Institution: University of Liverpool

Unit of Assessment: 13 – Electrical and Electronic Engineering, Metallurgy and Materials

a. Overview

The Department of Electrical Engineering and Electronics (EEE) is part of the School of Electrical Engineering, Electronics and Computer Science (EEECS) within the Faculty of Science and Engineering. Research in the Department is organised into four Groups:

- **Bio-MEMs, Organic and Silicon Electronics** (BOSE) – spanning bio-electronics, novel electronic materials, verification of integrated circuits and advanced mass spectrometer systems.
- **Intelligence Engineering and Industrial Automation** (IEIA) – intelligent systems for industrial applications, real-time processing for control systems, electrical energy and power systems, including sustainable energy.
- **Plasma and Complex Systems** (PCS) – fundamental and applied research in technological plasmas, electrical arcs, and condition monitoring for electrical power, healthcare/other complex systems (Centre for Intelligent Monitoring Systems, CIMS).
- **Signal Processing and Communications** (SPC) – signal and image processing, communications, high-frequency engineering, avionics, electro-magnetic compatibility and Terahertz imaging.

The Department funds an interdisciplinary centre, the Centre for Autonomous Systems Technology (CAST), which spans EEECS and School of Engineering, and contributes to the Faculty of Science & Engineering's Stephenson Institute for Renewable Energy.

b. Research strategy

Research Vision – The number of academic staff in the Department has grown by 30% in the REF period and this investment has driven the development of new research strengths. Our research strategy is based on two key features: the encouragement of interdisciplinary research across traditional group boundaries and Departmental structures; and enhancing doctoral training within EEE by increasing the quality and quantity of the PhD student cohort.

Departmental Research Themes – In the RAE 2008 submission, the research strategy focused principally on the four research groups listed in Section a. Since 2008, interdisciplinary work has been developed to promote a more agile approach to funding, add value to existing research, and help identify new areas for research. Three departmental Research Themes:

- **Information and Communications (IC);**
- **Energy Technology (ET);**
- **Sensors, Diagnostics and Biomedical devices (SDB);**

have been formalised to reflect existing synergies within the department (IC, ET) and the desire to build new capabilities in an area for future societal impact (SDB).

Each member of academic staff is in a research group and supports one or more of our research themes. The themes are supported through the allocation of departmental research funds and funded PhD studentships. The establishment of the research themes has led to a number of notable successes in terms of research outputs and grant awards, including:

- The use of aerospace tracking methods (from SPC) for the analysis of dusty plasma experiments (in PCS) which led to seven published papers inc. Ralph#3, #4, and a joint experimental-theoretical ESPRC Grant, EP/G007918 (SDB).
- The development of novel models (from SPC) for THz tunnelling devices (rectified-antennas or 'rectennas') (incorporating BOSE and SPC), leading to five papers, including Mitrovic#3 and underpinning an EPSRC Grant, EP/K018930 (IC, ET).

Further examples of successes are the recent award of an EPSRC project in Ambient Processing of Polymeric Web: Advanced Diagnostics and Applications (BOSE, PCS) EP/K016202 (SDB); and a €1.5M EU grant on the use of Mass spectrometry for aqueous mixtures: AquaMMS (BOSE, PCS) (SDB). Future plans include the further development of research in Smart Grids (ET, IC) and control for remote mechatronic systems and haptics (IC, SDB).

Inter-Departmental Research – The School of EEECS and the School of Engineering established the Centre for Autonomous Systems Technology (CAST) in 2010 to draw together strands of existing research, in an area which has been prioritised by the UK Government as one of the 'Eight Great Technologies'. Investment in CAST has included the appointment of three new Professors – Maskell (EEE), Parsons, Tuyls (CS) – and £300k to support work in robotics at the Virtual Engineering Centre (VEC) at the Daresbury Laboratories. Current research projects include: Human-Computer Interaction (EEE/Psychology); and Distributed Aerospace Simulation, which has funding under an MoD programme and uses sensor models and processing (EEE), full-motion flight simulation (Engineering), and autonomous route planning (VEC). Future work will be centred on new activities in robotics for domiciliary care and the certification of autonomous air vehicles.

