Institution: The University of Birmingham

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

a. Overview

This submission is from the **School of Electronic, Electrical and Computer Engineering** (EECE) at the University of Birmingham. EECE is one of 9 Schools in the College of Engineering and Physical Sciences (EPS). It has three research groups; Microwave Devices and Systems **(MDS)**, Human Computer Interaction **(HCI)** and Railway Research and Energy **(RRE)**, led by Hall, Baber and Roberts respectively. The **RRE** group contains the EECE contribution to two university-wide interdisciplinary research centers; the Birmingham Centre for Railway Research and Education and the Birmingham Centre for Energy Storage. The **HCI** group contains the EECE part of the University HCI center; primarily a collaboration with the School of Computer Science.

b. Research strategy

Our long term strategic goals have naturally aligned us with UK and international strategic priorities. As evidenced below, this is achieved through well established groups of critical mass, having extensive knowledge of world-wide research and commercial environments and naturally aligning their portfolios to outward facing requirements. The groups are sustainable, with a strong evolving knowledge of the end-user requirements and basic science. The University has **invested** in EECE strongly through its strategic framework "Shaping the Future". Each of our research groups have put forward detailed strategic plans for funding under this initiative and each was supported strongly by the University, as discussed below. Strategy formulation and implementation is overseen by the **College "Futures Group".**

Average **annual income** from all sources has risen 17% from £2.75M in RAE 2008 to £3.3M for REF2014. This includes an increase from £760k to £1M for industrial income. The **proportion** of funding from Research Councils, Government, Industry and Europe is 35:17:31:14. We believe this to be a healthy sustainable split which we plan to maintain. Academic output includes 718 publications, including 404 journal papers. This is an increase from 2.6 journal papers/FTE/year in the 2008 REF to 3.1 for REF2014. There have been 7 research books published (Ghafouri-Shiraz, Hall, Baber, Cherniakov, Jackson, Zhang x2).

The **Microwave Devices and Systems** group has developed over 50 years in the School and the topic represents one which can be applied across many industrial sectors. As evidenced below, the group has tremendous experience and an excellent reputation. Our strategy builds on this, and EPSRC have now designated our main research themes as growth areas i.e. Microsystems, RF and Microwave Communications, RF and Microwave Devices and Materials. We will build the area of terahertz electronics devices and systems through appropriate partnerships, as well as using our materials expertise to develop new components, circuits and systems. We will apply our expertise to the problem of intelligent devices and smart materials and bridging the optical-microwave gap; bringing practical devices to these areas. Specific topics which we will grow are terahertz communications, cognitive radio, on-body communications and radar sensor systems. We will grow the area of space technology using our collaborations with the School of Physics, QinetiQ and ESA and a recently funded RAE/DSTL chair.

MDS have fully delivered the strategic aims of the **2008 RAE**. We have funded three new staff (Gashinova, Antoniou, Feresidis) to build our strength in communications and radar. Highlights are the successful development of terahertz micromachined circuits and microwave materials and devices through significant EPSRC funding (£2.2M) and the development of practical and theoretical expertise in on-body communications systems and antennas, again with EPSRC funding (£1.6M) New radar systems have been investigated, including the exploitation of signals from GPS satellites and the successful development of security and car radar systems. The latter is funded by long term strategic agreements with SELEX (£1.7M) and Jaguar Land Rover (£900k) as well as EPSRC (£1.1M) funding. There is also world leading EPSRC (£434k) funded research on ionospheric propagation. The group has produced 207 Journal, 4 books and 176 conference publications. Note that all funding figures in brackets which relate to awards for contracts active during the REF period and are the funds coming directly to EECE.

The School invested heavily in 2002 to maximise the potential of the expertise in Applied Computing; this has developed rapidly into the **Human Computer Interaction** research group. Our strategy here aligns with the EPSRC themes of "Communities and Culture", "Assistive Technologies and Rehabilitation" and "Medical Imaging", and encompasses many industrial

sectors. Specifically in our strategy we will pursue work on the next-generation interaction technologies with the development of fundamental research in digital signal processing pursuing novel approaches to the challenge of fast, accurate speech recognition and including other modalities (e.g. eye movement) for enhanced human computer communications. We will exploit our expertise for novel applications of games-based simulation, enabling the MoD to enhance military training, and to the healthcare sector to evaluate new and affordable training and rehabilitation techniques. We will pursue research into medical sensors and biomedical informatics including the development of techniques to record directly from nerves, extending current clinical abilities to sense neural activity, as well as advanced medical imaging and visualisation of tumours improving diagnosis by radiologists.

