibrant research ethos and culture, and is key to attracting new high quality researchers. This is achieved through a number of mechanisms including maintaining a supportive and stimulating environment, a comprehensive Performance and Development Review (PDR) process (see c.i2) and an annual promotions exercise recognising excellence. Over the REF period **Harvey** and **Joyce** have been promoted to Chairs; **Siller** and **Gallacher** to Reader; and **Boodhoo**, **Hedley** and **Wang** to Senior Lecturer. New appointments, and in particular ECRs and new lecturers, have their workload carefully managed through their first three years in post to ensure that they have the opportunity to establish themselves as independent researchers. All the Schools operate a mentoring scheme for new staff at lecturer level with all staff receiving financial support for equipment and travel, and new appointments are allocated PhD studentships. All staff receive specific support from the Faculty Research Funding Development Manager who guides new staff through their "first grant" applications, and who ensures staff benefit from internal peer review of research proposals.

c.i.2 Staff Development

All the key principles outlined in the *Concordat to Support the Career Development of Researchers* have been implemented and in 2010 Newcastle became one of the first universities in Europe to be awarded the *HR Excellence in Research Award*. Additional support for research staff development is provided by a *Career Pathways Framework Programme*, which explicitly outlines the range of career pathways available, and assists research staff in planning development activities to support their future career aspirations. Central to the staff development process is the annual *Performance and Development Review* (PDR), at which all staff: (i) review the previous year's performance; (ii) agree objectives and identify priority tasks for the coming year; and (iii) outline their development plans. The PDR discussions also help identify generic and role-specific training opportunities to enable career development and progression.

Academic and research staff development is co-ordinated through the *Staff Development Unit* (SDU), who manage staff development processes and deliver training for all staff across the University. For generic skills development there are highly subscribed courses run by SDU which are intended to support researchers in their current role (*e.g.* research and dissemination skills and understanding of intellectual property), and courses which aim to develop researchers towards independent academic careers (*e.g.* networking and collaboration, personal impact, and research project management & strategy). For experienced researchers and academic staff who are new to leading research the SDU have developed a *Principal Investigator (PI) Development Programme*, which runs over six months and covers the roles and responsibilities of PIs including project, people and team management. All new lecturers undertake the *Certificate in Advanced Studies in Academic Practice*, which covers research, teaching and management unless they hold an equivalent qualification, whilst for experienced academic staff developing into leadership roles within Schools or Research Units the *Academic Leadership Programme* provides a six month programme to develop high level leadership, strategy development and team management skills.

c.i.3 Fellowships, International Appointments, Visiting Scholars

Fellowships and Personal Awards: Novakovic, *EPSRC Career Acceleration Fellowship*, 2009-14, Powering smart materials by oscillatory chemical reactions. £700k; Bull, *Royal Academy of Engineering/Leverhulme Senior Research Fellowship*, 2010-11, Mechanical Design of Very Thin Coatings Deposited by Atomic Layer Deposition (ALD) on compliant substrates, £46k. Metcalfe, *ERC Advanced Grant*, 2013-18, Single Pore Engineering for Membrane Development, €2M.
International appointments: Bretcanu appointed from Politecnico di Torino; Tao from Griffith University; Zivkovic from Adelaide. Research Associate appointments made from Universitat Politècnica de Catalunya; Kassel University; Free University Berlin; North Carolina State University; Shanghai Jiao Tung University
Visiting Appointments: Examples include: Chen (NTU, Singapore), Dalgarno (UTHM, Malaysia), Shaw (Xi'an Jiaotong University), Swailes (Ecole Centrale de Lyon), Roy (Waseda University, Japan), Roskilly (Beijing Institute of Technology), Sergeev (Charles University, Prague).

