Institution: University of Sheffield

Unit of Assessment: 13B - Electrical and Electronic Engineering, Metallurgy and Materials: **Electronic and Electrical Engineering**

a. Context

Our research spans Communications, Electrical Machines and Drives, and Semiconductor Materials and Devices with long established partnerships with industry. The regard in which the outcomes from our research are valued by industry is evident by direct industrial income of £7.3M since 2008. Impact is accrued from our research in many forms, including economic, environmental and health. **Economic impact** is delivered into many market sectors by collaborating with UK companies with global presence and from the commercialisation of research outcomes. For example, in automotive through communications (Harada, Jaguar/Landrover) and innovative drivetrains (Nissan), in aerospace through power, control and wireless sensors (Rolls-Royce), defence applications (DSTL, Selex, Lockheed Martin) and Telecommunications (Oclaro, NEC, Vodafone, IQE). **Environmental impact** with efficient machines and drives (Nissan, Toyota), wind power (Siemens, Romax) and Smart Meters (DECC, Ember Ltd. and Building Research Establishment). **Health** ranges from working with clinicians on a neo-natal ECG Monitor to working with leading semiconductor device manufacturers developing new light sources to aid ultra-high resolution optical coherence tomographic imaging (Michelson Diagnostics Ltd, UK).

b. Approach to impact

Our research encompasses a broad spectrum of activities from fundamental science, through application-specific applied research to industrial technology demonstrators. Our research group structure promotes an agile approach to impact which reflects the different scale of partner companies and organisations in different sectors, from global multinationals such as Siemens, Vodafone, Rolls-Royce and Nissan to local SMEs such as Inductelec and Gripple. Much of our research is aligned to the long term technical challenges of industry, EPSRC and TSB. Long-term partnerships with external industrial partners form a central plank of our strategy for delivering and sustaining impact. We actively promote and encourage staff to ensure that deriving down-stream benefits from their research is a central feature of their contributions in research. By way of example, for staff promotion, knowledge transfer to industry and commerce, when performed at the highest levels, are accorded equal recognition to excellence in more established measures of academic research and scholarship.

Flagship partnerships: Our approach to impact is focussed on bringing our acknowledged expertise to market via long-term research programmes funded in partnership with industry. A particularly successful mechanism is through our dedicated industry funded research centres, including two opened during the REF census period. These have different operational and funding models, but they have in common a financial and technical commitment from a single company to develop a stable and sustainable relationship which allows long-term planning, ensures continuity of research progress and consolidates expertise. The Department's portfolio, which we are continually looking to expand, comprises the following centres:

- **Rolls-Royce University Technology Centre in Advanced Electrical Machines and Drives** was established in 2003 (Director: Jewell). It currently has four core PDRAs and 11 research students. Its activities encompass novel electrical machines, power converters and power semiconductor devices in support of all Rolls-Royce business sectors, with a particular focus on electrical components for future aerospace gas-turbines. It is delivering key technology and modelling / simulation capability into Rolls-Royce as it readies its future generations of engines, which will increasingly feature electrical sub-systems for increased power generation and enhanced active control. (Contact: ellis.chong@rolls-royce.com)
- **Sheffield Siemens Wind Power Research Centre** The world's largest offshore wind turbine supplier, Siemens Wind Power, selected Sheffield in 2009 as its preferred partner to establish its centre of excellence in generator design following a world-wide search. Inaugurated in 2009 (Academic Director: Zhu) it is located in a dedicated facility on campus, and comprises 20 researchers – 50% Siemens employees and 50% Sheffield PDRAs and PhD students. Despite being set-up only 3 years ago it has already contributed several innovative design features which have already made their way into the newest generation of Siemens 3MW and 6MW direct-drive off-shore products, which are widely recognised as offering industry leading

performance in this rapidly expanding market. (Contact: arwyn.thomas@siemens.com)