In the **2008 RAE** the **HCI** strategy was to invest strongly in our areas of world class expertise including human factors, serious gaming, synthetic environments and multi-modal technologies. This strategy has been successfully implemented. A HCI Centre has been formed with Computer Science including 1 new Chair, 2 lecturers and a Birmingham Research Fellow. Birmingham fellowships are only awarded to the highest quality people with significant international reputation and are funded by the University for 5 years with the expectation of a subsequent lectureship. The HCI Centre provides a strong critical mass grouping for the future. The funding for this work has been forthcoming from EPSRC (£0.8M) and the Human Factors Integration Defence Technology Centre DTC with contracts awarded to the value of £1.2M. We said we would develop Bioinformatics and Bioelectronics interests and have realised this through EU (£672k) and EPSRC (£179k) funding, focusing on the rehabilitation of stroke patients, medical training environments, and data mining, with a range of hospital collaborators in the areas of cancer studies. We have successfully delivered results on EPSRC (£213k) and DSTL (£150k) funded projects on a spinal nerve interface. The breadth of applicability of research in the HCI group is illustrated by another EPSRC (£528k) supported project involving challenging signal analysis and data visualisation in mapping underground features (e.g. utility services). HCI staff publication count is 107 journal and 100 conference papers and 1 book.

In the **Railway Research and Energy** group, railways research has been prominent in the School for over 40 years and remains a stalwart of UK and worldwide transport policy, collaborating with the majority of UK railway companies. This is a subject that will continue to be prominent in both the near and far term. We have an excellent reputation with industry and academia in this area, and our plans are aligned to the UK Technical Strategy Leadership Group (TSLG). We are a key player in this group, both in terms of being a major technical contributor and providing an organisational framework. Our strategy aligns to 4 out of the 6 themes in the TSLG 2012 strategy including: intelligent traffic management, low carbon and energy efficient systems, beneficial utilisation of information, and cost effective and reliable solutions. Energy research in the School has been established for many decades, now focusing on the control of power from renewable sources and delivery systems. We have strategic relationships with National Grid and EON which we will expand and deepen. We will increase our collaborative work, particularly to emerging countries such as China. It is estimated that there will €50billion of investment over the next 17 years in this area, and with our strategic alignment with companies we are targeting significant growth over the next five years and beyond.

We have been highly successful in realising the investment in Railways and Energy promised in the **2008 RAE.** We appointed a new lecturer (Tricoli) and a Birmingham Research Fellow (Stewart). Contracts have come from all major companies in the rail industry totaling (£4.2M), EPSRC (£0.5M) and 10 EU projects (£1.7M). Recently a European Regional Development Fund grant of £1.5M was awarded for technology demonstrators working with local SME's. Our Energy research is primarily on energy networks and renewable energy control with industrial and government funding (£1.7M) and strategic agreements with E.ON and National Grid. A recent success is the £6M EPSRC grant under the Great Eight British Technologies initiative for the Birmingham Centre for Cryogenic Energy Storage; an additional £968k is allocated to EECE.

The output for the RRE group includes 52 journal and 20 conference contributions from the railway research, and work on energy has led to 18 journal and 6 conference papers as well as 2 books.

c. People, including:

i. Staffing strategy and staff development

Our primary method of the delivery of our strategy over the last five years has been through **staff appointments** directed towards enhancing and expanding the excellence in our current research

