Institution: Loughborough University

Unit of Assessment: B13 Electrical and Electronic Engineering, Metallurgy and Materials

a. Overview

This submission to UoA 13 represents all the research activity in the School of Electronic, Electrical and Systems Engineering (SEESE), which was formed in 2011 from the Department of Electronic and Electrical Engineering. Continuous growth and investment since 2008 and regular reviews of the research strategy have both further advanced the vibrant atmosphere surrounding the School's activities and ensured their long-term sustainability. The benefits arising are manifest in the progressive rise in the staff FTEs returned at recent RAEs: 18.3 in 2001, 26.2 in 2008 and 38 in 2014.

Research in SEESE is structured in three broadly based groups: Communications, Energy and Systems, each comprising a number of focussed activities housed in well-resourced and special-purpose laboratories. All academic and research staff are members of (at least) one group, as are all research students and each group enjoys the considerable support provided by a total of 19 distinguished Visiting Professors.

Each group has considerable autonomy over its own affairs, although a Research Committee of senior academics ensures that a consistent and coherent overall policy is in place. Where appropriate, each group includes dedicated technical staff, with a number of specialist IT staff providing School-wide support.

The current academic staff complement of the Unit is 38, divided between the 3 groups as follows; Communications – 4 Professors, 1 Reader, 1 Senior Lecturer, 6 Lecturers: Energy – 6 Professors, 4 Senior Lecturers, 3 Lecturers: Systems 6 Professors, 1 Reader, 3 Senior Lecturers, 3 Lecturers.

The main activities of the 3 groups can be outlined as :

Communications

This group has specific expertise in the areas of advanced signal processing, antennas, metamaterials and communication networks. The combinations of these areas address major research issues in communications, including advanced signal processing algorithms, security, and wearable antenna systems.

Energy

Energy is one of EPSRC's strategic priorities and the group addresses this through the Centre for Renewable Systems Technology (CREST). The group also conducts internationally leading research in Pulsed Power Engineering for a wide range of applications.

Systems

An important characteristic of this group is the focus on Systems Engineering in which architecture, model based systems engineering and systems of systems are all paramount. The group is also internationally renowned for its systems technologies research including the application of control system science to railways; healthcare technologies and electronic system design.

b. Research strategy

Overview

The University uses its Research Committee to refine the research elements of its strategic plan and focus its strategic funding. The groups in the Unit all fit within University priority areas defined by: Future Technology and Secure and Resilient Society [Communications and Systems groups]; Energy and Sustainability [Energy and Systems groups]; Health and Well Being [Systems group].

The vision and progress since RAE 2008 is outlined by group below:

Communications

Progress since the previous Assessment Exercise.

The Unit's focus has centred on extracting maximum benefit from our £537k EPSRC funded Platform Grant; from the new appointments in Signal Processing (**Chambers and Lambotharan**) and in novel antenna structures. The Platform Grant (led by **Parish**) has paved the way for the

expansion of our flexible antennas research which now continues via £880k of research funding (led by **Vardaxoglou**). It has also led to successful activities in security of wireless networks as evidenced by the award of further EPSRC funding in this area (£175k (**Parish**) and network security contributions to the Networked Battlespace award, see later).

We have made new staff appointments (**Gong, Lepper, Naqvi, Whittow**) and have a much improved external presence via our recent leadership of one of the two consortia as part of the University Defence Research Collaboration (UDRC) in Signal Processing for the Networked Battlespace (**Chambers**) to aid in implementing the UK's Defence Strategy for the 21st Century. This multi-partner activity directly aligns with EPSRC's strategic target to grow the UK's capability in Digital Signal Processing and to the University's research strategy related to "Secure and Resilient Societies" and "Future Technologies".

We are also the centre of the UK conference activities in the Antennas and Propagation field with the Loughborough Antennas and Propagation Conference (LAPC) being an annual feature, and in 2013 holding a "Colloquium on Antennas, Wireless and Electromagnetics" in collaboration with the Institution of Engineering and Technology (IET).

Over £3M has been invested into laboratory facilities by the University and others, including a tapered anechoic chamber for research which is one of the largest in the UK.