- **Romax Technology Centre.** Romax is the world's leading provider of simulation technologies, design expertise and consulting services for gearbox and driveline systems. Following on from collaborative projects, and recognising the increasing role that advanced electrical machines play in drivetrains for both automotive and power generation, Romax established a Technology Centre in Sheffield in 2013, which currently comprises 3 research engineers. Several projects funded by the Regional Growth Fund and TSB have led to improved bearing reliability. (Contact: barry.james@romaxtech.com)

In addition to established research centres, we foster long-term partnerships with global-scale companies, e.g. along with the UK Nissan Technical Centre (NTC) we participated in the first Nissan R&D project outside Japan in electric vehicle technologies. This led to significant knowledge transfer from Japan into their UK Technical Centre, and provided a basis for immediate expansion of NTC and established a long term partnership with 2 Nissan employed engineers resident in the Department at Sheffield, including secondments from the Nissan Research Centre in Japan. In the area of Defence, we have been long-standing key academic partners, contributing to an area of critical national defence capability (Ford and Tennant)

Contract research projects: We often respond to the needs of industry through direct research contracts. Examples include the supply short wavelength quantum cascade lasers with world-leading performance to Cascade Technologies to enable them to develop a unique and market leading test system for the aerosol industry and the development of quantum dot based SESAMs for M^2 Lasers Ltd. to extend the repetition rate of their products for various biomedical applications.

EPSRC Knowledge Transfer Account: We have made use of the University's £5.7m KTA award (2009-2012) to translate outcomes from EPSRC funded research into broader benefit:

- Zigbee Wireless Quality Trials with Ember Corporation and BRE which resulted in propagation data for DECC to inform the industry of roll out problems for Smart Metering.
- System Level Simulator for advanced mobile radio access networks, with NEC, Vodafone and Fujitsu, who have since adopted it for network planning impacting on traffic capacity. (Contact Simon.Fletcher@EU.NEC.COM).
- Zoo Digital – solved the problem of tracking different versions of the same content and their metadata using watermarking/data hiding technologies. (Stuart.Green@zoodigital.com).

Knowledge Transfer Partnerships - The University has an excellent and long-standing track record of securing and delivering valuable outcomes from KTPs, often hosting the highest number of KTPs in the UK. Over the REF census period, 8 KTPs have been active in the Department. Selected examples which illustrate the breadth and arising impact include:

- **Gripple** - developed minimalist architectural lighting systems and a wireless power transfer system. 3 patents and innovative cabling solution entering production. (Contact: G.Macrae@gripple.com)
- **Williams Grand Prix Engineering-** delivered time-domain simulation models for their patented flywheel system enabling them and their customers to evaluate the benefits of flywheel systems and their power requirements. (Contact: matthew.burke@williams1.com)

Industrial sponsorship of PhDs – This continues to be an important element mechanism, for recruiting high-calibre students, framing research questions in a broader context, providing a ready means of generating impact and for providing skilled personnel to industry. Examples of industry funded studentships include Harada Industries (hidden automotive antennas), Antenova (reconfigurable antennas - generating significant business with Glintt payment machines and smart meters), British Gas/Ranplan (Energy efficiency in buildings), TDK-Lambda (thermal management of power supplies).

Secondments – Secondments into industry of academic staff has proved to be a highly effective mechanism for accelerating the delivery of impact and consolidating partnership. In 2010-11, Tan was seconded to Land Instruments International to evaluate the potential for novel photo-detector technologies developed at Sheffield to be deployed in a range of high performance radiation thermometers. The outcome was a 1% increase in their 22% share of the world-wide radiation thermometer market and gave them the 'unique selling point' to compete in the $4bn thermal imaging market. As a follow-on, LAND has invested in a CASE studentship and a KTP project to incorporate a new infrared detector designed at Sheffield into their flagship thermometer. Jewell

and Madathil have both held Royal Society Industry Fellowships at Rolls-Royce.