International Incoming Visitors. Examples include: **2008:** Christi (Massey University), Sarioz (Istanbul Technical University), Skrbek (Charles University, Prague), Wu (Guangdong University of Technology). **2009:** Harsha (Varanasi Hindu University, India), Lattimer (Virginia Tech). **2010:** Sarma (TERI, India), Sciacca (University of Palermo), Sturm (DAAD, Germany), Wu (Shanghai Jiao Tong University). **2011:** Camino (Torino), Hu (Wuhan Normal University), Kim (INHA, Korea), Li (Shanghai Jiao Tong University), Mouritz (RMIT, Australia), Schartel (BAM, Germany), Tatli (Sakarya University). **2012:** Chen (Guangxi University), Fitzsimmons (Lloyds Register of Shipping), Silva-Martinez (UAEM, Mexico), Zou (Shanghai Jiao Tong University). **2013:** Aversenq (ENSIACET, France), Bachmann (Justus-Liebig-University, Germany), Flay (University of Aukland), Garcia Estrada (Universidad Nacional Autonoma de Mexcio), Gonzalez – Hernandez (Universidad de Murcia, Spain), Kavicka (University of Pardubic, Czech Republic), Mao (Xi'an Jiaotong University), Silveira Lopes (Instituto Militar de Engenharia, Brazil).

c.i.4 Diversity

Newcastle University has a comprehensive policy of equal opportunities for all employees and all students in which individuals are recruited and treated on the basis of their relevant merits and abilities. The University holds an Athena SWAN Bronze Award recognising its commitment to advancing women's careers in science, technology, engineering, maths and medicine and all three Schools in this submission are now applying for Athena SWAN Bronze Awards in their own right.

ii. Research students

c.ii.1 PGR Recruitment

The UoAs PGR recruitment comes from self-funded students, individual research studentships and cohort based studentship programmes with approximately 60% international students and 40% UK/EU. Individual research students are recruited through application in response to advertised studentships or, for self-funded students, direct application. The University undertakes a range of international recruitment activities throughout the year to promote research opportunities. Newcastle is also a member of the Sterling Group, a group of seventeen Universities which promote UK engineering research in Asia. Over the course of this REF period the UoA has led three major cohort based PhD programmes:

- The *Engineering Doctorate in Biopharmaceutical Process Development*, with £6.4M funding from EPSRC. An industrial doctorate scheme, running from 2009 to 2018, which has recruited 57 students (ten funded by the University) all placed with industrial sponsors, including GlaxoSmithKline, P&G, Unilever, Lonza Biologics, Novartis and Heinekin (PI: Martin).
- The €1.7M SUSHGEN (*Sustainable Hydrogen Generation*) Marie Curie Initial Training Network, which developed a collaborative training programme on hydrogen production from water, with seven PhD studentships, one at Newcastle (co-ordinator: Scott).
- The €3.75M MOMENTUM (*Multidisciplinary Research and Training on Composite Materials Applications in Transport Modes*) Marie Curie Research Training Network. This supported three PhD students at Newcastle and thirteen researchers in total, undertaking a joint programme of research in Composites in Transport (co-ordinator: Robinson).

UoA staff will also collaborate in a £7.9M *EPSRC Centre for Doctoral Training in Additive Manufacture and 3D Printing* (Newcastle PI: Dalgarno), starting in 2014. For UK/EU recruitment we believe that cohort based programmes will continue to become more important, and will continue to use and develop our expertise, facilities and research student training portfolio to lead integrated PhD programmes. Graduations have increased over the REF period with the three-year average increasing from 29 per year in 2008-10, to 40 per year from 2010-12, as a result of both better recruitment internationally and the academic units attracting more studentships.

c.ii.2 Research Student Training and Monitoring

The Faculty offers a comprehensive programme of over thirty skills training courses for research students, based on the Vitae Researcher Development Framework, and including research skills and techniques, communication skills, networking and team working, and career management. Students are required to establish and maintain a personal development programme throughout their degree. All research students are required to build up training credits in each year of their study, through attending skills training courses, making presentations within the University, and

attending and presenting at national and international conferences. Progress monitoring is through an online "ePortfolio" system, which students are required to update with documents relevant to their progression throughout their time at Newcastle. All academic units have an independent PGR progression panel that has responsibility for monitoring progress of all research students within that unit. In 2013, the University launched a PGR Innovation Fund to provide funding for groups of students working on projects to improve the postgraduate research student experience. For example funding was awarded for the 1st Northern Postgraduate Chemical Engineering Conference, which took place in Newcastle in August 2013, attracting 76 delegates.