groups. We believe we have critical mass in these groups, but also need to expand with our strategic aims in mind, making sure as staff retire we build on our position. Research leadership has been strengthened by increasing the number of Professors from 5 to 8. Two new Birmingham fellows have been appointed, one in HCI and one in Railways.
This strategy is overseen by the Head of School together with the School management committee. This is supported by a set of research related committees to plan strategy, evaluate policy and procedures and inform staff. The **committees** are the Research and Knowledge Transfer Committee, the Industrial Liaison Committee, the Postgraduate Staff-Student liaison Committee, the Ethics committee, Computer Committee and the School Health and Safety Committee.
All **new staff** are provided with an annually updated staff handbook. It covers all aspects of teaching and research within the School including our involvement in the UK wide "Green Impact" scheme (we have a Gold award), safety procedures, the School committees, postgraduate student supervision and mentoring, trade union representation, and the mechanisms for delivery of teaching and research. New staff develop their research and teaching objectives through a formalised Personal Development Plan administered and monitored through the College. They have a mentor and are required to have or gain the PG Certificate in Education for the development of research-informed teaching careers. New staff are provided with initial funding to build up their research portfolio.
Both research and academic staff have an annual university managed **Performance Development Review (PDR)**. The PDR is an opportunity for an individual to have a structured, constructive conversation about their performance and development needs, and for the University and individual to agree stretching but achievable objectives for the following review period. A formal annual promotion scheme provides staff with the incentives and rewards.
All academic staff benefit from **School funding**, the amount depending upon their research performance. The funding supports attendance at conferences or meetings or small pieces of equipment. There are **two annual away days** for all staff, one specifically dedicated to research. A **sabbatical** system is in place where staff can take up to 6 months away from teaching to develop their research profile. The School runs an active open **seminar programme,** with monthly seminars given by external speakers. Invitations alternate between those from members of the academic staff and those from postgraduate students who invite and host the event. In addition, there is a range of technical meetings and seminars within the individual research groups. For example MDS runs monthly meetings where students and staff discuss their research. The School has nurtured two **grant writing groups,** one for EPSRC and one for European funding. The head of the University European contracts unit attends the latter The School has a **mentor system** in place to help all staff with research proposals and other aspects of academic life.
The **University Human Resources (HR)** is responsible for the relationship between staff members and the University; it was winner of the 2013 Universities Human Resources 'exceptional achievement' award. Operations include delivery of resources which underpin the employment of all staff, the training of staff through POD (People and Organisational Development), the work place wellbeing and the University strategy and policy. There are over 50 courses available in POD with a number of them based on the nationally recognised Institute of Leadership and Management qualification. There is University **Workplace Wellbeing** team which has extended support for staff in the areas of Health and Safety, Occupation Health, Counselling, Support Services, Sustainability and Environment.
Research and Innovation Services work across the University to help researchers access funding and income opportunities. They provide a framework and support for EU programmes, large complex projects, centrally managed funds and calls, as well as managing strategic partnerships and IP support. Alta Innovations provides spin-out support. A University **Business Engagement team** is responsible for developing business links as well as calls for funding related to industrial or enterprise research. They coordinate courses in Enterprise Development.
In addition to the above, research staff are supported by a highly organised **University infrastructure** appropriate to a world class establishment. These include a Finance Office, IT Services, extensive computing and library facilities, an Estates Office, Alumni Office for developing networking and funding channels, Legal Services, and a Planning Office. Initiatives and strategies in all of these are publicised through University newsletters to all staff and disseminated via an intranet.
The processes of implementation of the **Concordat** to Support the Career Development of

Researchers was initially developed at University level. A review of the University's compliance with the principle of the Concordat to Support the Career Development of Researchers was carried out in 2010. With this, and additional internal surveys and focus groups, key areas of concern have been identified and a PVC sponsored task group was initiated in 2011 to propose actions. The majority of the University's organisational level process, policies and activities met with the concordant but changes were initiated for full and comprehensive compliance. A variety of University HR related polices have been revised, streamlined or updated including academic promotions, fixed term contracts, equality and diversity and redeployment. This process led to University level processes, policies and activities having implementation of the concordat in September 2013. Evidence of compliance with these in EECE is exemplified in the discussion elsewhere in this document.

The recent strategic academic staff appointments include nationals of Italy (Tricoli), Greece (Feresidis, Anoniou), Russia (Gashinova) and one female lecturer (Gashinova). The new Birmingham fellows are from Italy (Castellano, female) and the UK (Stewart). The School is internationally diverse with staff from Singapore (Huang), China (Zhang), Iran (Ghafouri-Shiraz), Poland (Brdys), Russia (Cherniakov), Algeria, (Oussalah), Greece (Arvanitis), Slovakia (Jancovic) and Cyprus (Constantinou). This international diversity has contributed to our **strong international presence** across the globe.

Honorary staff provide a vibrant background to the research. The School has 4 Emeritus Professors 8 Honorary Professors, 4 Honorary Lecturers and 29 Honorary Researchers. Appointments need written justification showing they are directed our strategic aims. Examples of the many contributions come from Prof Mick Mehler (BT), Ian Proudler and Geoff de Villiers (QinetiQ), Dr Andrew Foo (Pulsar), Prof Malcolm Irving (Brunel) and Steve Houghton (GCHQ). Cannon (FREng) and Angling have been seconded from QinetiQ (20% FTE each) providing a formal link with the world class research in QinetiQ.

We have had hundreds of **international visitors** during the REF period, these range from visiting students and research fellows working with us on research projects to high status individuals. For example, we have set up strong links with China through visits from Vice-Presidents from Jiaotong, Northeast Dianli and Zhejinag universities. A visit from the Chinese ambassador to the UK has promoted our collaborative efforts with China, and substantial international cooperative research programmes in Railways, Energy, and Microwave Engineering have been set up with these universities and others. Examples of other countries outside Europe where we have regular visits and substantial research collaboration with publications are Russia, USA, Singapore, New Zealand, Poland, Australia, and Malaysia.