Other collaborative intra- and inter-Faculty research includes: Materials Science (thin film devices: Hall, Mitrovic, novel surface processing: Bradley, Walsh), Energy/Stephenson Institute (ZnO electronics: Hall, Mitrovic), Medicine (retinal imaging techniques, bio-informatics: Al-Nuaimy, Goulermas, Shen; medical materials processing: Bradley, Walsh), biosciences (electrical properties of DNA and other bio-molecules: van Zalinge), risk (Maskell, Goulermas, Mu), and security and conflict (Maskell, Ralph). Research in Energy, Risk, and Security and Conflict contributes to the University's strategic Research Themes, which are motivated by the RCUK 'grand challenges' and the cross-Council priority areas. An indication of the success of this approach is that just over 20% of the submitted REF Outputs cross the traditional group boundaries. The aim is to increase this to 30% over the next REF period.

Enhancing Doctoral Training – The Department has enhanced its research base through an expansion in the number of PhD students by investing in a Doctoral Training Programme (DTP). The Department funds interdisciplinary PhD scholarships at Liverpool and collaborative PhD projects with international institutions. The collaborative projects make use of the University of Liverpool's strategic partnerships and dual PhD degree programmes with institutions in Japan, Taiwan, Singapore and China, e.g. EEE has established joint Research Laboratories and has jointly supervised PhD students with Xi'an Jiaotong University (XJTU – a Top 10 University in China). Since the RAE2008 submission the number of students registered for PhD programmes has increased by 65% to the current level of 96 students. Future aims are to maintain the average number of PhD students per staff member as the Department expands and to improve the quality of the student outcomes.

The interdisciplinary research builds on the underpinning research from each of the four groups. Some highlights of the outcomes of this research during the REF period include (by group):

Bio-MEMs, Organic and Silicon Electronics (BOSE) – Liverpool patented ion trap technology (Taylor#2,#4) is being exploited for portable mass spectrometry in the SNIFFLES F7 €3.2M project and the AquaMMS project €1.5M. Polymer based sensors were developed for the detection of cholesterol levels in human blood in the EU FP7 SIMS project (Raja). A novel gate stack was developed in the PULLNANO FP6 'Star' Integrated Project, which achieved the ITRS 22nm node technology target (Hall#4, Mitrovic#2).

Intelligence Engineering and Industrial Automation (IEIA) – The use of biological models for animal scavenging behaviour in power demand forecasting (Wu#1) was applied in National Grid grant 'Gas demand prediction' (£302.6k). UK Patent, No. 1001007.2 'Apparatus and method for measuring a phasor of an electrical power system signal', 2010. Wu's papers have produced 3722 citations since 2008 (Google Scholar). Installation of a photovoltaic array and three wind turbines on the roofs of the EEE buildings – to support the ET research theme and growing research into smart grids. Outputs (Wu#3,#4) led to the award of EPSRC grant EP/D080711 'Development of advanced morphological operators and soc morphological protection relays' with VaTech Reyrolle Distribution Ltd (£456.8k).

Plasma and Complex Systems (PCS) – First demonstration of the chemical routes in gas-phase polymerisation of a non-saturated monomer at atmospheric pressure for bio-film deposition (EP/G048444, £581.0k). First quantification of the negative ionic species densities present in reactive magnetron deposition of TiO_2 (Bradley#4, EP/E035183, £371.2k). Industrial engagement resulting in three KTP projects (Fuel Quality (Fairbanks Environment, KTP1601), Healthcare (MAST Ltd, KTP6389), Optical Fibre-based Temperature Sensor (Ashridge Engineering Ltd, KTP7117)) and a TSB funded project (MAST Ltd, TP60-132). Simulation software developed by

PCS (Yan#4) has produced a framework agreement for collaborative research for the electrical power industry with a Chinese company (Pinggao Group Ltd, see section e).