Vision and Research Strategy

We will continue to support the Digital Economy via our activities in mobile and wireless communications, advanced signal processing for multiple-input/multiple output (MIMO) and Blind Source Separation and communication network security. Our work directly addresses EPSRC's strategic target to "Grow" the UK's capability in Digital Signal Processing and the development of an intelligent information infrastructure. We have investment in place for strategic developments in the following areas:

1. We will drive signal processing techniques for the Networked Battlespace via the £4.5M EPSRC/Dstl programme led by **Chambers** (with **Gong, Lambotharan** and **Parish**). This work will develop and apply novel algorithms and approaches to a range of problems in this area, but with wider applicability. Issues such as dealing with missing or large volumes of data; identifying anomalies in different datasets and in communication networks will be addressed. This work aligns directly with the University's strategic plans for research growth in the areas of "Secure and Resilient Societies" and "Future Technologies".

2. We will advance antennas for wearable communication systems via our activities in metamaterials for antennas. This work is led by **Vardaxoglou** (with **Whittow**) and has support of value £800k, including £400k from EPSRC.

3. Building on the success of our (impact case study) Porpoise Deterrent Pinger we anticipate significant growth in the underwater acoustics area. The focus of this research is repositioning to focus on noise in the marine environment due to off shore power generation activities. We have received research funding of over £685K since 2008 (**Lepper**) from sources including industry (national and international), government and research councils and currently have significant roles (£456K) in three NERC funded projects worth around £1.6M in total in the area of noise impact from marine renewables.

4. We will capitalise upon the opportunities offered by the establishment of a London based campus (Loughborough University in London, LUiL) by building a research activity in Digital Technologies under the direction of a newly-awarded Chair in this area (Prof Ahmet Kondoz from January 2014). He will lead a Group in closely-linked research with local industry (mainly companies aligned to media and communications). This novel approach to conducting research will address directly the challenges facing these companies.

Energy

Progress since the previous Assessment Exercise.

Our activities in Renewable Energy have expanded significantly as evidenced by our research income which has grown from less than £1M at the beginning of the REF assessment period, to over £4M in 2012. A measure of success is that CREST either participated in, or indeed led (Solar), 3 Supergen consortia (Wind, Distributed Generation, Solar). Supergen is RCUK's key

initiative in Sustainable Power Generation and Supply, with about 12 programmes in total. The establishment of the Energy Technologies Institute (ETI) on campus is further recognition of Loughborough's internationally leading work in energy. New appointments (**Betts, Blanchard, Bowers, Eames, Rowley, Walls**) and major funding in the £4.1M PV SolarHub (**Walls**) and £4.3M Anglo-India PV initiative (**Gottschalg**) demonstrate our continued success in this area. Very recent awards totalling £3.6M have been announced to support research into energy storage (**Eames**) which will enable this activity to contribute in an area of expected increased significance, maintaining the impact of our work throughout the next assessment period.

Vision and Research Strategy

Energy is one of six strategic research areas for the University, ensuring that relevant expertise across the institution is integrated with wider and fundamental connections made such that our activities are enhanced further from their already strong base in the next assessment period. The strategy put forward is ambitious and will ensure that the Energy Group will remain one of the leading groups internationally as well as nationally.

1. Increase our strength in Power Systems Engineering by the recruitment of new staff. The School is now part of the prestigious IET Power Academy and this area has just been strengthened by the appointment of a new Lecturer, who will link to CREST's research enabling the group to work on grid related research.

2. Develop research in storage further by establishing a dedicated storage laboratory. The increasing use of intermittent energy sources and generation that has reduced responsivity will require increasing amounts of short and medium term storage. Increasing our capabilities in this area will ensure that CREST maintains its nationally leading role. This will be supported by research into demand and demand side management to allow a holistic picture.

3. Advance thin film production technology (for PV) through more effective use of our pilot lines, which were installed over the current assessment period and are now becoming fully functional.

4. Enhance our international standing by interacting with the relevant European bodies. Energy research in European Framework programmes will increasingly be governed by the EERA programmes. Our strategy is to enhance our participation in these and help the UK community to participate equally in this. **Gottschalg** is leading the PV EERA from the UK at the moment, **Watson, Walls, Claudio** and **Bowers** partake in their relevant EERAs (Wind and PV). More academics will get involved in this over the next assessment programme.

Systems

Progress since the previous Assessment Exercise.

Our activities in Systems Engineering have expanded via the appointment of additional staff (**Henshaw, Hubbard, Summers, Ward**) and the promotion of **Siemieniuch** to a Personal Chair. Our continued success in the Systems Engineering area is demonstrated via the award of a £2.1M collaborative activity in Model Based Systems Engineering (**Dickerson**) funded by EPSRC and Jaguar Landrover, and our leadership of the £400k **Network in Systems Engineering** (**Kalawsky**) in which we are charged with leading the UK Systems Engineering research community to further success. Our Systems of Systems work in open architectures has been exploited by the UK MoD and a number of major defence companies and our work influences systems engineering best practice via our activities with INCOSE, the relevant professional body.