The University has a strong commitment to equality and diversity, as evidenced through its Equality Scheme and membership of organisations such as the Athena SWAN Charter (Bronze Award) and Stonewall. It has groups for Women, disabled, LGBT and minority ethnic staff. A series of focus groups aimed at identifying barriers to female staff promotion have led to personal development activities such as promotions workshops. In EECE examined training in equality and diversity led to **all** staff successfully gaining a certificate. The mechanisms we have in place to deal with equality and diversity have enabled **disabled staff** to take full part in School activities; the staff profile includes one member in a wheel-chair, as well as a blind research fellow. The School is working towards its own Athena SWAN award

ii. Research students

The **University Graduate School** (UGS) provides top level administrative support including scholarships, training courses, Development Needs Analysis (DNA), and interdisciplinary events such as poster competitions. There is a UGS Conference in which EECE students are actively involved.

There has been £2.3M University investment in **postgraduate scholarships** during the REF period. This can be compared with **external income** from self funded students (£1.6M), EPSRC DTA (£1.3M), and CASE Awards (£156k). It is complemented by direct student funding from EPSRC (£592k), EU (£392k), MOD (£11k) and DSTL (£19k) research projects. Our overseas global reach is exemplified by external postgraduate student funding of £1.1M coming directly from China, Iraq, Malaysia, Algeria, Cyprus, Libya, Saudi Arabia, Nigeria, UAE, Mexico, Kuwait, and Thailand. Industry also supports our students to a level of £480k and includes contributions from Network Rail, Invensys, Japan Railways, National Grid, EON, QinetiQ, Selex, Jaguar, Cadbury Schweppes, Saif, Samsung, Disney, ESA and Comsats. In addition we have success in attracting

students on prestigious scholarships such as the Dorothy Hodgkin Award and the Li Siguang Scholarship. This diversity provides international pathways for the future.

Sustaining the student population is paramount. In addition to direct advertising and use of internet sites such as FindAPhD.com, an active programme of recruitment is underway with visits by staff to Greece, Turkey, China, India, Malaysia, Singapore, Hong Kong, and the USA. The College takes an active supporting role with cross disciplinary recruitment visits to Brazil, Kazakhstan, Saudi Arabia and UAE. Many of these visits involve meetings with local higher education institutions to explore research collaborations and possibilities for joint and split site PhDs. We have deep and lasting relationships with Huazhong University of Science and Technology (China) and Fudan University (China) in the undergraduate area, and many students continue on to pursue a PhD. We actively seek more such links. There has been an **increase in overseas postgraduate student applications every year** (rising from 139 to 241) demonstrating our increasing overseas profile.

New students are provided with a comprehensive **postgraduate handbook** detailing everything they need to know for successful postgraduate study. It includes information on contacts, supervision, mentoring, progress monitoring, illness, holidays, facilities, committees, employment, English tests, regulations, IET, safety, Graduate School, additional courses and much more. There is an introductory lunch where this is discussed and students meet the appropriate staff. As would be expected from a high quality School, new students are provided with a suitable working environment which includes a computer, laboratory facilities, desk, and software.

Students have a supervisor, an academic advisor and a mentor. There is a postgraduate **welfare tutor** and a postgraduate office with a dedicated **postgraduate secretary**. In addition to informal supervisor meetings monthly meetings are formally recorded. The School has a formal **Research Student liaison committee** where issues are discussed. This is chaired by the postgraduate research programme manager who oversees all aspect of postgraduate research. There is a postgraduate student social committee, providing channels for integration through induction activities and events such as a staff-student football and table tennis competitions.

There are 3, 9, 18, 27, and 36 month **assessments** marked by supervisor(s) and the academic advisor. The assessments are based on a report, interview, work plan and publications delivered and planned. The students produce a web page, DNA reports, and a formal presentation. Preparation of risk assessments is a pre-requisite for access to laboratories. Feedback to the students is written and oral. The **School Research Progress Review Board** meets at least annually to evaluate students' progress, and make decisions on progression. Postgraduate quality, planning and adherence to codes of practice are overseen by the College and the University Quality Assurance Committee in annual reviews.

There are a range of activities based around the research groups in which students takes an active role including **group meetings, group seminars and paper clubs**. There is annual trip to **Coniston** for team building exercise for postgraduate students. This is run as an interdisciplinary event with Computer Science or Civil Engineering and includes technical poster sessions and discussion of interdisciplinary research projects. The annual **School Open Day** is an important research event.

