Institution: University of Liverpool

Unit of Assessment: 15 – General Engineering

a. Context

The impact of research in the School of Engineering is principally Economic, with further contributions to Health and the Environment. Each staff member belongs to one of three Departmental research centres, namely: Engineering Dynamics (CED); Engineering Sustainability (CES); or Materials and Structures (CMS). Cross cutting knowledge transfer centres exist to promote exploitation of research, expertise and facilities by commercial enterprises, for example through the Virtual Engineering Centre (VEC) partnership on Autonomous Systems with BAE SYSTEMS. Inter-disciplinary research is fostered via University-wide institutes, such as the Liverpool Institute for Risk and Uncertainty (LIRU) and the Stephenson Institute for Renewable Energy (SIRE). Focused research centers, such as the AgustaWestland Liverpool Advanced Rotorcraft Centre (AWLARC), have been established to house major facilities and co-locate researchers. Impact is thoroughly embedded in the School, with the overwhelming majority of academics returned being engaged with knowledge exchange as part of their research. The research strategy of the School drives the development of thematic inter-disciplinary research with potential for exploitation.

b. Approach to impact

The Departmental Research Heads plan and coordinate research; provide mentoring; and manage staff-performance review. Through the Departmental research centres, staff are engaged with key users, using mechanisms including: directly funded research; studentships and consultancy; EPSRC follow-on funds; EPSRC Knowledge Transfer Account; Knowledge Transfer Partnerships; TSB Collaborative Research and Development; EU Framework; and overseas funding agencies (e.g. United States Air Force). Through the funding generated by these mechanisms, a range of relationships with companies has been developed, which formed the primary driver for impact during the assessment period. Examples of collaborative research since 2008 include: Airbus; BAE SYSTEMS; EDF; MBDA; Dowty; Ford; Ultravision; Jaguar Land Rover; Nanoco; NXP; Renishaw; SAFC Hitech; Stryker; and Shell. One example of the impact arising in this way is the AgustaWestland initiative**,** which established AWLARC in 2009 through an agreement covering intellectual property and the centre operation. The centre has driven the exploitation of a computational fluid dynamics research programme for the AW169/AW189 main and tail rotor development, as well as on-going engineering support for the AW109, AW101 and AW139. The Liverpool flow solver HMB is now established as a standard tool for the aerodynamics department at AgustaWestland (contact: James.Godman@agustawestland.com).

Three multi-million pound centres have been operational throughout the period of assessment, promoting research impact with small and medium enterprises (SME's). The Lairdside Laser Engineering Centre (LLEC) is supported by £1.74M from the European Regional Development Fund to provide access to facilities and expertise in Lasers. 42 regional SME's have been assisted in the assessment period. For example, BioAMD was helped to develop laser polymer welding for the manufacture of a blood coagulation monitoring device, now being marketed to a large pharmaceutical prime (contact: nasser.djennati@bioamd.com). The VEC was established in 2009, using a grant of £3.25M from ERDF/NWDA and subsequent funding of £2.5M from STFC, DBIS and industry, to promote the use of virtual engineering by companies, drawing on the expertise of the Centre for Autonomous Systems Technology and the LIRU. 45 SME's have been assisted and longer term partnerships established with seven prime companies. The partnership with BAE SYSTEMS on autonomy has established a facility for simulating autonomous vehicles operating in civilian airspace. This has been used to drive company and University interactions with SME's (contact: tony.balmer@baesystems.com). The NiCAL Microscopy Centre was established in 2012 using a grant from ERDF of £2.45M. It is housed in a new 250 m^2 space on campus and opens up the expertise and electron microscopy facilities to SME's. The Centre has a target of 100 industrial assists, of which 90 will be with SME's, over three years.

Co-funded doctoral projects since 2008, including Research Council CASE awards, have provided

a mechanism for developing deep interactions with companies, with 18 companies providing financial contributions (some multiple times): QinetiQ; BAE SYSTEMS (3); Airbus (2); Stryker (2); Stirling Dynamics; SAFC Hitech (2); AgustaWestland; CENER; Civil Aviation Authority; Renephra; MBDA; Fianium Lasers; Renuntiabo; SpehiTech; Arup; Dstl; Thermacore; and Doosan Babcock. As an example of impact, the development of selective laser melting technology at Liverpool now forms part of Renishaw's additive manufacturing Selective Laser Melting product range. Dr Wesley Brooks PhD project, completed in 2012 was focused on the process control software. He is now software development engineer with the company (contact: Simon.Scott@renishaw.com).

During the second half of the assessment period an increasingly structured approach to expanding the reach and significance of these interactions has been used, including an EPSRC Knowledge Transfer Account (Director, **Chalker**) to support 12 projects to enhance the technology readiness of outputs from basic research, spanning electronic and biomedical thin film materials; prosthetic devices, composites, laser manufacturing processes; and MEMs-based quadrupole mass spectrometers. In one project, an atomic layer deposition manufacturing process was developed with Nanoco Technologies to enhance the performance of quantum-dot based displays. Subsequently the project scientist was employed by the company and he is now leading the up-scaling of the company's own production facilities in-house (contact: MWerner@nanocotechnologies.com).