Our success in technology for Healthcare has helped to secure a HEFCE Catalyst Award "Exercise is Medicine" and has gained international recognition, especially through interest from NASA.

Studies of devices (VHDL design, system-on-chip, targeted processors) has been exploited through a spin-out company, Axilica specializing in novel EDA tool flows. Our control systems activities (**Goodall**, **Dixon**, **Ward**) have long been recognised as outstanding, especially by the rail industry, and have attracted over £1.2M during the assessment period. In this period, our Advanced VR Research Centre (**Kalawsky**) was identified as one of the e-Science Centres of Excellence.

Vision and Research Strategy

The Systems Group will continue its work on Systems Engineering, Control for Rail systems and Electronic Systems design. The vision is to focus on the development of the "Systems

Technologies" and through doing so to position ourselves as No.1 in the UK.

1. Develop and Lead a cohesive UK activity in Systems Engineering by leveraging our EPSRC Network award (**Kalawasky**).

2. Build-upon our collaboration with Jaguar Land Rover (**Dickerson, Dixon, Mulvaney**) and our established position as world leading in Rail (for systems and model-based vehicle/track interactions – **Goodall, Dixon, Ward**) to intensify the application of our Model Based Systems Engineering, Simulation and Control activities across the rail, road and aerospace domains.

3. We will capitalise on our award of a Chair appointment from the cross-disciplinary Catalyst project "Exercise is Medicine". This overtly cross-university activity will strengthen and extend our activities in the area of healthcare Technologies, including sensors and processing for health and exercise support.

c. People, including:

i. Staffing strategy and staff development

Summary of Major staff changes since previous assessment.

Communications

New Appointments: **Gong, Lepper*+, Navqui*+** and **Whittow*+** (all L).

Chair Promotion: **Lambotharan**. SL to Reader: **Edwards**

Energy

This area has seen significant expansion from 6 to 12.6 FTEs over the assessment period.

New Appointments: **Eames, Walls** (Chair); **Rowley*** (SL); **Betts*+, Blanchard*, Bowers*+, Claudio** (L). Chair Promotion: **Gottschalg, Novac, Watson.** L to SL: **Betts*+**

Systems

New Appointments: **Henshaw, Summers** (Chair); **Hubbard*+, Ward*+** (L).

Chair Promotion: **Siemieniuch.** SL to Reader**: Dwyer.**

Flexible Time Variation: **Goodall** (0.6 FTE)

***** indicates appointment from Research and Teaching Staff, including RAs and RSs, and demonstrates our policy of developing and promoting our own staff.

+ Followed New Lecturer Programme in current Assessment Period

These promotions and new appointments are at all academic levels and the research capacity in all 3 groups has been strengthened. They have together contributed significantly to our increased research income of £22M (c.f. £14M in the longer RAE2008 period); to our increased journal publications of 548 (c.f. 454) and our increased Ph.D. graduations of 103 (c.f. 90).

Staffing Strategy and Staff Development

New staff are appointed according to the strategic priorities of the Unit and University as agreed by their respective Research Committees. The research needs of each group, of our teaching commitments and of each of our physical sites are considered. Once appointed, new staff follow a carefully planned orientation course, during which they receive guidance and training on all aspects of their future role in the University. When this is satisfactorily completed their appointment is confirmed and thereafter their performance is appraised annually, with help being provided should any weaknesses become apparent.

Our staff development strategy specifically includes Leadership and Management training courses run by the Graduate School, Staff Development and the Careers and Employability Centres and is open to all staff. In 2012/13, **Dixon** was selected to join the "Developing Future Research Leaders" programme, an EPSRC funded-initiative that saw Research Staff and early career Lecturers receive a leadership development grant, dedicated coaching, participation in Action Learning and 360° Feedback. **Edwards** was also supported in taking Public Speaking training. Academic staff complete an annual Personal Research Plan (PRP) and Performance and Development review which facilitates discussions and areas for development for individuals This process embeds research in performance monitoring and reward systems and is monitored by the University's

Research Performance Monitoring Committee.