Research students are encouraged to take an active role in suggesting and implementing improvements to the research student experience with all academic units having PGR student representatives. Students are also invited to participate in the annual Postgraduate Research Experience Survey, organised by the HEA. For 2013 the survey showed 90% of respondents within this UoA to be satisfied with their experience of their research degree programme.

d. Income, infrastructure and facilities

d.i Income

This REF period has seen significant growth in our RCUK funding (up from £1.9M in 2008 to £2.9M in 2012) and international funding (funding from all international sources up from £2.5M in 2008 to £3.4M in 2012, mostly EC). Total research spend over the REF period has been over £38M, rising from £6.8M in 2008 to over £8M in 2010 and 2011, before dipping to £7.4M in 2012, a result of the loss of Regional Development Agency funding, which has now been mostly offset by RCUK and international funding growth. Newcastle University is one of twelve EPSRC Framework Universities, and is in the top 30 HEIs in Europe for EC FP7 funding, which provides a strong foundation to continue to compete for research awards from these funders.

Consultancy income over the REF period has been just over £10M, including contracts from large multinational organisations including Pilkington, David Brown and BAE SYSTEMS, and work with smaller companies such as BEL Valves, SMD, and Smith Electric Vehicles. Consultancy helps to foster industrial contacts for future research proposals, and is an important element of our strategic aim to support the industrial base.

d.ii Infrastructure and Facilities

New facilities established in this REF period, with specific University investment noted include:

- The University hosts the UK's *National EPSRC X-ray Photoelectron Spectroscopy* (XPS) Users' Service, NEXUS, established in 2011 with a £3.1M mid-range facility award from the EPSRC (PI: Cumpson). NEXUS was established with £1.6M spend on equipment using the EPSRC Award, and £100K from the University on infrastructure and has undertaken 160 projects for UK academics in the first two years of operation.
- £2M from EPSRC, ERDF and SRIF (PI: Roskilly) has been used to establish state-of-the-art thermal energy research facilities, including a non-thermal plasma reactor, gaseous and particulate emission analysers, gas chromatography, a high pressure high temperature combustion vessel, and dual-fuel combustion and combined heat and power systems.
- The Research Vessel "The Princess Royal", commissioned by the University in 2011 at a cost of £1.2M, to an innovative design developed by the Marine Technology research group (PI: Atlar). Within this REF period the main research activities have been related to engine and ship performance assessment and modelling. A further £1.2M has been invested by the University to develop a new quay for the vessel and associated shore station at the Port of Blyth.
- £1.3M has been invested in CEAM to establish (i) a new laboratory and pilot plant facilities for research in biopharmaceutical development, (ii), an electrochemical engineering laboratory and a reactor system for studying catalysis, and (iii) a rotating packed bed rig to examine carbon capture from power station flue gas.
- £1M has been invested to create a state-of-the-art anaerobic digestion facility at the University's Cockle Park Farm site, for research into energy from agricultural residues and energy crops. A further investment of £2.5M (University and industry) has been committed for plant based research and to provide a test bed for smart-grid and energy storage technologies.
- £1M has been invested in MSE to support (i) new machining, high speed machining and additive manufacture equipment for manufacturing research; (ii) the development of a new

biomaterials laboratory for tissue engineering research; (iii) materials characterisation equipment; and (iv) the development of composite material processing facilities.
- £496k EPSRC award for small items of equipment to develop the research base in Healthcare Technologies, Sustainability and Digital Economy.
- £260k EPSRC equipment award has been used for an ultra-high frequency laser vibrometer for MEMS characterisation.
- A £150K Leverhulme Trust grant has been used to develop an innovative shoulder joint simulator, which has now been commissioned to become a key research tool in this area.

Previously established specialist facilities available to researchers over the REF period include:
- At Barrow Hill in Derbyshire the Newcastle Centre for Railway Research has a full-scale rail test facility, with over a mile of track and connection to the mainline railway network, together with meeting facilities, workshops and high performance computer modelling facilities.
- Within Marine Technology: (i) The Emerson Cavitation Tunnel, used to study marine propulsion cavitation; (ii) The Jones Marine Engineering Laboratory, which features a diesel engine test bed which has been adapted to operate using novel fuels; (iii) The Dove Marine Laboratory, used to study species migration through ballast water and algae for energy and chemical products; and (iv) the Hydrodynamics laboratory which features a wave, wind, and tidal facility for wave and current renewable energy research and a towing tank for calm water, wave resistance and sea-keeping experiments.
- The Advanced Chemical and Materials Analysis Service provides a range of analytical techniques, including scanning electron microscopy; x-ray powder diffraction; inductively coupled plasma optical emission spectroscopy; FT infrared spectroscopy; structural mass spectrometry; and carbon, hydrogen, nitrogen combustion analysis. During the REF period the service has moved into a new state-of-the-art facility funded by the University
- The UK National Gear Metrology Laboratory (NGML) is accredited by the UK Accreditation Service (UKAS) for the measurement and calibration of gears, gear artefacts and gear measuring instruments, and is linked to primary calibration facilities at the NPL (UK) and Physikalisch-Technisch Bundersanstalt (Germany). It maintains and develops the UK reference calibration artefacts to establish and disseminate traceability to industry throughout the UK.