Signal Processing and Communications (SPC) – The development of trust and reputation mechanisms for autonomous underwater vehicles resulted in first joint UK(Dstl)/France(DGA) research scholarship programme with NATO's Undersea research Centre (CMRE, La Spezza) (2012). SPC has led the development of a green wireless communication system in an EPSRC project (EP/E026915/1) and its hardware validation in an EPSRC knowledge transfer project (EP/H500146/1, Zhu#1,#4). SPC developed real-time software for use in the QinetiQ Integrated Targeting System (2008) and a QinetiQ multi-seat RAF flight simulator (2010), which has led to further work MoD-funded research with the School of Engineering and the VEC.

c. People, including:

i. Staffing strategy and staff development

During the REF period, the number of academic staff has increased from 25 to 32, reflecting an overall strategy for growth, driven by a doubling of income from all sources during the REF period. The increased revenue has been used to support staff through refurbishment of the EEE laboratories and research facilities, as well as investment in CAST and the Doctoral Training Programme (DTP).

Since 2008, the Department has seen the retirement of several senior professorial staff (Fang, Jones, Lucas, Eccleston) and three have moved elsewhere to take senior posts as Heads of Department (Nandi (Brunel), Nicolau (McGill)) and a Chair (Zhong (Sheffield)). Together with the expansion of the Department, this has resulted in 16 of the 32 staff being appointed within the REF period. Of the new appointments, four have been at senior level to provide leadership in research and impact (Marshall, Maskell, Bowden, Counsell), and 12 have been at Lecturer level. The primary criteria for appointment have been track record or potential for high quality research and future impact. 12 of the 16 appointments have been external, including from Imperial College, Manchester, Bristol, Southampton, Surrey, Strathclyde, Loughborough, and Queen's Belfast. Consideration was given in all cases to the potential to contribute to the strategy to develop interdisciplinary research.

Maskell was appointed to a Chair from QinetiQ to lead the Department's activities in Autonomous Systems (CAST) and to lead Faculty activities in 'Big Data', another priority area for the UK Government. Marshall was appointed Professor from a Chair at Queen's Belfast to expand the research in communications to include the growing areas of network security and communication of data for haptic devices (SDB). Bowden was appointed to a Readership to strengthen the PCS research group and to provide critical mass in this area. The Department is looking towards future Impact with appointments to link to the Faculty Stephenson Institute for Renewable Energy, as part of the ET theme, and to establish a Building Research Centre (Counsell). In addition to these external appointments, there have been internal promotions. Since 2008 three staff have been promoted to personal chairs (Taylor, Huang, Ralph) and four to Readerships.

Of the lecturers who were appointed externally, three were appointed in the SPC group (Mu, Zhou, Lopez-Benitez), three in the SPC group (Su, Tu, Walsh), and one in the BOSE group (Khursheed). Mu was appointed after PDRA positions at Manchester & Bradford for her expertise in data/text mining and machine learning and to encourage research links with Computer Science. Zhou was previously at Bristol, working on radio frequency hardware (with Toshiba), and was appointed to add to the high-frequency/Terahertz engineering research (Huang, Shen). Lopez-Benitez came from Surrey to underpin the existing communications work (Marshall, Zhu) and to boost the IC research theme. Su was appointed in the PCS research group from Imperial College for his research work in optical sensors, and has already obtained funding (AquaMMS) with the mass spectrometry work in BOSE (SDB). Tu came from Manchester and was appointed to develop new work on plasma catalysis for fuel research (ET). Walsh was appointed from Loughborough to boost the PCS work on atmospheric plasmas. Khursheed was appointed from Southampton, where he worked closely with ARM plc on verification of large-scale integrated circuits. This area complements the existing links to ARM in the microprocessor/embedded systems research area (IEIA) and contributes to the SDB research theme.

On-going staffing plans are for growth in the Energy and Power Systems research area (IEIA, PCS), in the area of novel electronic devices (BOSE), to develop the ET research theme further and to increase the links with the Faculty Stephenson Institute in Renewable Energy. The growth in

this area will be underpinned by the planned refurbishment of the high current research facility and the strategic framework agreement with Pinggao Group Ltd (see section e). The investment in novel electronic devices is to build on previous investment in clean room facilities and the planned investment in a mass spectrometry/plasma system laboratory (see section d), which is aligned to the SBD research theme. There are also plans to appoint staff in the areas aligned to the growing research in robotics, haptics and autonomous systems, to build on the current links to Computer Science, the School of Engineering and the VEC.

