Institution: University of Sheffield

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

a. Overview

Research in the unit encompasses the full spectrum of activities in the Department of Electronic and Electrical Engineering. Research is organised into 3 broad-based groups:

- **Semiconductor Materials and Devices (SMD)** (Head: Hogg – 12.8 returned academic staff, 24 research associates and 50 PhD students) - Research in semiconductor materials and devices for light sources (quantum dot, quantum cascade, AlGaN/GaN) optical detectors (X-ray, bulk and nanostructure based IR detectors, avalanche photodiodes), electronic devices (GaN power transistors, carbon nanotubes, graphene) and microscopy (TEM, lens-less microscopy).
- **Communications (COMMS)** (Head: Langley with 11 returned academic staff, 6 research associates and 68 PhD students) - Research encompasses the wireless spectrum covering physical layer (antennas, some RF, baseband processing/coding/modulation/MIMO), radio resource management layers (packet scheduling, handover, load control, inter-cell interference coordination, access control), network planning layers (base station placement, coverage, propagation environments (indoor & outdoor) and application layers (video coding and compression, video transmission, video quality metrics).
- **Electrical Machines and Drives (EMD)** (Head: Zhu – 11 returned academic staff, 16 research associates and 57 PhD students) – Research encompasses electrical machines, electromagnetic actuators, electro-mechanical devices, power electronic devices and converters, energy storage technologies and control systems for power conversion.

In order to maximise collaboration within and across this group structure, we have limited the designation of self-standing Research Centres to single company funded long-term collaborations where sponsors expect a level of separation (Rolls-Royce University Technology Centre in Advanced Electrical Machines and Drives, The Sheffield-Siemens Wind Power Centre, Romax Technology Centre) and the EPSRC funded National Centre for III-V Technologies (NC35T).

b. Research strategy

Our vision

The core principles that drive our research strategy remain:

- To have the expertise, infrastructure and collaborations to carry out internationally leading research across the full spectrum from fundamental science to application-specific industrial research.
- To generate tangible and lasting research impact by being a preferred research partner to industry, government and academia world-wide.
- To be acknowledged as a centre of excellence in developing future academic researchers and engineers for industry.

Strategic plans for 2014 onwards

- Continue and accelerate the diversification of semiconductor research activities beyond the well-established core III-V epitaxy and device fabrication expertise of the NC35T, with a particular focus on medical, manufacturing and sensors systems.
- Expand our globally leading expertise in wireless signal propagation and networks in the built environment to increasingly encompass the wider environment including road vehicles, sensors, traffic control and the external facades of buildings.
- Establish EMD amongst the foremost groups world-wide on the monitoring, interfacing and conditioning of battery storage systems for utility grid-connection and transportation (road vehicles, aerospace and marine).
- Enhance our position at the forefront of spectrally efficient Green Radio, which is widely recognised as a critical IT technology since 90% of the internet/Cloud energy consumption is accounted for by the wireless access network. The core of this research will be increasing the

capacity and reducing energy consumption for wireless access through enhancing performance of radio technology across the protocol stack.

- To harness our expertise in innovative imaging methods (e.g. lens-less imaging and holographic lithography) to increasingly engage with end-users and international research consortia in fields such as life-sciences research, medical imaging, large science facilities and multi-functional antennas.
- Grow the number of industry funded research centres in market sectors such as transportation and sensor systems.

Current position with reference to RAE2008:

Significant achievements have been made over the REF census period as evidenced by the following quantitative comparisons with RAE 2008:

- Total invoiced research income has grown significantly to £30.22M for the REF2014 period (as detailed in section REF 4b) from a corresponding total of £22.62M in RAE2008. These totals correspond to £5.41M and £3.43M per annum respectively.
- 189 individual research awards compared to 155 for RAE2008.
- The total value of new research awards during REF 2014 census period, accounting for only the proportion of any joint awards which will accrue as income in time to the Department, is £34.00M (£6.08M per annum) as compared to a corresponding total for RAE2008 of £35.99M (£5.46M per annum).
- 77% of new awards secured from sources other than the NC35T core grant (67% in RAE 2008).
- 111 PhD degrees awarded at 20.0 per annum compared to 91 at 16.3 for RAE 2008.
- The number of current PhD students and PDRAs has grown during the census period from 84 to 175 and 38 to 46 respectively.

