Institution: The Open University

Unit of Assessment: B13 Electrical and Electronic Engineering, Metallurgy and Materials

a. Context

Our research submitted under UoA13 has innate engineering, economic and societal impact (see table below). It has benefitted the electricity industry and the UK economy through extending the lives of existing nuclear power stations. It has enabled aircraft constructors and operators to optimise life assessment and damage-tolerant design of commercial and military aircraft structures. Novel tools to facilitate engineering stress measurements have been developed and the technologies translated from scientific to industrial communities. More broadly our research has helped to protect the safety of UK society through underpinning assessment methods and standards for safety critical structures. Numerous small, hi-tech companies have benefited from our research developing coatings and catalysts.

Sector	**Non-academic beneficiaries/user groups**
Electricity power generation industry	Rolls-Royce, AREVA, EDF Energy UK, EDF France, E.ON, Doosan Babcock, AMEC, Frazer-Nash Consultancy, ETD Technology, JNES
Aerospace industry	Airbus UK, Airbus Germany, Bombardier, USAF, Rolls-Royce, Alcoa, QinetiQ, Metal Improvement Company.
Other engineering Industry	Lam Research, Oxford Instruments, Johnson Matthey Technology, Det Norske Veritas, Jaguar Land Rover, Red Bull, BP Solar, BorgWarner, Safeguard Europe Ltd, Hichrom, Gelest, Dow Corning, Mitsubishi
SMEs	ETD Technology, Ceravision, Cambridge Joining Technologies, AME, P2i, Bowers & Wilkins, Veqter, Applied Microengineering Ltd, Welding Alloys Ltd, Intelligent Energy Ltd, Cornelius Specialities, ToxiMet
Government bodies and research agencies	Office for Nuclear Regulation, MoD, STFC, NPL, TWI, Northern Ireland Waste Water Treatment
Standards bodies	BSI, ISO
Large-scale facilities	Our SScanSS system facilitates engineering neutron and X-ray engineering measurements for industry at: ILL (France), ANSTO (Australia), FRM-II (Germany), Chalk River (Canada), SNS & HIFR (Oak Ridge, USA), ISIS & Diamond (UK), NECSA (South Africa).

b. Approach to impact

Following RAE2008, our approach to impact has been to develop the engineering focus of our research through:

- investment in staff, infrastructure and facilities;
- building upon historical research strengths;
- nurturing existing research collaborations and seeking new partnerships;
- growing our research income from the energy and aerospace industrial sectors.

Key new appointments were made with a view to expanding and enhancing our links with industry. Ten of the staff returned here were appointed since RAE2008. Bouchard was recruited from industry as Professor of Materials for Energy (2008), and used his Royal Society Industry Fellowship to attract £1.5m of co-funded research projects in the Energy sector and create the EDF Energy (UK) High Temperature Centre at the OU. Fitzpatrick, promoted to a Chair in Materials Fabrication and Engineering funded by Lloyd's Register Educational Trust, expanded his research engagement with aircraft technology development programmes. The economically important theme of *Energy* was targeted for investment by making new strategic academic appointments. Six new academic appointments were made in the area of *Energy* in 2012, of whom three are returned in this UoA.

Key research strengths were identified following RAE2008 and unique capabilities developed of relevance to industrial problems in fabrication and processing, residual stress engineering, high-temperature behaviour and structural integrity.

Facilities and equipment investment (around £1.5m) has been targeted to support research themes most relevant to industrial collaborators. We have developed new, distinctive capabilities, e.g. diffusion bonding, contour residual stress measurement, and digital image correlation (DIC) high-temperature testing, which have attracted new collaborations (e.g. Mitsubishi, E.ON, TWI).

A networking approach has been adopted to foster long-term relationships with industrial contacts, where we aim to understand industry challenges and provide technical advice or 'demonstration' research to secure collaborator confidence. This has included participating in TSB and EU projects, and international research networks on a 'contribution in kind' basis.

Value for money options supporting research sponsored by industry have been exploited, for example matched-funded PhD studentships (OU 'Charter' scheme and Faculty-financed) with Rolls-Royce, EDF Energy, Lloyd's Register, AREVA, Jaguar Land Rover, AMEC, Airbus, Oxford Instruments and Plasma Technology. Similarly, the OU's Knowledge Exchange Voucher (KEV) scheme has been used to develop new research relationships with Bombardier, Welding Alloys Ltd and P2i. Financial gearing from the OU and an East Midlands Development Agency Demonstration Grant secured a major contract from Rolls-Royce for our Contour Method research.

Collaboration has been strongly encouraged. For example, we have a special relationship with the UK's ISIS Neutron Facility (spanning over 20 years), having led the construction of the ENGIN-X diffractometer, and are now involved in the design of the new IMAT instrument. We also created a virtual laboratory for the design and control of beamline experiments and have assisted industrial users awarded neutron beamtime through the Industrial Collaborative R&D Scheme (e.g. Airbus, AREVA, BAE Systems, BorgWarner, EDF Energy, Lloyd's Register). We have also developed links with China, India and Australia that have had significant industrial influences.

Consultancy work providing specialist advice and measurements to industrial clients (e.g. EDF Energy, AREVA, DNV, Red Bull and TWI) has been a priority. This strategy has strengthened our industrial relationships and fed through to improved research quality, agility, responsiveness and delivery. In 2013 we established a dedicated Measurements Business Unit to exploit our unique capabilities (application of the contour method, neutron and X-ray diffraction, and DIC).