Early Career academic staff undertake a New Lecturers Programme which introduces the University's Research Culture and the support available from the Research Office. Opportunities for research funding are disseminated to all staff via the Research Office webpages, a Research Staff e-bulletin and blog. Teaching is reduced to 33%, 50% and 66% of the average load in the Unit during the 1st, 2nd and 3rd years of this Programme to allow time for research activities to be developed. Mentoring is available for research staff, and academic staff are encouraged to participate as mentors. The Research Office provides bespoke one-to-one support for staff writing grant proposals.

Loughborough University undertook a comprehensive analysis of its alignment with the Concordat to support the Career Development of Researchers in 2009/10, and, as a result of this, researchers enjoy a Research Staff mentoring scheme, a revised Code of Practice for the Employment of Researchers, and the Loughborough University Research Staff Association.

The Unit is committed to achieving equality for all, including mandatory recruitment and selection training which embeds Equality and Diversity policy. We have also set up an Athena SWAN working group with a view toward applying for this award.

ii. Research students

Recruitment of Research Students

Recruitment of all students is in accordance with the University's formal admissions policy which requires that research students should have a good first degree in a discipline relevant to their proposed area of research and that they can demonstrate they can undertake a sustained programme of independent research. Decisions on the admission of candidates are taken by at least two members of staff and wherever possible an interview is conducted, often by telephone or Skype for international candidates.

Support of Research Students

Support and development of Research Students is provided at both Unit and University levels. For example, the School provides access to travel funds for conference attendance and for access to subject specific conferences such as the Midlands Energy Graduate School.

All Research Students are automatically members of one of the three research groups which provide relevant invited lectures from outside speakers. Research student progress is monitored through regular (at least monthly as is formally required although daily is frequently the norm) supervisory meetings which are recorded and all students have an annual progression review. This includes participation in an annual School Research Conference where Year 1 students give a verbal overview of their planned research, Year 2 students present a Poster recording their research and Year 3 students present a research paper. Progress from one year of research to the next requires the production of a detailed progress report and its defence in front of two academics (excluding the supervisors).

The Unit has established a fund to enable research students to attend international conferences to present their work as well as providing them with IT and equipment support.

Research Students attending conferences are encouraged to apply for one of the prizes or awards that are normally available.

Support from the wider University is coordinated by the Graduate School which works closely with the Careers and Employability Centre and the Library. A comprehensive training programme is provided that maps to the Researcher Development Framework, comprising face-to-face workshops, an annual research conference including poster competition and the 'Café Academique' which is a forum where PhD students can debate the latest ideas from all areas of research. The Careers and Employability Centre have a dedicated Careers Advisor for Researchers, to support research staff and research students.

Within the Unit, quality assurance of research degree programmes is provided by an Associate Dean Research who is a member of the University's Research Committee (chaired by the Pro Vice Chancellor for Research). At the institutional level, quality assurance is provided by the Dean of the Graduate School, who is responsible for considering and approving a range of research student business from admissions to examinations, as well as, for example, chairing student appeals,

thereby ensuring consistent and equitable treatment. The Dean of the Graduate School leads a cycle of regular research degree programme reviews as part of the University's quality assurance mechanisms. The outcomes of these reviews are reported to Research Committee. The University also participates in the UK wide Postgraduate Research Experience Survey (PRES).

d. Income, infrastructure and facilities

1. Summary of Major Grant Awards and Facilities

The total value of the research grants and contracts either operational or scheduled to be in place at the time of submission exceeds £15M, with each group holding at least one multi-million pound award as Lead Partner. More details of major grants are given below.

Communications

- "Signal Processing Solutions for the Networked Battlespace", (2013-18). £4.5M, PI **Chambers**
- "Enhancing Networks and Wireless Research at Loughborough University's Communications Research Group - A Case for Platform Grant Support" (June 2007-Nov 2010). £537k, PI **Parish**
- "Synthetic materials using metallic and non-metallic nanoparticles at microwave frequencies", (December 2010 - 30 November 2014). £496k PI **Vardaxoglou**
- "High Performance Flexible, Fabric Electronics for MegaHertz Frequency Communications", (January 2009 - 30 December 2013). £420k PI **Vardaxoglou**

The group operates 3 Microwave anechoic chambers, including one of 15x5x5m dimensions (2012). Collectively, these represent an investment of £2M which has been provided by external donation and by the University. Our centre of excellence in Mobile Communications, CMCR, has a unique set of facilities including a DASY4 robot and iSAR instrument.

The group also operates a 9x5m tank with a depth of 1.8m in which underwater acoustic measurements are made. Few such facilities remain in UK Universities.

