Institution: Oxford Brookes University

Unit of Assessment: 15 General Engineering

a. Context

Impacts arising from research undertaken in this UoA reside in the automotive, motorsport, and aerospace engineering sectors; construction engineering; and biomedical engineering.

Impact is focused in one or more of three related categories: (i) Developing and exploiting new technologies and processes, usually involving commercial exploitation and/or technology transfer; (ii) Evaluating and influencing policy processes and regulatory frameworks, usually through the development of guidance, metrics and internationally recognised standards; and (iii) Shaping practice, capacity building, and changing behaviours. Specific examples of impact generating activities and the associated beneficiaries are detailed in section b.

b. Approach to impact

The UoA has a long history of close collaboration with industry including automotive, motorsport, and aerospace engineering sectors; construction engineering; and biomedical engineering. There is a clear agenda to embed impact across all these areas of engagement, and to optimise benefits arising from effective application of intellectual capital.

Sustainable Mobility

Strong examples of shaping practice and changing behaviours are evidenced by the close working relationship the UoA has with the automotive industry, and the now emerging market for alternative powertrains and sustainable vehicles. The Sustainable Vehicle Engineering Centre (SVEC), led by **Hutchinson**, was developed from *DRIVENet*, the EPSRC-funded Network for the design for dismantling, reuse and recycling of road vehicles. In support of SVEC there has been a significant investment of HEIF funding (circa £470k). This has been used to enhance the previously existing high quality testing facilities.

SVEC focus uniquely on the whole life-cycle of the motor vehicle from raw materials to design, powertrain, energy sources, manufacture, disassembly, re-use of components and recycling of materials. **Hutchinson and Winfield** produced a ground-breaking marketplace report in 2007 [1], with a comprehensive review and analysis of global markets and waste streams using sophisticated forecasting models. This highly cited report has proven influential *viz:* "*This excellent report continues to represent the first study of its kind to quantify past and future levels of waste generated by the motor industry worldwide …it led directly to interest from JaguarLandRover who view end-of-life vehicle recycling as key for their use of lightweight materials in vehicle construction"* [2a]. The report influenced topics for TSB funding calls, modelling of carbon foot-printing at BP [2b], and methodologies in JLR's REALCAR programme. As a result, JLR have made a significant investment in their new vehicle programmes to replace the primary material input with recycled aluminium.

As a long-standing collaborator with Oxford Brookes University, BMW selected **Hutchinson** to lead the inter-disciplinary research in the MINI E real-life EV trials in Oxfordshire [TSB TP11/LCV/6/I/BF045J]. This formed part of *Project i* (BMW's holistic approach to tomorrow's mobility) and involved two six month trials of 40 vehicles with 138 private and fleet drivers. The project combined objective energy use data with subjective driver data as a means of achieving proper understanding of performance and acceptability. The data continues to play a fundamental role in strategic decision making. *"The early (MINI E project) findings have already informed the development of the 2011 BMW ActiveE…but the biggest beneficiary will be the BMW i3, the first purpose-built EV from the BMW Group, due in 2013."* (S Gray, BMW [3]).

Motorsport Engineering

The UoA has very close links with the Motorsport Industry. This was recognised in 2007 by the award to **Morrey** of £2.1M of capital funding from the South East of England Development Agency (SEEDA), to establish a Motorsport Engineering Centre. £800k of this was for capital equipment to be used for consultancy and industrial research. This capital funding has generated a great deal of interaction with the industry, an example of which is that for the last five years the Department has

hosted the annual 'World Motorsport Symposium'. The Department also has a strong history of doctoral and postgraduate training and employment with this industry, particularly with the following F1 teams: Lotus F1, Infiniti Red Bull, Williams F1, Force India, MacLaren and Marussia F1, and suppliers such as Xtrac, AP Racing, Prodrive and Wirth Research. This 'distinctive expertise in motorsport' and the important source of high level skills was acknowledged recently in the report 'The Oxfordshire Innovation Engine' [4]. In terms of impact, this has played a significant role in capacity building for this important cluster.

Joining Technology

An example of developing and exploiting new processes is evidenced by the outputs from a KTP with YASA Motors. Polymer composite materials, injection moulding and multi-material adhesive bonding techniques were optimised to reduce production times and costs for high power density, low mass, electric motors. *"This KTP has proven instrumental to sustaining the growth of YASA Motors in the areas of materials and bonding technologies"* (Dr King, YASA) [5]. The motors are installed currently in many commercial and niche high-performance vehicles (eg Delta E4 Coupe, Morgan Life Car, Lola Drayson electric land speed record car).

The Joining Technology Centre, led by **Broughton**, has well established links with the construction industry, and provides input into guidance and standards on the use of structural adhesives and polymer composites to the strengthening of existing structures. Evidence of this is its close involvement in the production of design guides; and contributions to industry best practice guides (Concrete Society TR 57, EU COST E34 chapters) and book chapters (Strengthening of Reinforced Concrete Structures, International Handbook of FRP Composites in Civil Engineering, Construction Materials Reference Book, ICE Manual of Construction Materials). The design guidance is used by leading designers (eg Arup, Halcrow), contractors (eg BWM, Concrete Repairs, Rotafix), materials suppliers (eg Sika), and client organisations (eg Highways Agency, Network Rail).