Progress against RAE 2008 plans -The following were the central elements of the research plans set out in our 2008 RAE submission. Against each element, we review the progress made in the current census period:

- ***Increasingly engage with renewable energy technologies, by drawing through expertise on high performance machine and converter technologies*** – There has been a step change in the volume and reach of research activities in renewable energy, predominantly in wind energy. We have in particular harnessed our expertise in permanent magnet machines to secure funding of £3.31M since 2008 from the Energy Technologies Institute, Northern Wind Technology Innovation Programme, TSB, EC (INNWIND project), directly from industry and the Regional Growth Fund. A central plank of this success has been the establishment of the Sheffield-Siemens Wind Power Research Centre in 2009 and the Romax Technology Centre on electromechanical drive-trains in 2013.
- ***Research into power semiconductor device and packaging technologies will be expanded*** – Starting from a modest baseline in 2007, we have seen significant growth in power semiconductor device research across both EMD and SMD groups. Specific highlights include world-first reports on polarisation super-junction devices in GaN (Madathil in collaboration with AIST and Powdec in Japan and Rolls-Royce), two TSB collaborative projects on advanced Silicon IGBT technology (Madathil) and as partner in an EPSRC programme grant on 'Silicon Compatible GaN Power Electronics' (Houston).
- ***Broaden the funding base for the EPSRC National Centre for III-V Technologies through knowledge transfer activities*** – Despite challenging market conditions and the closure of several major UK industrial facilities, we made solid progress in growing non-core funding of the NC35T, securing £329k from non-EPSRC base and a further £396k from external business. Commercial exploitation of optical components was achieved via several companies, e.g. the supply of lasers to Cascade Technologies and photovoltaics to Circadian Solar. A spin-off company, Seren Photonics was established in 2009 to commercialise a novel process for significantly enhancing the brightness of GaN LEDs for lighting applications by over 80%. To date, Seren Photonics have secured £2.6M in investment and recruited 7 staff.
- ***Expand wireless communications expertise*** – We have expanded wireless activities from

our long-standing strength in electromagnetic hardware to encompass mobile systems and networks, in large part, through the appointment of chairs to provide leadership in resource management and physical layer techniques for cellular mobile (O'Farrell) and radio propagation / radio network planning and optimisation (Zhang). This has contributed to a significant increase in communications related research income and major new research programmes in Green Radio (as members of the Mobile VCE alongside companies such as Vodafone, Fujitsu, NEC, etc) and wireless systems for the built environment (with Building Research Establishment, Arup, Buro Happold). The increase in COMMS group scope and size is evidenced by the growth in the total number of PhD students since 2008, rising from 18 to 68.