Students have won **prizes** for their publications including the Young Engineers Prize at the European Microwave conference (Gardner), best paper at the ARFTG conference (Lancaster), two CST university publication awards (Lancaster), and best student paper at ICSR'12 (Castellano).

d. Income, infrastructure and facilities

The School has been through a complete **£26M building refurbishment** between 2006 and 2010. All research laboratories and offices are now well-founded for contemporary needs. The building and provision within it is an effective, healthy, and environmentally friendly workplace, which encourages recruitment of staff and researchers, provides leverage on grant applications and maintains staff retention. This income from the university is complemented by the £16M research income summarised in section (b) together with details of successful research grant income in section (e)

The **MDS** group facilities are extensive, providing the most modern capabilities for world-class research. They occupy fourteen rooms in EECE including ten laboratories. Leading facilities include a **Terahertz Laboratory** consisting of Vector Network Analyzers (VNA) with capabilities up to 325 GHz (£275k) and a cryogenic probe station (to 50 GHz). There are two **Microwave Antenna Laboratories** with three anechoic chambers enabling antenna measurements from

1 GHz to 67 GHz and including automated 3 axis measurements, a reverberation chamber, and a microwave SAR scanner. There is a **Body Centric Communications Laboratory** containing human models for propagation research. There are two roof-top **Radar Laboratories** with radar test beds including a 40 m long automated railing system to imitate aircraft flights. There is an industry supported class 10,000 **Clean Room** for circuit fabrication with over £1M of equipment. A separate laboratory hosts ancillary equipment for wire bonding, substrate dicing, microscopes, furnaces, fume cupboards, a drying chamber, vacuum evaporation and sputter deposition. The **Laser Ablation Laboratory** for thin film research has 3 deposition chambers serviced by a LPX205 excimer laser (£150k). In addition we have a **Mobile Laboratory** for outdoor car radar testing; there are two customised 4x4 vehicles and a motorboat. For ionospheric studies, on Ascension Island, there are two geodetic GPS receivers (owed by EECE) and two geodetic GPS/Galileo/Glonass receivers (operated on behalf of DSTL). In Birmingham there are four 150-400 MHz satellite beacon receivers.

The **HCI** group is strongly supported by industry and has first-class facilities to perform research. The **Multimodal Laboratory** has a Qualysis 12 camera 3D motion tracker and an eyelink eye tracker as well as audio metric booth. The **Human Interface Technologies Laboratory** has a range of advanced display technologies (e.g. Virtual Reality and Augmented Reality Head-Mounted Displays, large-screen displays) and is sponsored by BAE Systems and DSTL. There is a range of small telerobotic (land, air and subsea vehicle) test beds, including one micro-robotic vehicle under development (sponsored by QinetiQ) and an extensive range of current 3D modelling and run-time software packages with one of the largest academic 3D model databases in the UK. In addition there is a suite of psycho-physiological recording equipment for heart rate, GSR, basic EEG, and a state-of-the-art Tobii eye tracker system, provided by DSTL.

The **Railway Systems Laboratory** has built up a substantial and effective research infrastructure with a full size set of railway points contained in a freezer unit (funded by TSB and Network Rail) and two full-size train door rigs (supplied by Vapor Canada and London Underground). There is a walk-in freezer for low temperature railway component testing (funded by Network Rail), a railway track circuit test rig (developed with London Underground), a bearing and gearbox test rig (funded by Hitachi), and a robot arm rig used for precision gauging and measurement of rail samples. The £640k **Electrical Systems Integration Laboratory**, funded by local government, contains a machine rig and dynamometer consisting of two nose-to-nose 100kW induction machines instrumented with precision torque and speed transducers (unique to UK). State of the art electronic drives and power analysers allow the evaluation of current and future drive-train architectures. The facility also includes a power cycler for evaluation of electrical energy storage and power converters. **The Spinning Rail Laboratory**, funded by local government, contains a 4.2 m diameter 'wheel of rail' that can be rotated at up to 50 mph to simulate the interaction between train-borne test equipment (e.g. non-destructive testing equipment) or electrical contact equipment (e.g. conductor shoes) and the rail. For ice-on-rail studies it can be temperature controlled to -50°C. The **Railway Simulation Laboratory** was funded by the European Regional Development Fund. It consists of a 10 seat computer room that runs the state-of-the-art HERMES railway simulator (developed by Graffica Ltd and the group).The **Birmingham-National Grid Real-time Power Grid Simulation Laboratory** provides the advanced simulation facility of future renewable energy delivery with HVDC grid.

The laboratory facilities described above not only enable us to do effective research but also attract funding and high quality staff. In addition a range of **College or University** managed advanced facilities exist, examples of these include the Centre for Electron Microscopy and Mechanical Workshops The EECE developed **Centre for Learning, Innovation and Collaboration** extended its capabilities campus wide. It offers advanced state-of-the-art IT services such as video conference, software and web development and facilities such as SharePoint collaboration. Examples of the use of such facilities are the UK millimeter workshop (Lancaster), HideRail (Roberts), Speech Seminar (Russell) and an Antennas course (Hall) which had some sessions with webinars. This facility complements the University's **Creative Media** facility offering services from brochure design, web design, audio and visual production and importantly training for staff in the media spotlight. Three members of staff have reported their research on TV and radio (Jackson, Stone, Russell). The University's facility **Venue Birmingham** offers extensive professional conference accommodation.