Biomedical Instrumentation and Imaging Techniques

A further example of developing and exploiting new technologies and processes is the long involvement that Oxford Brookes University has with the development of biomedical instrumentation and imaging techniques, starting with research on Electrical Impedance Tomography (EIT), initiated in 1985. From the theoretical point of view, EIT has two major challenges: non-linearity and ill-posedness. Over many years **Sebu** in collaboration with colleagues at Bremen, Mainz, Montpellier, Sheffield, Toulouse and Ankara has made numerous contributions to EIT [6, **Sebu, 6732**].

The theoretical work on image reconstruction algorithms for EIT was extended to practical applications in the early 90s by **Lidgey** and McLeod at Brookes, resulting in the design and construction of an EIT tomograph. This was the first of a series of increasingly sophisticated devices developed at Brookes, which were unique in Europe in providing absolute impedance measurements through a body section. These were tested over the years in clinical studies in collaboration with the Department of Anaesthetics, University of Oxford, which led to a European patent application (PCT/GB2005/002076, May 2005). In this work, **Lidgey** and **Hayatleh** used advanced digital signal processing and novel analogue electronic interface circuitry design, and **Hayatleh** is now applying these novel current-mode design techniques to EIT and to the design of instrumentation amplifiers [**Hayatleh, 7627**], resulting in other patents/products in other areas of biomedical instrumentation.

The level of mathematical sophistication in the theoretical work and the practical development of imaging devices at the University were for some time matched only by the research at Sheffield University and Rennselaer Polytechnic Institute in the USA, as described in Holder's book *Electrical Impedance Tomography* (2005). Since 1993, the underpinning research in EIT has led to four European patent applications, and three US patents.

Architectural Engineering

The Architectural Engineering Group has also benefitted from strategic research and development agreements with industry including the UK and EU steel sector (circa. £1m), as well as with a wide range of industrial companies with whom there has been recurrent activity.

The 'Architectural Engineering' research group is currently charged by Tata Steel (and previously by Corus and British Steel), to lead an intensive R&D programme around light steel construction, the primary structural technology for the rapidly developing modular and off-site volumetric construction sectors. This has generated essential design data for light steel in the areas of building physics, durability and construction and structural compliance, and subsequent construction of full scale test buildings, providing high-quality data in structural, thermal, acoustic and environmental performance. The research has allowed commercial exploitation with major private sector infrastructure investment programmes to deliver products at commercial volumes. Data has assisted manufacturers to achieve regulatory approval from building control agencies including local authorities and specialist providers such as Lantac, NHBC and Zurich. This is an example not only of successful applied technology-led transformation, but is also typical of the collaboration that exists with disciplines returned under related UoAs (notably UoA 16) delivering impacts that may not be achievable without a high degree of interdisciplinary working.

The UoA as a whole engages in a strong programme of industrial consultancy and contract testing, in the areas of: Stress Analysis and Materials, for Siemens Magnet Technology; Joining Technology, for Bostik; Engine Testing and emissions analysis, for Oxonica and Energenics; and Architectural Engineering, for TATA.

References

[1] PH Winfield, AR Hutchinson and MJ Pemberton. *Whole life vehicle waste streams – a global perspective*, ISBN 978 0 9556254 1-1, Oxford Brookes University, 2007.
[2] a) Geoff.scamans@innovaltec.com, SCO Innoval Technology, Feb 2013; b) Rosemary.albinson@castrol.com, Technology & Transport Strategy Advisor, BP. Sept 2013.
[3] Suzanne.gray@bmw.com, Suzanne Gray, General Manager, BMW *Project i* E, January 2012.
[4] 'The Oxfordshire Innovation Engine', SQW (launched by David Willetts), October 2013.
[5] Charles.king@yasamotors.com, VP Process Innovation, YASA Motors. The Engineer: Technology and Innovation Awards, 2011.
[6] S Ciulli, M K. Pidcock, C Sebu, *An integral equation method for the inverse conductivity problem*, Phys. Lett. A **325**: 253-267, doi:10.1016/j.physleta.2004.03.060, (2004).

c. Strategy and plans

The UoA strategy, as detailed in REF5, has a number of objectives specifically targeted at further strengthening the ongoing generation of impact and external collaborations, specifically to:

1. Increase the number of industrially funded PhD studentships, building on the strong network of existing industrial partnerships;
2. Maximise the impact generated from underpinning research, and to capture the benefits and outcomes, particularly building on work in the areas of Sustainable Mobility, Biomedical Instrumentation and Imaging, and Lightweight Structures.
3. Further expand collaborative research through engagement with initiatives such as Horizon 2020 and the TSB Catapult Centres
4. Engage in further major 'breakthrough' projects, with the automotive and motorsport industry, particularly in the areas of hybrid vehicle power-plants, end-of-life vehicle issues, materials sustainability and vehicle dynamics.

d. Relationship to case studies

The selected case studies exemplify the UoA's approach to impact. All have relevance across the themes indicated in section a: (i) Developing and exploiting new technologies and processes (ii) Evaluating and influencing policy processes and regulatory frameworks (iii) Shaping practice, capacity building, and changing behaviours. The 'Light Steel', 'Light-Weighting' and 'AVERT' case studies engage all of the research themes whilst the 'Slender Structures' study principally engages themes ii. and iii.