Exemplar research achievements

- Our photo-detector research has established a world lead in InAs based infrared detectors, with infrared avalanche photodiodes becoming a major research theme with detectors being developed for photon counting, LIDAR (funded by ESA) and imaging systems (funded DSTL and MOD). Highly promising InAs, GaAs and AlGaAs X-ray detectors have also been developed (Ng, 3 projects funded by EPSRC and STFC).
- The development of novel semiconductor materials continues to be an important element of our research, e.g. GaAsBi with the highest % Bi (David), high quality InGaAsN (Ng, David), the first demonstration of an InAsBi infrared photodiode (Tan, David) and AlAsSb avalanche photodiodes Si-like excess noise but with superior temperature stability (Tan).
- In collaboration with Powdec and AIST from Japan, we demonstrated for the first time a GaN super hetero-junction field-effect transistor (HFET) based on polarisation junctions with a breakdown voltage in excess of 1.1kV without the use of the field plates (Madathil). This device is a key stepping stone for next-generation ultra-low-loss power devices which achieve performance beyond the GaN material limit. This demonstration built on previous research which realised two-dimensional gases of both electrons and holes.
- We have made major contributions to furthering the Green Radio agenda, in particular in efficient wireless systems across the urban and built environments (O'Farrell/Langley/Zhang). We have demonstrated a potential energy reduction of 90% in mobile radio access networks and developed intelligent reconfigurable RF infrastructure for in-building communication which are major stepping stones in developing intelligent, energy efficient wireless networks in our future smart cities.
- A unique platform for bottom-up self-assembly for graphene based microelectronics has been developed (De Souza).
- We have pioneered the development of new classes of permanent-magnet and hybrid excited flux-switching machines in collaboration with partners in the automotive, aerospace and wind energy sectors. Novel contributions include the development of new topologies which significantly reduce cost, increase torque density, enhance fault tolerance, as well as fundamental analysis and investigation of electromagnetic and control performance. This has resulted in numerous publications (including 27 in various IEEE Transactions) and 9 patents with Sheffield staff and PhD students as inventors (5 by IMRA Europe - a division of Toyota, 3 by Rolls-Royce and 1 by Siemens).
- Several breakthrough achievements in ptychographic have enabled lens-less microscopy to be applied in biological, materials science and atomic imaging (Rodenburg).
- Our reconfigurable antenna systems and materials research has established us at the forefront of Cognitive Radio technology worldwide, producing a single mobile telephone antenna operating from 76MHz to 2300 MHz funded by Antenova (Langley) and demonstrating electromagnetic band gap antennas tuning from 700MHz up to 18 GHz (EDA/Selex funded Langley/Ford). This research will play a key role in next generation wireless systems.
- In photonics, we demonstrated the shortest GaN based VCSEL (T-Wang) and the world first regrown photonic crystal surface emitting laser (Hogg, Groom).

c. People:

i. Staffing strategy and staff development

Recruitment - Our recruitment strategy is to ensure continuity and sustainability in recognised areas of strength while supporting initiatives to expand the scope of research performed within EEE. Recruitment of more senior staff has been based on a combination of reinforcing areas of strength to provide succession (Heffernan as new NC35T Director) and expanding our research activities through bringing in leadership in new areas (O'Farrell, Zhang). This strategy, set alongside a particularly successful period during which the research achievements of six staff were recognised by promotions to personal chairs (Atallah, Hogg, Stone, Tozer, J-Wang, T-Wang) has provided the research leadership capacity and research income to enable us to focus on very pro-active recruitment of early career staff. To this end, 10 new staff have been appointed to their first academic posts since 2008 (Gladwin, Green, Griffo, Groom, Li, Maiden, Ng, Odavic, Chu, Shao).

Personal Development

Academic staff – We have well-established and effective probationary procedures to support early-career academics in the transition from largely postdoctoral research roles to independent and productive academics. This includes a specific Faculty support programmes on preparing EPSRC first grant submissions, workshops on raising awareness and improving knowledge of EU funding and modules on harnessing their research in the curriculum. All established staff engage in the annual Staff Review and Development Scheme, which encourages a planned approach towards the setting of annual research objectives and workloads. We encourage and support established members of staff to seek opportunities to develop their careers and enhance the reach of their research by spending extended periods of time at leading research organisations worldwide. Examples during the census period include:

- Pierre de Fermat Chaire d'excellence at LAAS-CNRS Toulouse (Hopkinson 2011-12)
- Visiting Fellowships at The National Institute of Advanced Industrial Science and Technology, Japan (Madathil and DeSouza 2008)

Academic staff have held externally funded, competitive and prestigious Research Fellowships and Research Chairs which have allowed them to devote time to growing collaborations with industry:

- Two Royal Society Industry Fellowships (Jewell at Rolls-Royce, Madathil at Rolls-Royce)
- Two Royal Academy of Engineering Research Chairs (Madathil with Rolls-Royce, Zhu with Siemens Wind Power)
- Royal Society University Research Fellow (Ng)