Facility development planned in the next REF period includes:
- The University will invest £2M in large-scale facilities for energy, power and transport research as part of the £50M Science Central development in the heart of the city.
- A new award under the EPSRC Capital for Great Technologies call will allow for investment of £3.5M (£2.3M from EPSRC; £1.2M University, PI: Cumpson) in equipment for interface engineering and characterisation. The funds will purchase a He-ion microscope with analytical capability (a UK first) and a Time-of-Flight Secondary Ion Mass Spectrometer as key interface characterisation techniques, and new atomic layer deposition and additive layer manufacture equipment which will be used to create new interfaces and gradient structures.
- The University will invest £2M to develop the *Neptune National Centre for Sub-Sea and Offshore Engineering*, with a further £5M from HEFCE and industry, with nationally leading large scale hyperbaric and environmental test facilities. The Centre will feature large-scale hyperbaric and environmental test facilities capable of testing at temperatures and pressures equivalent to deep ocean conditions.

e. Collaboration or contribution to the discipline or research base

The development of interdisciplinary, collaborative research programmes and linkages with industry is supported in a number of ways including:
- Over this REF period the University has invested £1.9M in developing interdisciplinary research networks in *Sustainability* and *Musculoskeletal Disease and Therapy*, as part of building capacity to address its societal challenge themes.
- Direct funding for University Research Centres and Institutes including NIReS, Swan Energy Centre, nanoLAB and Biopharmaceutical and Bioprocessing Technology Centre.
- Support for travel in the development of research proposals, including a specific fund to support travel to meetings related to the development of EC proposals.

Our research outputs give an indication of our main academic collaborators over the REF period. From the research outputs we are submitting to REF2014, there are:

- Jointly authored papers reporting collaborations with the Allied Healthcare, Biology, Chemistry, Civil Engineering, Electrical Engineering, Mathematics, Medicine and Physics disciplines.
- Jointly authored papers reporting collaborations with Birmingham, Brunel, Cambridge, Cardiff, Cranfield, Durham, Edinburgh, Leeds, Liverpool, Loughborough, Oxford, Sheffield, St Andrews, Strathclyde, Surrey and Ulster Universities; King's College London; Imperial College and UCL.
- Jointly authored papers with international collaborators based in Australia, China, the Czech Republic, Georgia, Germany, Greece, India, Iran, Israel, Italy, Japan, Korea, Libya, Malaysia, the Netherlands, Norway, Singapore, Spain, Sweden, Switzerland, Thailand, Turkey, and the USA. *35%* of our submitted outputs arise from international collaborations.

Interaction with research users to inform strategy is gained through a variety of mechanisms:

- Ongoing dialogue with existing industrial collaborators to build long-term relationships (e.g. Marine Technology have worked with International Paint, now Akzo-Nobel, for over 30 years).
- The use of Industrial Advisory Committees, at a School, Research Centre or project level (e.g. the Biopharmaceutical and Bioprocessing Technology Centre, and the Newcastle Centre for Railway Research both maintain Advisory Committees with industrial membership; as does the EPSRC Centre for Innovative Manufacture for Medical Devices).
- Participating on external advisory boards and committees (list in section e.2).
- The appointment of Visiting Professors from Industry (e.g. Graham Penning, from David Brown Gear Technology; and Ian Ritchey, from Rolls-Royce).
- University level strategic partnerships (e.g. Arup, BAE systems and Siemens where we are a "Preferred Partner" University, one of only seven in the UK).