EECE national and international **training courses** include: underwater acoustics (6 day, ~25

attendees), Malaysian Institute of Land Surveys (~45 attendees), GCHQ speech recognition (3 days, ~10 attendees), automotive radar (3 day ~25 attendees) and the European funded School of Antennas, with courses on reconfigurable antennas (5 days, ~27 attendees) and active integrated antennas (~7 attendees).
60% of staff do **consultancy**; this is encouraged through a formal application process and can be managed through the University company, Alta Innovations. Such consultancies are valuable for improving industrial links and enriching the vitality and relevance of the underpinning research base.

e. Collaboration or contribution to the discipline or research base
Collaboration is exemplified by inclusion in 25 European framework awards totaling €166M (£3.7M to EECE) with 390 partners. These figures do not include collaborations through the European School of Antennas (24 partners) and the EURNEX Railway Network (70 partners). There are many other international and national collaborations described below.
In **MDS** our EPSRC (£248k) supported theoretical work on networks with the School of Physics and work on Cognitive Radio (EPSRC £437k) runs in parallel with our on-body network research in collaboration with Queen Mary College, initially looking at 2 GHz systems (EPSRC £331k) then at secure, high capacity systems in EPSRC grant PATRICIAN (£620k). Collaborations with the universities of Durham, Kent, Rennes, Auckland and direct participation from Roke Manor, with frequent input from Queens University Belfast, BAE SYSTEMS, E2V, and Samsung have produced a range of unique outputs, including the world's first surface wave antenna tailored for on-body communications (Constantinou paper 4).
The £6M (~50% to EECE) EPSRC Superconductivity Portfolio Award delivered a detailed report listing 144 journal publications, 31 international collaborations, 105 outreach activities. It demonstrated leverage of £5M of funding to Birmingham. Cross University collaborative work continues in EECE with work on Josephson devices (EPSRC, £243k), frequency agile circuits (EPSRC £210k), dielectric materials (EPSRC £288k, DSTL £100k, NATO £13k), an EPSRC (£151k) Partnerships for Public Engagement grant, as well as installation of superconducting filters on three international radio telescopes. Expertise gained in filter design has lead to two EPSRC grants (£712k and £837k) on terahertz passive circuits, leading to work on manufacturing microwave circuits with the recent FP7 project HINMICO (£310k). The appointments of Cannon and Angling have led to new EPSRC (£435k) and DSTL (£106k) supported work on ionospheric studies, with initial work on a CubeSat (STFC, £21k).
Radar work has been strongly supported by three EPSRC grants (£204k, £453k, £452k). The area of passive imaging using radiation from GPS satellites is now established with a DTC (£700k) collaborating with Selex, BAE SYSTEMS, and Thales. The EPSRC grant (£452k) with Southampton University (industrial advisory board: Rail Network, SELEX, Thales, BAE Systems) is looking at civil applications e.g. landslides, slopes stability, wind turbines and highways monitoring.
MDS Esteem Examples include Hall (FIEEE, FIET) who received the IEEE AP-S John Kraus Antenna Award and the European Association of Antennas and Propagation Award as well as the LAPC IET James Roderick James Lifetime Achievement Award. Cannon (FREng) was Vice-President and Treasurer of the International Union of Radio Science (URSI) (2011-2014), chair of URSI UK National Committee (2009-2011), and Chair of the RAE study on Extreme Space Weather (2012). He is panel member at the Electrical Infrastructure Security Summit (House of Parliament, 2012) and in 2011 and 2012 met with Sir John Beddington (Government Chief Scientific Advisor). Angling (FInstP) is on a range of committees including chair of the ESA Space Weather Team Ionospheric Effect Group (2012-), chair of the committee on ionospheric research URSI G4 (2005-11), and member of the Space Environment Impacts Experts Group informing the cabinet office (2011-). Constantinou was elected chair of the UK URSI Panel (2011-2014). Lancaster (FIET, FInstP) and Gardner (FIET) were on the IET RF and Microwave Engineering Network Executive. Lancaster is a member of the UK Terahertz Waveguide Standard Advisory Group (2009-) and Gardner is on the steering committee for ESF funded 'New Focus' network programme (2011-). Cherniakov is UK representative in NATO set-152 group and Feresidis was awarded the RAE Senior Research fellow for 2013-14.
MDS Conference organisation include Cherniakov as chairman of the Radar 2012 International conference, Constantinou was chair of the URSI conference (2008-10), Feresidis was organiser of a special session at the International Congress on Metamaterials (2009), Gardner was co-organiser of IEEE special session on Antennas for SDR at IEEE APS (2010), Hall was co-

organiser and chair of IET Seminars on “Body-Centric Wireless Communications” (2009, 2011) and Lancaster organised the UK mm wave workshop at Birmingham in 2009 and 2013 (with NPL). The group members were additionally on 45 technical programme committees and chaired 32 conference sessions had 11 keynote and 37 invited talks winning 6 prizes.