Research staff - The University of Sheffield's commitment to providing a high quality environment for research staff was recognised in 2012 with the European Commission's HR Excellence in Research Award. In order to obtain the award, institutions measure their performance against the principles stated in the UK Concordat for the Career Development of Researchers. EEE remains committed to putting the principles of the Concordat into concrete action for the benefit of its research staff. By way of example, we have put in place procedures to migrate established research staff on to open-ended contracts with Department underwriting to provide security and continuity for researchers and to retain key skills and expertise within the Department. The REF census period has seen dramatic expansion in the provision of professional development opportunities, particularly, but not exclusively, for early career staff and research students approaching graduation. By way of examples:

- The Faculty of Engineering has invested in a dedicated Researcher Development Manager with a particular focus on supporting staff on fixed-term research contracts through the delivery of bespoke training courses and programmes.
- The University has established the 'Think Ahead' framework which draws together expertise from Research and Innovation Services and the Careers Service to provide a coordinated and well-resourced mechanism for a range of opportunities, information and guidance to support professional development, with a particular emphasis on career planning for both academic and industrial tracks.
- The Engineering Researcher Society (ERS) was formed in 2011 to promote and support early career researchers. This Faculty-wide group provides a thriving community for social and research networking and myriad opportunities for professional development, including: residential workshops (e.g. Discover Your Potential, The Professional Researcher), bursaries

for development opportunities, externally provided training courses (e.g. PRINCE2 Practitioner level), in-house training courses on topics such Grant Writing, Media Training, regular seminars including speakers from VITAE, UKRSA and a bespoke Engineering researcher induction**.** Researchers from EEE played a prominent role in its foundation and subsequent success (Michon as inaugural chair) and in engaging across many fronts.

- Our research staff have benefited from University investment in its 'Mentoring for research staff' programme.
- Three outstanding PhD students have secured University / EPSRC Prize Fellowships on completion of their PhDs (Kennedy – Quantum Cascade Lasers; Bastiman – MBE growth; Edo – diffractive imaging). As well as providing an opportunity to develop their independent research, these fellowships include a structured programme of professional development, including measurable deliverables, which target key skills for an academic research career.

Promoting equality and diversity - We are internationally diverse Department, as evidenced for example, by our academic staff being drawn from 12 countries of origin. Our student cohorts are similarly diverse. In the census period, we created the roles of International Student Adviser (David) and Female Student Adviser (Ng) to support undergraduate and post graduate students.

The key diversity challenge for us, as it is for the engineering profession as a whole, is to attract, retain and develop female engineers. In partnership with other Faculty of Engineering Departments, specifically through the Women in Engineering Initiative, we are taking positive actions and making investments to increase the number of female academics, researchers and students. During the REF census period we increased female academic staff numbers from 1 to 4, bringing our percentage of female academic staff up to 11.5% of returned staff. Although recognising that this number is still low in absolute terms, it brings us more into line with our peers in medium to large sized EEE Departments and the HESA sector average of 12% in EEE.

As a Department we have been working towards achieving a Silver Athena Swan award. The process has involved identifying potential barriers to recruiting, retaining and developing female academic staff. An action plan has been formulated to address these challenges and has been endorsed by the Head of Department. By way of examples of developments in the REF census period:

- The department strongly encourages staff to take part in the University's Impact mentoring programme for female academics both as mentors (Jewell) and mentees (Ng).
- Ng is a founding member of a university-wide Parent-to-Parent mentoring programme which provides support in planning maternity, paternity and adoption leave and is also contributing to a Faculty career development programme for PhD students promoting the opportunities and support to ensure that family life can be compatible with a successful academic career.
- The department commissioned an online survey to better understand staff's appreciation of equality and diversity. The resulting data has been used in the action plan to improve our policies in areas of identified shortcomings, e.g. we commissioned a training course for all staff with recruitment responsibility on unconscious bias.

ii. Research students

Research student recruitment: We have increased the PhD research student population in EEE from 84 at the start of 2008 to 175 in 2013 through a combination of pro-active recruitment, securing greater opportunities to undertake research with industry, the promotion of research to undergraduate students via summer placements and a marked increase in investment in scholarships and fee-waivers. By way of illustration of our approach, since 2010, we have funded 24 summer placement research projects for undergraduates via the Derek Griess Fund (a bequest from a former graduate) and a further 8 from the University-wide Sheffield Undergraduate Research Experience scheme.