Other facilities include a Multimodal, audio and video sensor, Smart Office supporting signal processing research and a computer network testbed on which cyber attacks are investigated.

Energy

The national headline research programmes in energy research are the Supergen programmes, which are currently transforming into the Supergen hubs, which will place the group ideally to input to future research strategy. The energy research group is contributing to two of these hubs (HDPS, Wind Energy Technologies) and is leading the PV Supergen, SuperSolar. CREST's PV laboratory is internationally one of the very best as demonstrated in our participation in the EU infrastructure project 'Solar Photovoltaic European Research Infrastructure (SOPHIA)'

In the assessment period, major grants won by the Energy group were:

- PV Supergen SuperSolar, EPSRC, overall value £4.1M, PI **Walls**
- UK-India Performance and Stability of Photovoltaics, EPSRC (UK) & DST (India), overall value £4.3M PI **Gottschalg**
- Energy Storage, EPSRC value £1.2M, PI **Eames**
- PV Supergen Challenge PV2025, EPSRC, overall value £1.1M, PI **Gottschalg**

Many smaller grants have also been won. 5 researchers have attracted in excess of £1M of funding spent in the Unit (**Eames**, **Gottschalg**, **Novac**, **Walls**, **Watson**).There has been a significant increase in the research income won by the group, from about £450k in 2008 to about £4.5M in 2012, i.e. a tenfold increase.

The infrastructure in the group is world leading. CREST boasts a world leading photovoltaic laboratory with pilot lines for crystalline Silicon devices, Cadmium-Telluride and organic solar cells. This is complemented by a PV calibration and characterisation facility, which is unparalleled in the UK and competes with the best in the world; it represents an investment of £1.2M since 2008.

The pulsed power area is the only List X approved academic facility of its kind, a significant mark of trust awarded by the MoD. This status is unique in academia due to the very demanding security requirements, which mean it is typically restricted to industrial enterprises.

Systems

This group works extensively with colleagues in other Units to provide expertise on systems engineering. The group has significant activities in Aerospace, Railways, Automotive, Health and Infrastructure with headline grants during the assessment period including:

- Designing for adaptability and evolution in systems of systems engineering (DANSE), EU overall value €12M, (**Kalawsky**).
- PSi Theme 1 - Analysis of the Vehicle as a Complex System, EPSRC & Jaguar LandRover, overall value £2.2M (**Dickerson**)
- Trans-Atlantic Research & Education Agenda in System of Systems, EU, £480k, (**Henshaw**)
- Systems Engineering Doctorate Centre, EPSRC/Industry, total £4.5M,PI: (**Goodall)**.

Alongside these headline large grants, there has also been significant success in winning other strategic grants, which in many cases have or will enable follow-on applications. A good example of this is the UK Systems-NET led by **Kalawsky** (EPSRC, £400k) which is enabling a strategic and long lasting alliance to provide coordination and capability shaping in systems engineering. The total portfolio of grants for rail activities in the period is over £1.3M and in the area of embedded systems the EU funding during the period totals £400k.

The major infrastructure and facilities of the Systems group include state-of-the-art high speed computing equipment and experimental facilities. Since 2008, the Control and Health Monitoring lab has been significantly developed in collaboration with BAE Systems. The significant investment in facilities includes: Herti UAV airframe, fuel-system hardware simulator, flight simulator, aileron rig, and power generation set. Together this represents an aircraft simulation environment, rare in academia, which enables research in fault detection/monitoring and evaluation of the system interactions. The other key experimental area is the Virtual Engineering Centre which includes multi-million pound investment in two large 3D vision domes, Advanced Virtual Engineering Facility, immersive work bench displays, aircraft flight simulator and UAV ground control station and dedicated collaborative facilities that allow linking of this lab to other laboratories or to individual workers across the world. These facilities have been built up through grants and collaboration with our industrial partners.

2. Planned Initiatives

The Unit will be involved in a number of major initiatives which will contribute to its future research success including:

1. Sensor Technologies for Healthcare. This is part of a £7M HEFCE Catalyst funded programme in “Exercise is Medicine” and will fund a Chair position to lead work in the enabling technologies for sensors in healthcare. This is a cross-university initiative in which the group will work closely with specialists from the Sports and Health Science and Mechanical Engineering areas to have a significant effect on the Government’s health and obesity agenda.

2. Digital Technologies. This activity will be a key part of the University’s Loughborough in London Campus on the Olympic Park site contributing ground breaking research in conjunction with the communications Group. This £14M commitment by the University will promote research and teaching in digital driven areas including media systems.