Support for Early Career Staff – Newly appointed staff are mentored closely to assist them in becoming established academics. Each new member of staff is mentored by the Head of Department, with regular meetings every 4-6 weeks. Mentoring addresses progress towards the individual's confirmation in appointment, grant proposals, general research plans and their relationship to the Department research strategy. The meetings also help to identify requirements for equipment, laboratory space and other support, e.g. a new plasma laboratory to support Walsh and an optics laboratory to support Su (see section d). Specific technical mentoring is led by the research area leaders. In addition, the Head of School of EEECS holds 'away days' for non-professorial staff to discuss strategic issues and to canvas the opinion of junior academic staff. In addition, the School provides proposal writing workshops (aimed at EPSRC and other funding bodies) and plans to provide mock review panels for new staff.

Sabbatical Research Leave – The Department has had an active sabbatical system since 2008-09. Approximately one member of staff has taken research leave each year since 2008, with colleagues covering teaching and administrative duties during the sabbatical period (usually six months). Research leave is recommended by the Head of Department on the basis of a detailed research plan (with specific targets in terms of publications, research collaborations, grant proposals, and dates for delivery against these targets). Recent examples of sabbaticals and international visits include Taylor (Purdue) and Huang (UCLA), and currently Bradley (South Australia). The provision of sabbatical leave has been a contributory factor in two of the REF impact cases (Huang, Taylor).

Post-Doctoral Researchers – Post-Doctoral Research Assistants (PDRAs) are line-managed and supervised by an academic member of staff (normally the Principal Investigator on the grant or research contract). Researchers are encouraged to engage in professional development, e.g. the University offers specific courses in Teaching in Higher Education for PDRAs. Since 2008, four PDRAs and former PhD students from EEE have obtained permanent academic jobs at Liverpool: Raja, Mitrovic, Al-Ataby, and Mu. Five PDRAs from EEE have obtained permanent academic jobs at other Universities in the REF period, including: Clare is a Lecturer at Nottingham, Zhong is a Full Professor at Fuzhou, and Chatta is Head of Department at University of Engineering & Technology-Lahore.

Equality and Diversity – The University has held a Bronze Athena Swan award since 2010. EEE supports University policies on Equality & Diversity, and has active disability-dyslexia support staff. There are four full-time female academic staff, three of whom have been appointed in the REF period, and a high proportion of female post-doctoral research staff and students. The Department provides a range of support for staff, PDRAs and research students. All our staff can access a range of 'family friendly' options, including maternity, paternity and adoption leave, parental, compassionate, domestic and personal leave. The University has a flexible working policy to allow staff to vary or adjust their pattern of work based on their personal circumstances. The Department supports the Concordat to Support the Career Development of Researchers.

ii. Research students

The Department has three PhD students per FTE staff member: there are 96 PhD students currently registered in EEE. To support the recruitment of high-quality PhD students, £280k per annum is invested in EEE for the Doctoral Training Programme (DTP). This fully funds around 15 PhD scholarships. As the Department expands, the aim is to increase the number of PhD students to average four PhD students per member of staff.

Doctoral Training Programme – The School of EEECS is investing in a number of fully funded Home/EU and partially funded overseas studentships (typically, 10 studentships are provided for suitably qualified students). Scholarships are advertised internationally to attract high-quality applications, followed by an interview based selection process. Of 83 newly registered PhD

students since 2011, 50% have come from institutions other than Liverpool. Examples include UK students from UCL, Bristol, Southampton and Warwick, and international students from Vrije Brussels (Belgium), Lausanne (Switzerland), and Oldenburg (Germany).

The DTP provides training in research skills and subject-specific technical expertise to augment careers-related and general PhD training provided by the University. The School delivers a bespoke Research Skills module aligned to the requirements of professional engineers and computer scientists. This training is available for all PhD students in the School.