Research student training and support mechanisms: All PhD students are assigned a supervisory team comprising, as a minimum, two academic supervisors, supplemented where appropriate with an additional industrial supervisor. Our mainstream training and support is delivered via the University-wide Doctoral Development Programme which develops both specialist technical research skills and more generic professional skills. This training draws from a University-wide portfolio of some 77 modules and activities, including many bespoke professional skills

training modules for engineers in subjects such as Public Engagement and Innovation Management. All students receive compulsory training in Research Ethics and Integrity. An individual Training Need Analysis is performed at the outset to establish a training plan in consultation with the supervisory team. Active participation in international conferences is strongly encouraged, with an expectation that each student makes use of a ring-fenced allocation of Departmental funds for them to attend a key conference to present their research. In addition to drawing on the very extensive array of specialist research equipment across the University, we continue to commit investment in base-line equipment provision specifically to support PGR students.

d. Income, infrastructure and facilities

Information on the research funding portfolio: During the REF census period, EEE invoiced research income was £30.22M as detailed in REF4b with new awards up to July 31st 2013 totalling £34.00M. The new awards portfolio is well-balanced and robust in terms of drawing on a wide spectrum of sources. Of particular note is the significant increase in *direct* industrial funding, such that at £7.3M of new awards, it is now our second largest source of research funding after RCUK. We plan to continue the diversification of our research funding, in particular drawing on the opportunities for participation in EU Horizon 2020 by pro-actively engaging early career staff in growing contacts and collaborators in EU (e.g. by requiring and funding attendance at EU events as an element of probation, by supporting the hosting of scoping meetings). In support of our plans for further growth and diversification of our research funding, we have recently employed a dedicated Business Development Manager in the Department to work alongside a significant Faculty level investment of some £800k per annum in a new Faculty Research and Innovation Hub. This hub provides localised and tailored support, e.g. to raise awareness of developments in the broader research-funding landscape for Engineering and to develop external partnerships and funding proposals. The aim of the hub is to allow academic staff to focus on building the quality and sustainability of their research. This hub has 9 staff: 4 supporting research funding, 4 supporting industrial partnerships and 1 working with the University's Researcher Professional Development Team to support staff on research contracts.

Specialist infrastructure and facilities: We continue to develop, and invest in, experimental facilities for communications research, building in large part on our comprehensive portfolio of RF engineering facilities. These include a far-field test facility at Buxton, four anechoic chambers, a bespoke automotive antenna test facility based around a chamber which replicates on-road conditions including a turntable. This unique facility played a key role in the TSB funded SEFERE project with partners including Jaguar Land Rover, Volvo and MIRA. We recently upgraded our Ground Based Synthetic Aperture Radar (GBSAR) facility, with support from Lockheed-Martin, and are now able to perform bi-static radar measurements. This unique facility continues to be in demand from industry for holographic imaging of radar cross-section. We operate a Naval Research Lab standard reflectivity arch, one of very few in the UK, which allows rapid, repeatable non-destructive testing of microwave absorbent materials over a wide frequency range. In support of this range of facilities we have invested in specialised test equipment, including £150k on a Vector Signal Generator/Analyser and £80k on a Vector Network Analyser.

We operate an extensive, and growing, array of semiconductor research facilities, spanning epitaxy, device fabrication and characterisation with an estimated total replacement value in excess of £20M. We have 3 MBE reactors, including a small flexible reactor which can be used by PhD students, and 3 MOCVD reactors. Many of these facilities are widely deployed in support of wider UK academic research in III-V semiconductors via the NC35T (supporting 70 projects with a total value of £47.9M in this REF period) and in support of UK III-V industry which is characterised by many high technology SMEs for whom access to such high value facilities is key. Plans for a £1.2M clean room extension are in train to allow expansion of research in both epitaxy (including additional reactors) and device fabrication.