3. A major redevelopment of the main site housing the Unit’s activity is planned for the period 2014 to 2017. This will represent a total investment of £50M and will incorporate the redevelopment and renewal of research laboratories for most of the Communications and some of the Energy and Systems Group research activities.

e. Collaboration or contribution to the discipline or research base

Communications

Contribution to professional associations or learned societies

In this group, **Chambers and Vardaxoglou** are both FREng, FIEEE and FIET. **Flint** is also FIET.

Member, Fellows Panel: FREng (**Chambers**); IEEE (**Vardaxoglou**).

Major and international research collaborations

Due to the international reputation of our antennas research, ESA invited Prof. Vardaxoglou to work with them at their European Space Research and Technology Centre (ESTEC) in Noordwijk, The Netherlands. This collaboration's overarching objective is to make a step change in current understanding of FSS (Frequency Selective Surfaces) as applied to satellite antenna systems and improve communications link capacity. Our antennas work has resulted in other collaborations with Ohio State University, Sienna University (**Vardaxoglou**) and Pretoria University (**Whittow**).

Other collaborations include: The National Physical Laboratory (NPL), for multiple underwater acoustics projects (**Lepper**); a number of collaborative partnerships with Chinese Universities: for example, University of Electronic Science & Technology of China, for cooperative relay communications systems value £1M (**Gong**); advanced signal processing research with University of Josef Fourier Grenoble (**Chambers**); work with two Universities in Naples (including Federico II) to further the understanding of cross-layer effects in wireless networks (**Parish** and **Whittow**), and, active involvement in the Council for Refugee Academics Iraqi Fellowship Scheme (**Edwards**).

Leadership in the academic community

Associated editorships in leading journals: ISRN Communications Journal (**Edwards**); EURASIP Journal on Wireless Communications and Networking (**Lambotharan**); IET Signal Processing (**Lambotharan**); IEEE Trans Signal Processing (**Chambers**);

Organisation of scientific committee of national and international conferences:

The group runs the annual LAPC (Loughborough Antennas and Propagation Conference), the leading event of its type in the UK. Now in its 9th year, over 1000 papers have been published by 1500 authors. Internationally recognized experts Profs Leo Kemper (Michigan State University) and Raj Mittra (Pennsylvania State University) say it is "premier" and "at a level comparable to the finest global conferences in this domain of scholarship".

Initiation of COST focused action group for standardisation of antenna measurements data (**Vardaxoglou**).

Invited Presentations: Wireless World Research Forum, Stockholm, Sweden, Sustainability and the Future Internet (**Edwards**); 2010 IEEE International Conference on Wireless Information Technology and Systems (**Edwards**); International Workshop on Cognitive Radios and Smart Antennas (CORSA) (**Lambotharan**); **Panel Expert**, Research Council for Natural Sciences and Engineering at the Academy of Finland. Communications Engineering (**Edwards**); **EPSRC College of Peers membership**: (**Chambers**, **Parish**, **Vardaxoglou**)

Vice Chair and Treasurer, IEEE UKRI ComSoc (**Parish**); **Council Member, IET** (**Flint**).

Visiting Professor, Harbin Engineering University China; University of Josef Fourier Grenoble (**Chambers**)

Energy

Contribution to professional associations or learned societies

In this group **Smith** is FREng and FIET, **Novac** is FIEEE and **Walls** is a FIoP.

Best paper awards: **Watson** (3), **Gottschalg** (3), **Betts** (3)

Major and international research collaborations

The energy group has very strong links with industry. EOn (**Betts**, **Gottschalg**, **Thomson**), Tata (**Gottschalg**)**,** Taylor Hobson (**Walls**)**, BAE Systems (Novac/Smith)**) and MBDA (**Novac/Smith**) have all directly funded research work. Research is also funded by government departments, e.g. MoD (**Novac**, **Smith**), Dstl (**Novac/Smith**), AWE (**Novac/Smith**) and DECC (**Eames**).

Projects of pan-European nature include a Marie Curie ITN WAUDIT (**Watson**), which includes all the leading EU players on wind energy meteorology. A number of EU projects were carried out in the photovoltaic area such as the FP-6 Integrated projects Performance, PV-Catapult and the FP-7 infrastructure programme SOPHIA (**Gottschalg**, **Betts**), which include the leading players in the applied photovoltaics area. The group also has UK-India collaborative projects such as Stability and Performance of Photovoltaics (**Gottschalg)**, creating links to multiple IITs and Government.