Knowledge transfer from academia to industry has been actively supported. For example, our collaboration with US supplier Gelest led to a three-year KTP with Hichrom (around £200k, starting in 2011) to look at coatings for silica particles used in chromatography. Also, following consultancy work on organo-silicon product innovation, TWI sponsored a CASE award with us to develop their silsesquioxane technology further for anti-abrasive coatings of metals and antifouling treatments for hulls. Knowledge transfer has also been supported through the secondment of researchers to industry (e.g. ETD, Jaguar Land Rover), other research institutions (ANSTO, BARC and IGCAR in India) and Large-Scale Facilities (several PhD placements at ISIS).

Dissemination of research outputs has been through seminars, conferences and collaborative forums attended by the energy and aerospace industries, as well as in high impact factor journals. We have hosted several major events (e.g. International Contour Seminar in 2012).

Codes, standards and committees work supporting safety critical industries has been supported, for example in the development of BS7910, the R6 Defect Assessment Procedure, the NPL Good Practice Guide for X-ray Residual Stress Measurement, the ISO committee preparing a neutron diffraction full-standard for publication, and chairing the ISIS Facility Access Panel (FAP7) for the use of ENGIN-X diffractometer (2001–02, 2008–13).

Policy influence. We have informed government policy: for example Fitzpatrick gave evidence to the House of Lords Select Committee on Nuclear R&D Capabilities (2011), and was a member of the Foreign and Commonwealth Office / RCUK delegation to India establishing civil nuclear research collaboration in 2008.

c. Strategy and plans

We will strengthen the impact of our research by 2020 through consolidating our position as one of the top five materials research communities in the UK with a focus on engineering application. We will increase the volume, reach and impact of our materials research by: increasing the number of research-active staff and PhD students by 50%; developing a 'Materials Community of Interest'

integrating research across atomic, molecular and continuum length-scales; and developing an 'Energy Community of Interest' bringing together more diverse technologies and stakeholders.

We will expand our research in nuclear materials through the recently awarded £2m Lloyd's Register Foundation International Joint Research Centre for the Safety of Nuclear Energy with the University of Lancaster, University of Tennessee and Harbin (China), and other existing collaborative programmes with UK universities. New activity will fuel a vigorous expansion of our successful engagement with the nuclear industry in the UK, France, India, China and Australia.

Research undertaken by our (EDF Energy) High Temperature Centre over the past four years is set to deliver substantial impact in relation to the future operation of UK gas-cooled reactors. We have a new four-year funding agreement (2014-17) with EDF Energy and plans to exchange senior staff, under the Royal Society Industry Fellowship scheme, which will help to embed this research. We will extend the scope of our high-temperature research, examining new materials for nuclear, fossil fuel and aerospace applications supported by new sponsors. In particular, we plan to exploit our world lead and unique experimental capability in application of DIC at high temperatures.

We will maintain our seminal position in the design and development of neutron and synchrotron beamline systems. In particular, we will strengthen our long-standing relationship with the ISIS Facility through a programme of jointly funded PhD students, focusing on support for new instrumentation (e.g. the new IMAT instrument, and a multi-instrument creep–fatigue rig).

We will build upon our successful historical approach to impact (see section b above) by consolidating current partnerships in the power generation (nuclear, fossil, solar, fuel cells, etc.) and aerospace (airframes, engines, and supply chain) industries and make new relationships with the petrochemical, automotive and electronics industries.

We have recently (2013) established a new Measurement Services Business Unit servicing commercial clients (e.g. for contour, neutron and X-ray residual stress measurements, DIC, creep testing), and expect a turnover of at least £300k by year 2. This will increase our impact and draw in research funding support from a wider community of industries. In 2016 we will review whether to create a spin-out company or expand the in-house Business Unit.

We have a growing research presence at the fundamental scientific end of the materials spectrum: graphene, quantum computing models, catalyst nano-materials and silsesquioxanes where our strategy is to become involved with small, hi-tech companies. For example, our silsesquioxane expertise has recently attracted a £10k pilot contract with Safeguard Europe Ltd, a company that makes damp-proof treatments for walls; and a three-year KTP (£221k) with Cornelius Specialties to help develop new contact lens materials with greater permeability for daily wear.

More generally, we will broaden the scope of our impact through increased public engagement at national level – government and government departments, scientific bodies (Royal Society, Royal Academy), professional bodies, etc. – through the OU's unique reach and through holding international seminars. We will also actively expand our current, successful research partnerships with related departments at universities in the UK, for example Cambridge, Oxford, Imperial, Manchester, Bristol and Lancaster, as well as developing strategic international relationships with academia and industrial partners in France, India, China, Brazil and Australia. The Open University is an RCUK funded Catalyst for Public Engagement in Research, which is embedding public engagement in the University's research strategies and the work of researchers at all levels, including the OU's unique reach through TV broadcasting and web channels.

d. Relationship to case studies

The case study 'Neutron diffraction strain measurement for industry' illustrates how impact arises from long-term (over 15 years) research and development that engages and collaborates with both scientific and industrial communities. The case study 'Life extensions of nuclear power plant' exemplifies how our industry-funded research has delivered high economic impact for both the sponsor and UK society, as well as contributing to the advancement of engineering assessment procedures and standards. Finally, the case study 'Aircraft structures: Life extension and damage tolerant design' illustrates the effectiveness of our approach to impact, that is by making world-class materials engineering research accessible to industrial partners and by delivering innovative high-quality results.