Our industrial links are illustrated in part by our submitted REF2014 outputs, which include industrial co-authors from Akzo-Nobel, Atlantic Inertial Systems, Bombardier, Chevron North Sea, Commercial Microbiology, D'Appolonia, FlowHow, Fujifilm Diosynth Biotechnologies, Innospec Ltd, Jaguar Land Rover, Lloyd's Register, Materialise, Nano-Porous Solutions, NobilBio Ricerche, Offshore Structure Analysis, and Tronics Microsystems. Other major collaborators include Astra Zeneca, BAE SYSTEMS, David Brown, Doosan Babcock Energy, GSK, JRI Orthopaedics, Novartis, Pilkington, Rolls Royce, Scania, ThyssenKrupp Tallent, Unilever, and Vestas Wind Energy Systems. There have been many more industrial links which have led to important research output and carried out over the REF period.

Since 2009 CEAM, MSE and MAST have established a significant presence in Singapore, through NUIS (Newcastle University International Singapore). The initial focus was to deliver undergraduate degree programmes in association with the Singapore Institute of Technology and has subsequently expanded to encompass research. This has materialised in the recruitment of 5 PGR students and research projects funded by Singaporean industry and government (~£1m in last 2 years), including research on lithium ion batteries for deep water marine applications, converting biomass to chemicals, ship hydrodynamics, and pharmaceutical process intensification, and we will continue to build on this strong foundation.

e.i Selected Specific Exemplars of Collaborative and Interdisciplinary Research

Advanced Materials: EPSRC/NSF funded research into cyberplasm (EP/H019081), using synthetic biology to create a micro-scale biohybrid robot, with collaboration from Northeastern University, University of Birmingham at Alabama, and MIT. Collaboration in £4M EPSRC Programme Grant *Coordination Chemistry for Energy and Our Sustainable Futures* (EP/I011870), building on research into metal-organic frameworks (with new award EP/K005499). Research supported by Daiwa Foundation on lithium ion battery anodes with Waseda University in Japan. Participation in European Co-operation in Science and Technology (COST) Action TD903 (enzymatic and proteomic processes in biomineralization).

Bioengineering: Co-ordination of €4M EC RESTORATION project (resorbable ceramic biocomposites; 280575; 11 EU partners), Dalgarno is Deputy Director of both the £5.5M *Arthritis Research UK Tissue Engineering Centre*, and the £6M *EPSRC Centre for Innovative Manufacture in Medical Devices* (EP/K029592). Research on the failure of metal-on-metal hip joints, supported by British Orthopaedic Association and new award from US Food and Drug Administration.

Design, Manufacture & Materials: Leadership of EC projects SecureMetro (blast and fire