Other significant collaborations are on one-to-one levels, such as **Eames**' work with CSIRO (Australia) and Fraunhofer ISE and the characterisation of solar cells with Bari University (**Claudio**). Further examples include Jiatong University and Eindhoven University on plasma

simulations and plasma modelling (**Iza**) and Colorado School of Mines on thin film solar research (**Walls**).

Exemplars of interdisciplinary work

Caliber project (£2M overall) on Vacuum glazings, and EU-ED (£1.5M), on storage (**Eames).**

Joint consultancy work with chemistry and, chemical engineering on biomedical plasma applications (**Iza**).

Data-driven modelling of sustainable energy systems, linking 3 different areas (3PhDs 2RAs, £0.5M).

NERC funded collaboration (**Watson**), wind-aerodynamics, impact on soil/peat bog.

UK-India STAPP (**Gottschalg, Betts**) which links photovoltaic applications, mechanical and chemical engineering.

Leadership in the academic community

Associated editorships in leading journals: IEEE Transactions on Dielectrics and Electrical Insulation (**Novac**, 2010-2011), IEEE Transactions on Sustainable Energy (**Betts**), IET Renewable Energy Power (**Gottschalg**), Wind Engineering (**Watson**), Energies (**Walls, Watson**), Future Photovoltaics (**Walls**).

Organisation or scientific committee of national and international conferences: IEEE Photovoltaics Specialists Conf. (**Walls**), European Photovoltaics Solar Energy Conf. (**Gottschalg**), European Wind Energy Conf. (**Watson**), PVSAT (**Gottschalg**), Solar UK (**Walls**).

Other: Technology innovation needs assessment (TINA) for DECC (**Eames**)

Low carbon innovations group, future roles of low carbon heat (**Eames**)

NSF US panel – **Eames**; EPSRC – thermal (**Gottschalg, Eames**)

UK representative, COST action (**Iza**); EERA participation: Smart cities work programme leader (**Rowley**); European Wind Academy (**Watson**); Member of the Solar European Industry Initiative Steering Group (**Walls**); Member of the UK Solar PV Strategy Group at the Department of Energy and Climate Change (**Walls**); Offshore Advisory Board (**Watson**); Organiser of IoP meetings on photovoltaics and plasmas (**Walls**); Lead of PV Supergen Hub (**Walls**); Committee member of IoP Ion and Plasma Surface Interactions Group European Academies Science Advisory Council (EASAC) – **Eames** (representing **Royal Society**); UK-lead of PV-EERA (**Gottschalg**); Vice-chair of UK-Solar Energy Society (**Gottschalg**); Member of British Photovoltaic Association (**Gottschalg**)

The Pulsed Power team (**Iza**) have active research links with FOI, (Sweden) LANL (USA), TTU (USA), University of Pau (France) and Universiti Teknologi (Malaysia).

Systems

Contribution to professional associations or learned societies

In this group, **Goodall** is a FREng, FIET and FIMechE, **Dixon** is also a FIMechE, **Summers** is a FInstMC and **Kalawsky** is a FRSA.

Best paper awards: Siemieniuch (1); **Goodall** (1); **Summers** (1)

Other Awards: IMechE James Watt International Gold Medal: **Goodall**; InstMC Honeywell Prize: **Goodall**; BAE Systems Directors Award: **Kalawsky**

Major and international research collaborations

In the embedded systems area, (**Mulvaney** and **Chouliaras**) work with Selex Galileo and Axilica (a company spin-out from the group). Selex has funded research directly and acted as a partner in European grants. The group has a 20 year partnership in remote health monitoring and currently holds two joint British Council grants (**Mulvaney**). The group has a longstanding collaboration with Jaguar LandRover which has recently been strengthened through a £2.2M grant co-sponsored by JLR and EPSRC (**Dickerson, Dixon, Mulvaney**). Another well-established collaboration is with BAE Systems for a range of topics including soft systems (**Simunich**, **Hubbard**), aircraft control (**Goodall**), fault detection (**Dixon**), novel actuation (**Dixon**, **Goodall**), network enabled communication – NECTISE (**Henshaw**). In model-based systems engineering there are

collaborations with IBM, EADS (Germany), Thales (France), INRIA (France), CARMEC, IAI (Israel) and ALES (Italy) (**Kalawsky**). Collaboration with the rail industry is via RSSB, RRUKA and directly with Tracsis and Network Rail (**Goodall**, **Dixon**, **Ward**) and this team are regularly invited to present at RSSB/RRUKA seminars. Other industrial collaborations include: SMAC and CCFE.