Dual PhD Degree Programmes (Internationalisation) – Building on the University Internationalisation Strategy, the Department has developed research collaborations with Universities in Taiwan (National Tsing Hua University), Singapore (A-Star) and China (XJTU, Huazhong University of Science and Technology), through the joint supervision of PhD students, who obtain a PhD award from Liverpool and the overseas host institution. The dual degree is based on a '2+2' model, which can be two years at Liverpool followed by two years overseas, or vice versa. Currently, there are 16 PhD students in EEE being supervised jointly for such degrees.

PhD Student Progression – PhD student progression is monitored regularly by a University wide electronic post-graduate record system, with a minimum of one meeting between student and supervisor recorded per month. Student attainment is monitored formally at the six month point (by report), after 12 months, and then at 24 months and 36 months. At the end of each academic year, the students are required to present their work to academic staff outside their immediate research area, and it is only upon satisfactory completion of the formal report, presentation and viva that they are recommended for progression. Of the REF Outputs submitted, 60% were from work or collaborations that included a PhD student from EEE.

d. Income, infrastructure and facilities

Research Support and Research Facilities – Investment in research facilities since 2008, excluding general maintenance and repair, is in excess of £6M through direct support of laboratories and equipment for specific research activities.

Major investments over the REF period have included a £3M investment in clean room facilities for electronics at the biological interface which was made to support the SDB theme. The BioNanoLab consist of 300 m^2 clean room facilities, containing micro- and nano-fabrication facilities, advanced microscopy, and surface analysis – including for biomolecules immobilised on surfaces. These facilities have enabled the development of cross-Faculty research, with a research group from Integrative Biology (Cossins) being one of the principal users of the facility (Cossins, Wilson, Nicolau, BB/I013245, £224.5k).

In 2012, EEE signed a collaborative research agreement with Pinggao Group Ltd (China) for research in electrical power and electrical distribution. As part of this project, Pinggao is investing £5M over five years and the Department has committed £1.5M to support these activities. These investments are in addition to the research projects already funded by Pinggao (£660k over the REF period). The plan includes refurbishment of the existing high current laboratories, and has already led to the creation of a new power systems/control lab (45 m^2) in EEE to support the ET theme (Yan (PCS), Jiang (IEIA)). These large engineering facilities have been supplemented by the refurbishment of four new plasma and laser/optical laboratories (£50k). One new medium-sized laboratory houses atmospheric plasma/plasma catalysis experiments (97 m^2, Bradley, Tu) and EEE is funding a new negative ion facility (£100k, Bowden).

In 2012, two new smaller laboratories were constructed and equipped for early career researchers working on plasma treatments for water (Walsh, EP/J005894, £92.2k) and optical/laser systems (20 m^2 laboratory, inc. three optical tables). An additional optical laboratory will be provided in 2014 to support another early career researcher (Su, PCS) in work with Taylor (BOSE) on a recently awarded EU grant (AquaMMS). In Autonomous Systems, EEECS is funding CAST activities with two new robotics laboratories, one on-site in EEE for work on robotic navigation and human-robotic interactions (£250k) and one at the VEC at Daresbury for work on robotics for domiciliary care (also supporting SDB) (£300k), and new professorial packages.

The new facilities add to the established laboratories. The Department has a fully equipped and staffed electronics workshop, a unique high current laboratory (Spencer), electronic fabrication facilities (including 220 m^2 of clean rooms, in addition to the BioNanoLab facilities, BOSE), and a range of state of the art experimental measurement faculties (including large anechoic and

reverberation chambers for electromagnetic field measurements: Huang, Shen, Zhou).