resistant urban trains; 234148; 11 EU partners; €3.7M), SafeJoint (dissimilar material joining; 310498; 8 EU partners; €4M), SmartFusion (smart urban freight; 285195; 14 EU partners; €4M), and participation in a further 16 EC projects (with total funding in excess of £2M). Collaboration with RMIT in Australia on the behaviour of composites in fire, funded by US Office of Naval Research. Research into health monitoring and reliability of offshore wind turbines (269202).
Electrochemical Engineering Science: Leading the £3.6M *Supergen Fuel Cell Consortium* (EP/G030995) and related fuel cell research (EP/F035764), and collaborating in the *Supergen Biological Fuel Cells Consortium* (EP/H019480). Research into the use of microbial fuel cells to recover energy and trace metals from wastewater (NE/K015788). Collaboration in ELIBAMA EC project (automotive lithium-ion battery manufacturing; 285385). ESPRC award *Collaborative Research in Energy with South Africa: Intermediate Temperature Proton Conducting Membrane Systems for the Hydrogen Economy* (EP/G042012), with University of the Western Cape.
Marine Technology: Research on structural performance of naval vessels, in collaboration with Georgia Tech, Cornell, Lehigh, Connecticut, and Michigan Universities, funded by US Office of Naval Research. Co-ordination of EC Inomanship (Innovative Energy Management System for Cargo Ship, £1.9M, 266082, 7 EU partners) and Assessment of Life-Cycle Effects of Repairs on Tankers (31459, 9 EU partners), and collaboration in RISPECT (design for inspection and maintenance, 218499). Collaboration in TARGETS (266008) and STEAMLINE (233896) marine propulsion projects; and in the Hydro-Testing Alliance (31316). Research into low emissions and ultra-slow shipping (266126, EP/H019871, 266030). Collaboration in new £3.5M EPSRC Shipping in Changing Climates award (EP/K039253). Partnering in the £10M EPSRC UK Carbon Capture and Storage Research Centre (EP/K000446), leading research on pipeline networks for carbon capture and storage (EP/G061955; £1.5M), and collaborating in research on advanced structural materials for marine renewables (EP/K013319, £1M).
MEMS & Sensors: Awarded the UK's *National EPSRC XPS Users' Service* (£3.1M), plus further £2.3M from EPSRC Capital for Great Technologies call for interface engineering. Research on graphene for biosensing (EP/I015930), with international collaboration on graphene sensors with University of California, Los Angeles and Jadavpur University funded by UK India Education and Research Initiative (UKIERI). Collaboration in Newcastle led programmes on biodiagnostics (016817, €21M, 30 partners; EP/G061394, £1.8M). Collaboration in new £11M IRC in Early Warning Sensing Systems for Infectious Diseases (EP/K031953). Research into resonant MEMS gyroscopes (EP/K000349; EP/G029296).
Fluid Dynamics & Thermal Systems: Leading the EPSRC *GLOBAL - Sustainable Energy through China-UK Research Engagement* programme (EP/K004689), collaborating with 14 universities and research institutes in China. Research into domestic and industrial co- and tri-generation and thermal management (EP/F061978; EP/I027904; EP/G056706; total £1.1M). Utilising renewable energy to aid rural communities (EP/L002477; EP/L002531/1; total £1.4M) collaborating with partners in UK, Germany, Ghana, South Africa, Sierra Leone, Kenya and the Philippines. Research on turbulent flame propagation (EP/J021997; EP/J003573; EP/I028013), with leadership of the UK Consortium on Turbulent Reacting Flows (EP/K025163). Research on computational modelling for nuclear industry safety (EP/I003010; 231747; with studentships funded by French Institut de Radioprotection et Surete Nucleaire and the Norwegian Institutt for Energitechnikk) and fundamental and applied studies on the behaviour of particles in turbulent flows (EP/E029973; EP/D061601). Participation in COST Action MP0806 (particles in turbulence).
Process Intensification & Catalysis: Leading the £4.9M *Supergen: Delivery of Sustainable Hydrogen* consortium (EP/G01244X), research on solid oxide fuel cells (EP/J000892), and collaborating in the *Hydrogen and Fuel Cell Supergen* Hub (EP/J016454). Collaboration with Indian Institute of Petroleum on biofuel extraction processes, funded by UKIERI. Research on applied catalysis, through the *UK Catalysis Hub* (EP/K014706); an EPSRC platform grant on ceramic membranes for energy applications capture (EP/G012865); and research on thermo-chemical oxygen storage and production (EP/K029649). Collaboration in £2.5M EPSRC *Clearing Land for Wealth* project (EP/K026216), using synthetic biology to recover nanoparticulate arsenic and platinum, and in €14M Bioproduction project (26515) to research sustainable bioprocesses.
Process Measurement & Optimisation: Awarded the £6.4M *EPSRC Industrial Doctorate Centre: Biopharmaceutical Process Development* (EP/G037620), with collaboration from GSK, Novartis, ABB, P&G, Unilever, and Astra Zeneca. Collaboration in Flexible, Fast and Future Factory EC project (228867), and in the AD-WINE (High performance anaerobic digesters for the treatment of

medium sized wineries effluents; 286052) Marie Curie Industry-Academia Partnerships and Pathways project with Leibniz Universitat Hannover. Collaboration in EC project Intelligent Reactive Polymer Composite Moulding (228662). Collaboration in EC project ECOCARB (emissions reduction and energy utilisation of coke oven underfired heating; RFCR-CT-2008-00007); and new EC-China staff exchange award on Coal-fired Supercritical Power Plant with Carbon Capture (with Tsinghua, East China, and Southeast Universities; 612230).

e.ii Selected Exemplars of Leadership in the Academic Community within REF period