Research Networks - We play prominent roles in several industry-academic networks which focus on bringing the very latest and best technology to real-world problems. By way of example, the Wireless Friendly Building Forum (WFBF) was founded by Sheffield in 2009 to bring together partners such as BRE, ARUP, Buro-Happold, Zigbee Alliance, and the Chartered Institution of Building Services Engineers. This is delivering improved signal propagation in the built environment and educating the building industry and users (health, emergency services).

Consultancy – University policies and contracting procedures encourage and support consultancies, in many cases to develop a relationship with a commercial partner and to generate impact from highly specialised experimental facilities. Examples include: material characterisation in our unique Ground Based Synthetic Aperture Radar facility - BAE SYSTEMS, Lockheed Martin and Nanoparticulate Surface Adhesion Ltd.; novel Frequency Selective Surfaces for BAE SYSTEMS, Emerson and Cuming Microwave Products and QinetiQ.

Commercialisation of research outcomes – Our staff and research students have been inventors on 47 patent applications during the REF census period, via patents pursued by industrial sponsors and resulting from University owned intellectual property. The Faculty has a dedicated Commercialisation Manager who nurtures opportunities arising from our research, guiding them towards the most appropriate commercialisation route of patenting, licensing or spin-out. We have a long track record of successful spin-outs, e.g. Magstim 1988 with 65 employees, Magnetic Systems Technology Ltd 1992 with 33 employees. A more recent success is Antenova which has 6% of the global mobile antenna market (2 Billion units) and leads the global antenna design market with a 15% share, employing 40 staff. We are actively involved in the supporting the growth of three spin-out companies via staff secondments and research contracts (Phase Focus, Magnomatics and Seren Photonics). These 3 employ a total of 60 engineers in the region. We also support the licensing and assignment of University intellectual property in cases where external companies are best placed to lead exploitation, e.g. U2T Photonics purchased a suite of patents on modulation schemes for quantum dot lasers for their ultra-high speed optical components.

c. Strategy and plans

We will continue to place the delivery of tangible and long-lasting impact at the **core of our research strategy**, building on our strengths in partnering with leading companies in their respective sectors and our proven track-record in fostering well-founded and sustainable spin-out companies. Although the delivery of impact, principally economic, is firmly embedded in our research, we will remain vigilant in drawing on best practice for exploiting opportunities and taking advantage of the Faculty Innovation Hub. We will continue to recognise and reward staff for excellence in knowledge transfer and ensure that opportunities for industrial secondments, both into and out of the Department, are created through careful planning and timing of academic duties. We will build on or success in establishing industry funded research centres, adapting as required the funding models to match the scale and nature of different sectors, harnessing the University's commitment to make such endeavours durable by ensuring a true partnership from the outset. Our future approach to impact aligns with the Faculty's strategic vision of ensuring that its research has an impact beyond the traditional academic disciplines. We will prioritise the growth of our nascent collaborations in the field of healthcare, including investment in new staff and facilities to support translational research, in particular drawing-through our expertise in semiconductor based light sources and customised sensors for diagnostics. We will continue to make use of our well-established partnerships in Energy (wind power, hybrid and all-electric vehicles and aerospace propulsion) to drive innovation and exploitation of our research.

d. Relationship to case studies

Our case studies are the direct result of exploiting impact from our research in the commercial sector. **Antenova Ltd**. arose directly from exploiting our dielectric/tunable antennas research expertise commercially for small mobile devices. **Magnomatics** commercialised research on high performance electric drives, in particular those employing magnetic gearing technologies. **Phase Focus** is exploiting a new form of lens-less imaging microscopy invented and developed in EEE that has revolutionised optical, X-ray and electron imaging. **Inductelec Ltd.,** Research by a PhD student in the EMD group funded by an SME in Sheffield enabled them to launch a new range of radio frequency (RF) induction heaters, making them globally leading products.