We have two high performance Transmission Electron Microscopes (TEMs) in support of both semiconductor research and fundamental investigations of electron imaging methods. The most recent acquisition is a £3.3M JEOL R005 scanning TEM installed in 2009/10. This double aberration correction TEM is one of only four prototypes world-wide with demonstrated resolution of 50pm, a resolution in TEM mode which is at the forefront of world-wide capability.

Extensive refurbishment of the EMD laboratories was undertaken in 2009 supported, in part, by the award of a Royal Society Wolfson Laboratory Refurbishment Grant. Siemens Wind Power have provided an extensive suite of test equipment and instrumentation in support of the establishment of its research centre, including a scaled direct-drive wind power generator for hardware-in-the-loop controller and condition monitoring research.

We have achieved a step-change in our infrastructure for energy storage research with the recent award of a grant £4.9M from the EPSRC Capital for Great Technologies to a consortium of 3 Universities led by Sheffield (Stone). The core element is a 2MW, 335 KWh battery storage which is connected to the UK grid at 11kV. This £3.3M facility is hosted at Western Power's Sub Station located at Willenhall and will be operated and managed by Sheffield through a combination of Sheffield research staff based at Willenhall and through a state-of-the-art remote monitoring and control system. It is a unique research facility in the UK (and amongst the very few worldwide at this rating) and indeed will be one of the largest operational storage elements currently on the UK grid. It will provide a valuable test-bed for performance assessment of high power energy storage components and control systems under realistic conditions. In addition to this core facility at Willenhall, this EPSRC award resulted in the installation of battery testing and monitoring equipment with a total value of £900k in Sheffield.

e. Collaboration or contribution to the discipline or research base

International visitors: Bringing international visiting Fellows and industrial researchers of the highest calibre to Sheffield for extended research visits remains an important means of fostering international collaboration, and is a Department priority in terms of supporting staff in growing the profile of their collaborations. We typically host some 20 visiting researchers at any given time, ranging from early career researchers to global leaders in their field. Specific examples of visiting researchers funded from competitive and prestigious schemes during the census period include:

- Royal Academy of Engineering Distinguished Fellowships to Thomas Lipo (Wisconsin-Madison; 2010; Wind power direct drive permanent magnet generation systems), Thomas Jahns (Wisconsin-Madison; 2013; Novel permanent magnet machines and power electronics for electric vehicles) and Osamu Wada (Kobe; 2011; All-optical signal processing).
- Royal Society Newton International Fellowship awarded to the Department to support Akira Nakajima from the National Institute of Advanced Industrial Science and Technology in Japan to research novel GaN power devices.
- Leverhulme Visiting Professorship to Osamu Wada (Kobe; 2011-2012; Advanced quantum structures for all optical signal processing, biomedical imaging and THz generation).

We have maintained our strong links with many industrial companies in Japan and have hosted secondments of R&D staff from Murata Manufacturing (2009 and 2012), Daikin Industries (2008) Nissan (2009-2011), Mitsubishi (2013).

Technology transfer and influence to research: Direct funding from industry is our second largest category of research funding after RCUK, drawing from an increasing pool of UK, European and Overseas companies. Staff secondments, both out of and in to the Department, and the recruitment of industry sponsored PhD students and research staff remains key planks in our approach to ensuring effective technology transfer. Examples of strong industrial collaboration and technology transfer include:

- Our research work on reconfigurable antenna systems and smart structures has expanded via collaborations with Antenova, Selex and Lockheed Martin. We have remained key academic preferred partners with DSTL, QinetiQ and BAE SYSTEMS in the field of radar technologies, contributing to an important area of critical national defence capability (Tennant, Ford – further details from NAREDIT@ mail.dstl.gov.uk).
- Research on semiconductor detectors has benefited from growing links with Land Instrument, both in terms of delivering impact and ensuring connectivity to future industrial sensor system requirements.
- Our success in delivering long-term value to industry from our research is evident by three

industry-funded research Centres with Rolls-Royce (Jewell, Madathil), Siemens Wind Power (Zhu) and Romax Technology (Atallah). These have flourished and now have total research staff and student complements of 15, 22 and 5 respectively. We also have long-standing links with Nissan, with engineers from both their UK and Japan R&D centres being seconded into EEE for extended periods.