The development of new laboratory space has improved the general research environment, as well as providing flexible space for the promotion of interdisciplinary work and to support Early Career Researchers (ECRs). Plans for future investment centre on the refurbishment of the high current laboratory with Pinggao, and the development of the new J. Harry Leck Laboratory, named in memory of a former Professor in EEE who initiated the early work on mass spectrometry at Liverpool. The laboratory will be centred on the growing interaction between technological plasmas (PCS) and mass spectrometry (BOSE) under the SDB research theme, evidenced by the recent AquaMMS EU grant awarded to Taylor and Su, and the EPSRC project in Ambient Processing of Polymeric Web: Advanced Diagnostics and Applications (Taylor, Bradley).

The University continues to invest in its research facilities across the campus. As part of the £36M Engineering Restructuring Project, improved facilities have been provided to support increased research activity in bio-engineering, flight simulation, selective laser melting, explosive loading and a vibration loading facility that is better placed to serve the automotive industry – EEE has benefited from collaborative links to all of these facilities. For example, the MoD-funded AMS DE-RISC project (Ralph) utilised the flight simulation facilities in the School of Engineering. In recognition of the ever-increasing concern of decreasing fossil fuels to provide long term energy solutions, the University has established a £6M Stephenson Research Institute for Renewable Energy to focus on developing clean and sustainable energy technologies, closely linked to research in EEE via IEIA, PCS and ET and the future aim is to make use of the wind turbines and photovoltaic arrays in EEE to develop more collaborative research in this area.

The University has also invested significantly to improve its library provision. Liverpool is one of the few universities that subscribes to all of the national NESLi2 'big deal' site licences for journals. This gives particular advantage to researchers in Science, Medicine and Engineering. Liverpool has a large collection of electronic books, including IEEE Xplore, and is one of only two UK libraries to participate, with North American and Australian Research Libraries, in a consortium to provide rapid supply of inter-library loan journal articles. Computing services have been significantly improved over the last few years. In 2009, the University began a five-year investment totalling approximately £5M in its data network. In 2012 the University made a £1M investment in high performance computing (HPC).

In addition to investments in infrastructure, EEE has made funds available for research equipment. The School funds larger purchases (equipment in excess of £25k) and the Department has a Research Support Budget (RSB) for smaller pieces of equipment. Total investment from these sources in 2012/13 was £150k in EEE, and a similar sum has been allocated by the Departmental for the year 2013/14. The Department plans to increase these funds as Department grows in size and to reflect the needs of the academic staff.

The general research income of the department averages around £2.4M/year over the REF period, which compares to an average research income of approximately £1.7M/year for RAE2008. To add to this income, the Department carries out a significant amount of industrially-funded research, some of which is associated with the submitted impact cases. Other work, such as the collaborative agreement with Pinggao and contract research work with National Grid (Wu 'Gas demand forecasting', £302.6k since 2008), demonstrate our aim to address issues of future societal impact. To further industrial links in key areas, such as the University research priority in Security and Conflict, the Department has become an Associate Member of the MoD Weapon Science and Technology Centre (WSTC) and the MoD-funded Defence Human Capability Science & Technology Centre (DHCSTC), and is planning to become an Associate Member of the MoD Niteworks partnership. These industrial links provide opportunities for research which are not generally supported by research councils and provide new opportunities to engage with industry.

The Department also maintains a database of relevant successful EPSRC responsive mode proposals and details for thematic EPSRC calls. The Department uses existing links within the EU, from collaborative work and previous/current projects, to obtain funding from Horizon 2020 and the ERC. The shift towards interdisciplinary research will also place the Department in a strong position to exploit cross-council priority areas and the RCUK 'grand challenges'. To address these cross-council research challenges, EEE is already investing in Autonomous Systems and Energy Technology/Power Engineering, and has plans to build new activities around haptics (Marshall), 'Big Data' (Maskell) and mass spectrometry (Taylor/Bradley, Taylor/Su). The interdisciplinary

activities have already improved the research outcomes of the Department. The success of this strategy will be judged in terms of significant increases in the levels of research funding and the percentage of research outputs associated with interdisciplinary research work.

e. Collaboration and contribution to the discipline or research base

Collaborative Research – EEE has a wide range of national and international collaborative relationships, both within Electrical Engineering and Electronics and across traditional subject boundaries. International collaborations account for 30% of the submitted REF outputs: e.g. Taylor#2 with Purdue (USA), Ralph#2 with UMass-Boston (USA)-Melbourne (Australia), Bradley #1,#2,#3 with University of South Australia. National collaborations also account for 30% of the outputs submitted for REF: e.g. Hall#2, #3 (Southampton). In addition, 20% of the REF outputs come from collaborations outside traditional EEE disciplines: e.g. Wu#1 (with collaborators in Biology) and Biktasheva#3,#4 (with collaborators in Medicine).