Dwyer's work in electro-migration has led to collaboration with Nanyang Technological University and University of Hannover where we contribute simulation studies. In Healthcare there are strong collaborative links with internationally leading institutions including: Tsinghua University, Huazhong University of Science & Technology (HUST), Shanghai University, Dublin City University, Stanford University, Royal College of Surgeons in Ireland, Fraunhofer-Institut Biomedizinische Technik (IBMT), Germany, VTT Technical Research Centre of Finland and Phillips health Research (**Hu, Kalawsky, Summers**). **Kalawsky** collaborates with and is Adjunct Professor at University of Southern Australia. In the rail area **Dixon**, **Goodal**l and **Ward** collaborate with other world-leading research institutes: Nihon University (Japan) and Politecnico Di Milano (Italy).

Exemplars of interdisciplinary work

Systems engineering is necessarily inter-disciplinary. Example projects include: i) EU DANSE is developing novel interdisciplinary methods, models and simulation tools that support optimization of evolving, adaptive and iterative complex systems of systems in a number of industry inspired interdisciplinary test cases such as air traffic management, autonomous ground transport, integrated water treatment and supply, and emergency response systems. ii) EPSRC: FALLOT (funded through Bridging the Gap initiative) used integrative biology and multi-scale engineering systems to tackle complex congenital heart defects and thus reduce morbidity and mortality. iii) The REPOINT projects (£174+£356k, **Dixon**) have integrated the radical re-engineering of railway track switch mechanisms, designing redundant sensing, drives and control, and seeking to modify the rules of train control in order to get system-level capacity benefits. iv) EPSRC Systems-NET is enabling a strategic and long-lasting interdisciplinary alliance across the UK Government, Industry and Academic sectors to ensure availability of future systems capability. v) EPSRC Low Energy Effort Demand Reduction £1.7m, a joint activity between Energy and Systems groups (**Kalawsky** and **Thompson**).

Leadership in the academic community

Associated editorships in leading journals: The Ergonomics Open Journal (**Kalawsky**); The Open Cybernetics And Systemics Journal (**Kalawsky**); International Journal of Intelligent Defence Support Systems (**Kalawsky**); Engineering Letters (**Mulvaney**); Aeronautical Journal (**Henshaw**); IEEE Systems Journal (**Henshaw**); Int. Journal of Automation and Computing (**Dixon**); Guest co-editor, IEEE Systems Journal (**Hubbard**).

Organisation or scientific committee of national and international conferences:

IFAC SafeProcess 2009 & 2012 (**Dixon**), IFAC Mechatronics 2013 (**Dixon**), SysTol 2010 and 2013 (**Dixon**), IAVSD2011,2013 (**Goodall**), IEEE Conf. on Systems of Systems 2010 (**Henshaw** - Chair), Conf. on Systems Engineering Research 2009 (**Kalawsky** – Chair).

Invited Presentations: ASME World Conference on Innovative VR, Milan, Italy (**Kalawsky**); British Council – Israel Event on Resilient Water Supply Networks (**Kalawsky**); IET Tustin / Annual UKACC Lecture 2012 – MagLev: the dream and the reality, (**Goodall**); Invited Lecture: Train Technologies for 2050, 13th EU Hitachi Science & Technology Forum (**Goodall**); Invited Talk on Control Engineering, at Time for Causality Workshop, SUSTAIN, Bristol (**Dixon**).

Other: EPSRC College of Peers (**Dixon**, **Henshaw**, **Goodall**, **Kalawsky**, **Summers**). Group membership of InCOSE and UK Automatic Control Council (UKACC).

International Federation of Automatic Control (IFAC) Technical Committees for SafeProcess (**Dixon**) and Mechatronics (**Dixon**, **Goodall**); Vice President of IFAC (**Goodall**), Chair of IMechE Railway Division, 2010 (**Goodall**); Member of Exec Committee for IET Control and Automation Professional Network (**Dixon**); IEEE Technical Committee on model based systems engineering (**Kalawsky**); International Advisory Board Member, Defence and Systems Institute, Australia (**Kalawasky**); INCOSE Vision 2020 Working Group (**Kalawsky**); International reviewer - Transportation Research Board (Washington DC), Japan Prize Submission, and Georgia National Science Foundation in the State Science Grants Competition (**Kalawsky**).