Collaborative TSB research projects have also proved to be an important and effective mechanism for technology transfer. We have been partners in 23 TSB funding competition projects with a total awards to Sheffield of £4.04M (partners including Rolls-Royce, Nissan, Mitsubishi, QinetiQ, Selex, Lockheed-Martin, Aero Engine Controls, IXYS). We have been partners in 8 Knowledge Transfer Partnerships with Gripple Ltd., Williams Grand Prix England Ltd., Controlled Power Technology Ltd., Fords Packaging Systems Ltd., Land Instruments Ltd., CIT Digital Ltd., Ranplan Ltd. and Lablogic Systems Ltd.

On a wider European front, we have been a partner in 11 Industry-Academia collaborative R&D projects under Framework VII, engaging on projects in the automotive, aerospace, wireless communications, optoelectronic and microelectronic sectors, partnering with many of European leaders in their fields, e.g. Airbus, Philips, Fiat, and Continental.

Consultancies and professional services: The expertise within the department is sought by a broad spectrum of industry, as evidenced by 74 consultancies undertaken within the Department with a total value of ~ £361k since 2008.

Interdisciplinary research: We have participated in numerous academic consortia to tackle multi-disciplinary challenges. The following are a small selection drawn from many examples, which provide some sense of the profile and breadth of these activities:

- Our expertise in wireless network techniques is key to a NERC funded programme which is monitoring glacial flow in collaboration with glaciologists at Newcastle and GPS expertise at Swansea. This project has delivered advanced wireless network techniques into the scientific community, resulting in significant enhancements to measurement practices for monitoring glacier movement, with potential for read-across to other large scale networks for environmental sensing.
- In collaboration with clinicians in tissue engineering and oral surgery, our expertise in III-V lasers has resulted in new methods and hardware for the non-invasive three-dimensional imaging of the near surface of skin using optical coherence tomography (OCT). Our key contribution has been the development of entirely new semiconductor light sources tailored to monitor skin cancer and the growth of skin on tissue constructs / scaffolds. This research has delivered enhanced OCT resolution and the miniaturisation of the light sources, the latter being central to the practicality of a point of care cancer diagnostic tool.
- In collaboration with the Department of Psychology and Sheffield Children's Hospital we have developed a system (WithCare+) for the remote monitoring of type-1 Diabetes in children and young adults. A patent for the system has been granted (GB2467079) and a pilot clinical trial of the system with 24 families is currently underway, due to be completed in June 2014. The system is now being adapted for deployment in adult diabetes clinics, including the integration of richer patient data and greater scope for patient interaction with the system.
- We have developed a leading activity in body worn antennas made from textile materials with integrated electromagnetic band-gap layers to shield radiation from the body. Achievements include the first demonstration a dual band antenna system and unique findings on the effects of crumpling on individual and array antenna performance and switchable structures. Recent research is focussed on knitting antennas and meta-materials in collaboration with Nottingham Trent University under contracts with QinetiQ and DSTL.

Exemplars of leadership in the academic community: Staff in the Department are pro-actively engaged in numerous national and international academic endeavours such journal editorship, conference chairs and organising committees, national and international research grant refereeing, professional institution committees.

Members of the editorial boards / associate editors IEEE Trans. on Cybernetics (Shao), IEEE Trans. on Nanotechnology (DeSouza), IEEE Trans. on Transactions on Device and Materials Reliability (Madathil), IEEE Trans. on Industry Applications (Zhu to 2010), Neurocomputing (Shao),

IET Optoelectronics (Hogg), OSA Optics Express (Tan), ISRN Electronics (Hopkinson), International Journal of Automation and Computing (Zhu), Elsevier Computer Communications (Zhang), ISRN Signal Processing (Liu), IEEE Communications Society MMTC R-Letters (Chu).