The Department's collaborative links to international research groups include: in the US (Huang-UCLA, Biktasheva-Washington, Ralph-UMass-Boston, Taylor-Purdue), in Europe (Huang-Katholieke Universiteit Leuven) and in Australia (Bradley-South Australia, Ralph-Melbourne). Bradley had international funded collaborative projects with UniSA, Australia funded by Science Linkage (ISL), Premier Science Research Fund (PSRF) and Australian Research Council (ARC) Discovery grants in the study of microplasmas for applications in life science (Oct 2008-13).

Our ambition is to build on existing collaborations to increase the number of international collaborative outputs for the next REF period, reflecting the international profile of the Department and the PhD student population, and to increase the papers with disciplines outside EEE, reflecting the Department's interdisciplinary research strategy.

Collaborative links reflect the international profile of the Department and are aligned to the University's Internationalisation strategy, which aims to promote cross-border collaborative agreements at an institutional level. The University strategy provides for dual PhD degrees with partner institutions. EEE is engaging with this scheme and currently has 16 PhD students on dual degree programmes: including joint students with NTHU (Taiwan), A*STAR (Singapore), XJTU and HUST (China). Outside these University schemes, Taylor has a joint PhD student with Prof G. Cooks (Purdue), which arose directly from a sabbatical visit in 2009.

University and EEE strategic plans include building research links to developed countries (USA (University of South Carolina) and Japan (Riken)) and other developing economies, such as Brazil and Malaysia, e.g. EEE has links to Brazil via the Science without Borders scheme.

In addition to direct academic links, our research plan includes strategic partnerships with major industrial organisations, e.g. Toshiba (Japan) and Pinggao (China). Pinggao Group Ltd and China State Grid have funded research projects totalling £660k in Electrical Power and Discharges, utilising the unique high current facilities available in EEE. Pinggao Group Ltd is the only subsidiary of the State Grid Corporation of China. Pinggao designs and manufactures high voltage switchgear products up to 1100kV. It is one of the three largest switchgear manufacturers in China. In 2012, the University of Liverpool became the only non-Chinese university to have signed a strategic partnership agreement with Pinggao.

The forging of new industrial links is strongly encouraged. University funds are available to support these links in the form of Knowledge Exchange (KE) vouchers – allocated to individual researchers to work with companies, with preference being given to local companies to foster the development of new collaborative relationships, and to provide technology transfer of specific research activities with a view to creating impact for future REF submissions.

Contributions to the Discipline and Research Base – The staff in EEE are active in Professional Institutions, with 85% of the academics being full members of at least one learned society, principally IET and IEEE, but also IoP, RAeS, with 90% of the professors being a Fellow in at least one society. Wu was elected to be a Fellow of IEEE in 2010.

Visiting Professorships: Bradley is a Visiting Professor at the Mawson Institute (UNiSA) South Australia (from 2008) and was a Visiting Professor at the Open University (2006-2010); Goulermas is a Visiting Professor in Health, Sports and Rehabilitation Sciences, University of Salford since 2009; Huang was a Visiting Professor, Wuhan University (China) 2006-10, and at Chiba University (Japan) in 2010 and a Visiting Professor at UCLA, USA in 2010; Marshall is an

Adjunct Professor, Sunway University, Malaysia (since 2011), and was a Visiting Professor, University of Nice at Sophia Antipolis, France, 2011/12; Maskell was visiting industrial professor at the University of Bristol in 2012; Shen has been a visiting professor at Fuzhou University (China) since 2012; Taylor has been a Visiting Professor at the University of Amsterdam since 2012; Wu is a Visiting Professor, Huazhong University of Science and Technology (China), Visiting Professor, Electrical Power Research Institute, State Grid of China, Guangbiao Visiting Professor, Zhejiang University (China), and Distinguished Visiting Professor, South China University of Technology (China); Yan was a Visiting Professor at XJTU (2007-2011), and a Haitian Scholar of Dalian University of Technology (2007-2009).