MDS Contribution to journals includes Cannon as Editor-in-Chief of the American Geophysical Union Journal, Radio Science (competitive interview), Cherniakov on the Editorial board of the IET Journal Radar, Sonar and Navigation, and Ghafouri-Shiraz Associate Editor for IEEE Journal of Lightwave Technology, and member of the editorial board of Microwave and Optical Technology Letters. Also, Hall was on the Editorial board of Microwave and Optical Technology Letters and Tarte on Advisory Board of Superconductor Science and Technology. Feresedis, Gardner, Jackson and Hall are guest editors for a special issue of IET Antennas and Propagation. The group members had 4 invited journal papers.

In **HCI** we have developed new mathematical speech detection technologies (e.g. for regional accent, ethnic group, and children) in three EPSRC grants (£225k, £356k and £116k), in part using proprietary data collected under contract to our spin-out company The Speech Ark. Diversification of this theme is through with substantial work on multimodal interactions, extending the use of speaker recognition algorithms. This includes FP7 projects DETECTOR (€2.4M, £573k, £5k, 8 partners), looking at a range of aspects of surveillance and COGWATCH (€4.6M, £1.1M, £360k, 8 partners) using sensor data (body motion and gaze) from stroke patients. A BBSRC grant (£152k) with the School of Psychology, with funding from local government and Biocensus extended the work. We have maintained strong fundamental work in speech which is now strategically supported by GCHQ (£623k). A partnership with the University of Science and Technology China (USTC) has produced a 2+2 PhD programme. **Note for EU grants**, the 1st figure in brackets is the total project costs, the 2nd the funding the university receives and the 3rd the funding to EECE.

MRI signal processing expertise is applied to childhood cancer studies in collaboration with the School of Cancer Studies (Cancer Research UK University total £2M) and brain functionality with sleep disorders and epilepsy with the School of Psychology (EPSRC £179k). The former is with five other UK universities and their hospitals. Various imaging work funded by MRC with NMR spectroscopy on cancer tissue has resulted in new algorithms (Arvanitis paper 2) and insights into understanding cancers. Patient record processing and clinical trials support has been undertaken in the FP7 project TRANSFORM (€9M, £465k, £312k, 17 partners) and in other smaller NHS projects. Our biomedical informatics work extends to a spinal nerve interface with two DSTL grants (£65k and £87k) and a large EPSRC grant (£1.8M our share £213k) collaborating with Kings College and Cambridge University.

Games based simulation technologies for training and rehabilitation primarily directed towards defence applications has been strongly supported through a DTC (£1.4M) and industrial contracts (£0.8M). In addition there is EPSRC (£188k) support for work on visualisation for energy efficient buildings.

We have substantial collaborative work in mapping underground features (pipes, cables etc.) by non contact methods. A £2.5M EPSRC (£109k) award with 13 industrial partners supports work with the School of Physics developing new gravity sensors, and two collaborative EPSRC awards (£373k and £46k) totaling £4.1M and having 40 industrial partners looking at a multi sensor approach. Underground mapping has 11 journal and 10 conference papers.

HCI Esteem examples include Baber awarded the Institute of Ergonomics and Human Factors Bartlett Medal. Stone (FIEHF) was awarded the MoD Chief Scientific Advisor’s Commendation for research excellence in defence science and technology and he led the research team that was awarded the BAE Systems Chairman’s Bronze and Silver awards for efforts in support of “Gaming for Front Line Safety”. He was a member of the winning team Enterprising Birmingham Business Plan Competition. Stone was also Royal Academy of Engineering Visiting Professor in Integrated Systems Design, University of Plymouth and a member of the Australian Defence Simulation Support Panel, a member of the UK Simulation & Synthetic Environments National Technical Committee and represents the UK on a NATO Healthcare Technologies Panel. He is UK representative on the NATO HFM 215 Research Task Group on Advanced Training Technologies for Healthcare and trustee of the US Institute for the Visualisation of History. The HCI team was awarded the Ergonomics Society President’s Medal. Arvanitis (FRSM) is member of Brain Tumour Imaging SIG of the European Society of Paediatric Oncology SIOP-Europe (2011-) and Member of the Children’s Cancer and Leukaemia Group (CCLG): Functional Imaging Special Group FIG

(2007 –). Russell (FIMA) is Chair of ISCA special interest group on speech and language technology in education (SLaTE) and Elected member of IEEE Speech and Language Technical Committee (2009-2012).