Guest editors of journal special issues IEEE Trans. on Cybernetics (Shao 2013), Pattern Recognition Letters (Shao 2011), Neurocomputing, (Shao 2011), Semiconductor Science and Technology (Hopkinson 2013), Journal of Physics D (Hopkinson 2013), Annals of Telecommunications (O'Farrell 2012), Journal of Communications (O'Farrell 2012), ACM/Springer Journal of Mobile Networks & Applications (Chu, 2012), Advances in Condensed Matter Physics (T-Wang 2012), IET Circuits, Devices and Systems (Madathil 2013), Elsevier Journal Signal Processing (Abhayaratne, 2009).

Fellowship of Professional Institutions 2 IEEE Fellows (David, Zhu), 8 IET Fellows (David, DeSouza, Houston, Langley, Madathil, O'Farrell, J-Wang, Zhu), 4 IoP Fellows (DeSouza, Madathil, Rodenburg, Walther), 1 BCS Fellow (Shao).

Examples of leaderships in policy setting, across large research consortia and international bodies include:

- J-Wang is the only academic member of the UK Automotive Council Technology Work Group on Electric Machines and Power Electronics (alongside 13 representative from leading OEMs, Tier 1 and innovation based SMEs). This formulated the industry's strategy for promoting investment in R&D in electric machines and power electronics and developed the road map for UK supply chains for electric and hybrid-electric vehicles.
- O'Farrell has been prominent in the Mobile Virtual Centre of Excellence Green Radio project funded by EPSRC and industry, providing leadership on the steering board and steering group and playing a key role in translating the mission into collaborative programmes with an international presence. This was the first global project on energy efficient wireless communications, with participation from 15 global-scale companies including Alcatel Lucent, Nokia, Siemens Networks, NEC, Fujitsu, Thales, Toshiba, Vodafone and Orange. Academic collaborators were the Universities of Edinburgh, Bristol and Kings College London.
- Madathil was a member of the Strategy Group for the Department of Business Innovation and Skills strategy document 'Power Electronics: A Strategy for Success'. This document, published in October 2011, prepared the ground for strategic EPSRC and TSB investments in power electronics research in the UK.
- Langley founded the Wireless Friendly Building Forum (WFBF) in 2009 to bring together partners such as Building Research Establishment, ARUP, Buro-Happold, Zigbee Alliance, and the Chartered Institution of Building Services Engineers. This is delivering improved wireless signal propagation in the built environment and educating the building industry and users (health, emergency services) to derive maximum benefit from wireless systems.
- Hopkinson has been a long-standing strategic advisor to the EU FP7 ICT program and to national research bodies such as the Italian INR, French ANR, the ministries of Education of Greece, Spain, Flanders region and the Qatar Foundation on aspects of semiconductor and nanotechnology research. He served as the senior referee for the final EU-Eurostars programme panel which support SME research and development.
- Staff have provided leadership to several large research consortia, in setting the agenda for the research, drawing together large consortia and in providing intellectual leadership to deliver high quality outcomes. By way of examples: DeSouza leads and coordinates the £4.9M PARSIMO EU project which draws together 9 industrial and academic partners to address key challenges in system-in package design. Rodenburg led the EPSRC Basic Technology research programme on 'Ultimate Microsocopy -Limited Resolution Without High Quality Lenses', which drew together a consortium comprising STFC and 6 leading UK universities in microscopy and its applications, achieving many successes in furthering the underpinning technology and demonstrating its utility across many end-use disciplines. J-Wang led and coordinated the £2.5M EU funded P-MOB project drawing together a 7 partner consortium to research enabling technologies for efficient electric personal mobility, achieving a notable landmark in demonstrating 20km/day on solar energy for a micro-size vehicle.