Conferences Organised. Composites in Fire 5 and 6, Newcastle in 2008 (105 delegates from 9 countries) and 2011 (95 delegates from 7 countries). Newcastle Nanoindentation Conferences, 2008 (40 delegates from 8 countries) and 2010 (50 delegates from 15 countries). 1st, 2nd & 3rd International Conferences on Advanced Model Measurement Technology for the EU Maritime Industry, Nantes in 2009 (jointly organised with Sirehna; 103 delegates from 20 countries), Newcastle in 2011 (97 delegates from 18 countries), and Gdansk in 2013 (jointly organised with CTO; 80 delegates from 19 countries). Sustainable Thermal Energy Management (SusTEM) held in Newcastle in 2010 (as a national conference with 93 delegates, predominantly UK) and 2011 (as an international conference, with 131 delegates from 7 countries). Low Carbon Shipping Conference, held in Newcastle in 2012 (national conference with 69 delegates). UK Surface Analysis Forum Workshop and Summer Meeting (2013, 71 delegates) held in Newcastle. 1st Mexican Workshop on Additive Manufacturing (jointly organised with Tecnológico de Monterrey), held in Monterrey, Mexico in 2013 (201 delegates from 6 countries).

EPSRC College Members. Bull, Chakraborty, Dalgarno, Martin, Metcalfe, Novakovic, Reeks, Roskilly, Roy, Scott, Siller.

Fellows of the Royal Academy of Engineering. Martin, Metcalfe.

Editorial Boards. Bretcanu: ISRN Ceramics Journal. Bull: Journal of Physics D: Applied Physics; Advances in Materials Science and Engineering. Chakraborty: ISRN Journal of Mechanical Engineering. Dalgarno: Biofabrication. Dow: Marine Structures Journal; Journal of Ships and Offshore Structures. Gibson: Plastics, Rubber and Composites (Associate Ed.); Composites A. Metcalfe: Chemical Engineering Science (Executive Ed.). Pancholi: Bubble Science, Engineering & Technology. Reeks: Journal of Flow, Turbulence and Combustion (Ed.). Roskilly: Applied Energy (Subject & Special Issues Ed.); Applied Thermal Engineering (Special Issue Ed.), Journal of Marine Engineering and Technology (Associate Ed.), Journal of Marine Energy and Technology (Ed.). Siller: Vacuum. Tao: Ocean Engineering, Journal of Marine Engineering and Technology, ASME Journal of Offshore Mechanics and Arctic Engineering (Associate Ed.). Thomas: Fuel (Associate Principal Ed.); Progress in Energy and Combustion Science. Zhang: Neurocomputing.

Advisory Boards. Atlar: MoD Low Signature Propeller Industry Forum; International Towing Tank Conference Advisory Council; 26th ITTC Special Committee on Surface Treatment. Bull, Montague, Martin: BRITEST Board. Dow: Lloyd's Register Technical Panel for Naval Ship Rules, International Ship and Offshore Structures Congress. Martin: Academic Board of Chemical Innovation KTN; BBSRC/EPSRC Bioprocessing Industry Club. Reeks: Scientific Advisory Committee for PHEBUS International Severe Accident Experiment. Robinson: International Railway Research Board; European Railway Research Advisory Council; Advisor to European Commission DG-Research; Scientific Advisor to MoD. Shaw: British Gear Association Executive and Technical Committees. Tao: ITTC Ocean Engineering Committee, ISSC Natural Gas Storage and Transport Committee, Lloyds Register Technical Committee, ASME-OMAE Offshore Technology Committee.

Invited Conference Presentations and Research Seminars: Over 110 in total.

Awards. The 2008 IMechE Technical Strategy Board "Water Arbitration Prize", given to the best original paper published by the Institution that year (Gallacher). ASME Freeman Scholar Award 2010 (Reeks). 2008 IMechE Safety in Engineering Award, and 2009 IMechE Railway Division Sir Alfred Rosling Bennett / Charles S Lake Award (Robinson). IChemE 2012 Chemical Engineering Project of the Year (Martin, Montague). 2013 Tribology Silver Medal Award from the IMechE/Tribology Trust Fund (Bull).

International Grant Reviewing: Australia (Tao), Austria (Bull, Dalgarno), Belgium (Dow), Canada (Reeks, Bull), China (Liu), Cyprus (Bull), Czech Republic (Chen), Germany (Dalgarno, Siller), Greece (Gibson), Hong Kong (Joyce, Tao), Ireland (Martin), Israel (Reeks), Japan (Siller), Netherlands (Atlar, Reeks), Norway (Atlar, Gibson, Thomas), Oman (Gibson), Poland (Dalgarno), Portugal (Tao), Qatar (Bull), Slovakia (Bull), USA (Bull, Dalgarno, Reeks, Siller).