HCI Conference contributions include Arvanitis as workshop co-organiser at IEEE International Conference on Advanced Learning Technologies, ICALT08 and organiser and co-chair of the IEEE International Conference on Cybernetic Intelligent Systems (2009). Baber was co-chair of the British Computer Society Conference (2012) and Russell chair and organiser of SLaTE 2009. Castellano general chair of workshops co-located with ICMI'08, ICMI'09, BCS-HCI'09, ACM Multimedia 2010, FDG 2013, workshop Chair for ACII'11 and BCS HCI'12 and publication Chair for ICMI'12. The group members were additional on 115 technical programme committees and chaired 17 conference sessions had 15 keynote and 25 invited talks winning 2 prizes.

HCI Contribution to journals includes Arvanitis as editorial Board Member of AACE Journal, International Journal on E-Learning and Journal of Biomedical Education. Castellano is a member of the Editorial Board of the Journal on Multimodal User Interfaces, and member of the Editorial Board of the International Journal of Interactive Worlds. Ousallah is an associated editor of the journals International Cybernetics Systems, Open Cybernetics Systems, ISRN Robotics, and Associate Review manager of Elsevier Information fusion. Russell is a member of editorial Boards for Computer Speech and Language, Natural Language Engineering and the editorial board for IEEE SLTC Electronic Newsletter. Stone is Editor of the journal Virtual Reality and on Editorial Board of Displays. There were a further 4 guest editorships and 2 invited journal papers.

In **RRE** the Railways Systems Research is supported by 38 industrial contracts (£4.2M), this includes a £1.8M strategic relationship with Network Rail. There is a £457k EPSRC Programme grant with Southampton and Nottingham Universities and there are 10 EU awards (total €54M, £1.7M 111 partners). 3 Case awards demonstrate commitment to basic research supporting their significant impact.

Our work on Energy has industrial and government funding (£1.7M), focusing on the development of long term framework agreements with National Grid (£433k) and EON (£235k). Interests from the former are initially real-time DC control and the latter electric vehicles and energy storage. These rolling projects are complementary to our FP7 project ICOEUR (€4.8M, £170k, £170k) and EPSRC funded work (£270k) developed through a UK-China workshop on smart grids with Cardiff University, Imperial College, Alstom, National Grid and China EPRI. The recent £6M EPSRC grant for the University Centre for Cryogenic Energy Storage (£968k to EECE) is positive for the future.

RRE Esteem Examples include Roberts awarded the National Science Foundation of China best Young Scientist. He is on the Executive board of the IET Railway Group and is whole systems performance manager for RRUK. Tricoli won the Dermot O'Sullivan ESA Power Electronic prize. Hillmansen is member of the IMechE conferences and seminars committee and RRUK representative on the industry panel: Future Fuels Technology Group. He was invited to present evidence to the Select Committee on Energy and Climate Change and presented to the Engineering Council of ATOC (2012).

RRE Conference organisation includes Hillmansen as chair of 4th International Conference on Railway Traction Systems (2010) and Chair of "Gaining Traction in Energy Efficiency" IMechE railway Division seminar, Westminster (2011). Brdys was chair of technical committee on Large Scale Complex Systems of the International Federation on Automatic Control (IFAC) (2008-2014, re-elected 2012); Tricoli was conference secretary for IEEE ICCEP (2009, 2011, 2013) and Zhang Secretary of the Technical Committee on Power Plants and Power Systems of IFAC. The group members were additionally on 47 technical programme committees and chaired 10 conference sessions had 7 keynote and 23 invited talks winning 5 prizes.

RRE Contribution to journals includes Brdys as Editor of ActaEnergetica, electrical power systems international journal and Hillmansen is Board Member of Proc IMechE Part F: Journal of Rail and Rapid Transit. Roberts is on the Editorial boards of Electrical Systems in Transportation (2010-), International Journal of Systems Support Technology (2007-) and International Journal of Condition Monitoring (2002-). In addition Zhang is editor of IEEE Transactions on Smart Grids, IEEE Transactions on Power Systems, IEEE Power and Energy Letters and Electric Power Components and Systems. In addition he is Founder and Co-Editor-In-Chief of Multidiscipline Modeling in Materials and Structures and international advisory editor of China Electric Power. There were a further 5 guest editorships and 3 invited journal papers.