Journal Editorships: Goulermas is an Associate Editor for the International Journal Of Modelling, Identification And Control (IJMIC); Hall is on the editorial board of Solid State Electronics and IEEE Electron Devices Letters; Huang is Editor-in-chief of Wireless Engineering and Technology; Marshall has been a member of Editorial Board of the Journal of Networks since 2006, and was a Guest Editor for a special issue of the International Journal of Sensor Networks and a special issue of Artificial Intelligence Review Journal; Taylor was guest editor of International Journal of Mass Spectrometry; Tu (ECR) was guest editor for a special issue of Journal of Energy Chemistry (2012-2013); Yan is a member of the editorial board of Int. J. Modelling & Simulation Appl. In Elec. Eng. (since 2012); Zhu is an Associate Editor for the IEEE Transactions on Wireless Communications.

Funding Panels: Hall has sat on six EPSRC panels and has chaired an EPSRC ICT platform grant panel. Hall also sits on the Steering Board of the EPSRC-funded network e-futures, providing input to the ESCO report, which outlined the crucial underpinning of Electronics Systems to UK, which is estimated at £120B (7.1% of GDP). Marshall was one of two reviewers for a FP7 STREP project (CHAT) (2011-2012) and attended four EU review panels. Ralph is a register member of the Defence Scientific Advisory Committee, and has sat on MoD Balance of Investment and Programme Review Panels for Research in the Weapons Domain (2008, £25M annual budget, 2-star/Maj-General level review).

Research Leadership: Four major EU projects have been led by Liverpool over the REF period. BISNES: Bio-Inspired Self-Assembled Nano-Enabled Surface (€4.6M, FP7/214538, Nicolau, van Zalinge). MONAD: MOlecular motors-based NAno-Devices (€3.7M, FP7/228971, Nicolau, van Zalinge). SNIFFLES: Artificial sniffer using linear ion trap technology (€3.2M, FP7/285045, Taylor, Sutcliffe). AquaMMS: 'Development of a portable miniature mass spectrometer to monitor important, but technically difficult parameters in aquaculture' (€1.5M, FP7/606496, Taylor, Su). In addition, Bradley is the Liverpool director of the EPSRC-funded Fusion Doctoral Training Network (2009-2014) with York, Manchester, Durham, Oxford and the Culham Centre for Fusion Energy.

Conference Organisation (examples only): Hall is a member of the steering committees for ESSDERC/ESSCIRC and INFOS International Conference Series; Huang is the UK national representative to EU COST IC1102, and was Chair of the 2010 IEEE International Workshop on Antenna Technology (iWAT10), Lisbon, Portugal, Track-Chair of the IEEE VTC 2011, San Francisco, USA, and Conference Chair of the Loughborough Antennas and Propagation Conference (LAPC 2012); Maskell was organiser for the ISIF Fusion 2010 conference in Edinburgh, a member of the Board of Directors of the International Society of Information Fusion (ISF), and is the chair for IET conference on Data Fusion and Target Tracking to take place in Liverpool in 2014; Mu (ECR) is on the program committee of the International Conference on Simulation and Modeling Methodologies, Technologies and Applications (SIMULTECH), 2011; Ralph is on the organising committee of the RAeS Classified Conferences in Weapon Systems (both from 2011); Taylor is Board member for the Harsh Environment Mass Spectrometry (HEMS) Workshop; Tu (ECR) is a member of International Advisory Committee for the ISPCEM (International Symposium on Plasmas for Catalyses and Energy Materials, from 2012), and a member of the Science Board of the Hydrogen and Fuel Cells SUPERGEN Hub (from 2013); Zhu is the programme co-chair of the ICSAI 2012 conference.