The University's Business Managers support our staff as a key element of our Knowledge Exchange strategy. This has also led to the development of a new Intellectual Property policy to promote the award and exploitation of patents. 23 patent applications have been made by School staff in the period. Exploitation of these includes the examples given in the case studies of **Chalker, Zhao** and **Sutcliffe**. Other patented work is in the areas of laser micro-structuring, sky guides for pilot assistance, laser ignition systems and the continuous monitoring of inter-ocular pressure. Academic promotion since 2011 has included explicit recognition of Knowledge Exchange. The School's processes weighed the contribution under this heading in its recommendations on individual cases, and the approach was documented in minutes circulated to all staff to promote the importance of this activity. Over 20 new academic appointments have been made to the School of Engineering since 2010, and a substantial part of the selection process has explored the ideas and attitude towards establishing impact from research. The result is that the School has a cohort of staff with ideas and energy for impact.

c. Strategy and plans

The University has developed a strategy for promoting impact, and a number of elements of this are particularly significant to the School of Engineering:

1. The University has established the senior post of Provost for Innovation, providing governance for a broad range of knowledge exchange activities;
2. The Local Enterprise Partnership has produced the Merseyside innovation plan. The regional priority growth sectors are high-value manufacturing, biomedical technologies and the blue/green economy amongst others. The University and the School are reflecting all of these areas in its research development plans;
3. Establishment of an investment fund (£7M over five years) to underpin IP protection, which includes support for patenting and licencing agreements. An investment case has been made to broaden the application of orthopaedic implants to dental and veterinary applications;
4. The sharing of income has been introduced to incentivise consultancy, with business processes introduced to support contractual and payment issues.
5. A system of key account management for selected large companies has been piloted with Unilever, and will be expanded to cover five other companies by the end of 2014.
6. For small and medium enterprises, the ERDF funded centres in materials (based in Chemistry with strong Engineering engagement), virtual engineering, laser engineering and microscopy (all described above), have driven more than 100 business assists in the last three years, and will be consolidated and expanded to drive the exploitation of high-end facilities and expertise by local companies.
7. The profile of impact is being raised by requiring the recording of examples in the annual staff

Professional Development Review.

The School of Engineering's specific plans to promote impact have the following features:

8. The development of new research strengths is in areas which have high potential for impact, namely: (a) the Liverpool Institute for Risk and Uncertainty, formed in 2012, is pursuing the potential for impact across all its areas of activity. One example of this is the optimisation of structural design with Jaguar Land Rover, into which methods to account for uncertainty are being incorporated to increase the robustness of the outcome (contact: tzzeguer@jaguarlandrover.com); (b) in Advanced Manufacturing, processes for additive manufacturing and inkjet printing are being developed, patented and commercialised with established companies or through the formation of spin-outs (**Sutcliffe** has produced an impact case study and seven patents in the current assessment period to illustrate the potential); (c) in Biomedical Engineering the potential for impact through the eight Liverpool hospitals has been a primary consideration for academic appointments. For example, Prof **Elsheikh** (appointed 2010) is working with Ultravision (contact: John.Clamp@ultravision.co.uk) and an ophthalmic consultant at the Liverpool Royal Hospital (contact: sharding@liv.ac.uk) to develop a device for continuous internal eye pressure monitoring to address a long standing problem in glaucoma management.
9. The knowledge transfer centres described above, NiCAL, VEC and LLEC all have business plans to maintain or expand their activities with companies in the future. These have become very significant activities for driving business-academia cooperation.
10. The achievement of a broadly based, trusting relationship with a company provides the ideal conditions for impact to be realised. The School has several of these relationships now as described in this document (AgustaWestland) and the case studies (e.g. Stryker, SAFC Hitech and Versarien). Support mechanisms for developing business-level partnerships is highly prioritised, including: alignment of business development support; investment in new academic staff where opportunities arise; and the allocation of support through local investments, such as knowledge exchange vouchers to stimulate projects to realise impact out of research. All of these methods are being exploited to build the relationship with the National Nuclear Laboratories, for example.
11. Mentorship and incentivisation of staff, to promote the realisation of impact. This is being achieved through the exploitation of industrial secondment schemes and through structured events on particular impact topics for early career researchers.

d. Relationship to case studies

The impact strategy has supported four case studies: Orthopaedic implants; Porous metals; Thin films; and Flood prediction. The University's Knowledge Exchange Voucher funding scheme has been exploited to support three of the impact cases submitted. Sutcliffe took a two-year secondment with Renishaw to develop the SLM technology exploited in the Orthopaedic Implants case. All cases have benefited from support for PhD studentships. Various lessons have been learned from the case studies, which now underpin the impact strategy. The management of business-level engagements has evolved from the long-term partnerships typified by the Orthopaedics and Thin films impact cases. The exploitation of secondments or employment of people is now a strong factor in promoting knowledge transfer and building trust. Patents play a central role in three of the studies, and awareness and support needs to be increased for this activity, as described in item 3 above.