Institution: Queen's University Belfast

Unit of Assessment: UoA13

a. Overview

Electronics and Electrical Engineering at Queen's has a long heritage in international research excellence. It combines this with worldwide university and industry links and major successes in technology transfer and spin-off company creation. Its continuing aim is to provide a vibrant, highly stimulating environment for conducting carefully selected research of the highest international standard, thereby attracting best calibre academic and postdoctoral staff, overseas visitors and PhD students. It also, for many years, has been to the forefront (often ahead of government policy) in using its research base to actively promote wider economic benefit. The School of Electronics, Electrical Engineering and Computer Science created in 2005 embraces UoA13 and UoA11 and comprises around 360 people (Academics/ PG Researchers/ PhDs/ Technician/Clerical). Research related to UoA13 is conducted in two divisions (i) The Institute of Electronics, Communications and Information Technology, ECIT, comprising High Frequency Electronic Circuits and Antennas, Secure Digital Systems, Digital Communications, (ii) Energy Power and Intelligent Control. Each cluster of activity comprises 30 to 50 people and is lead by a Director of Research.

b. Research strategy

Achievement of strategic aims during the assessment period

Over the assessment period the scope of activity and indicative achievements that have occurred within the UoA are identified below on a per research cluster basis. Significant new initiatives that have occurred (consistent with our RAE2008 future plans) include the creation of several major new multi-disciplinary centres. The largest development (£30M) is the UK's Innovation and Knowledge Centre for Secure Information Technologies CSIT funded by EPSRC/TSB. CSIT provides research and technology transfer for the safeguard and trustworthiness of information stored and transmitted electronically and is now an EPSRC/GCHQ Academic Centre of Excellence in Cyber Security Research.

High Frequency Electronic Circuits and Antennas HFE (Appleby, Buchanan, Cahill, Dickie, Fusco, Goussetis, Linton, McNeill, Mitchell, Mury Schuchinsky, Shitvov). Since RAE 2008 research, strengthened through the £5.4M Centre for Advanced Microwireless, has repositioned towards integrated millimetre wave systems and activity extended through strategic collaboration with industry and selected academic partners. Research is focused on providing technically advanced solutions for front-end transceiver and antenna applications in the range 40GHz to 850GHz. Activities encompass SiGe and GaAs millimetre wave MMIC design for Gigabit/sec wireless, (**Fusco, Mury)**, packaging, (**Linton**), sub-millimetre wave micromachined frequency selective surfaces, (**Cahill, Dickie, Fusco, Mitchell**), analysis and characterisation of artificial and anisotropic electromagnetic media, (**Goussetis, Schuchinsky**), passive intermodulation effects, (**Schuchinsky**, **Shitvov**), and innovative reconfigurable antenna technologies, (**Buchanan, Fusco**). Research capability in both MEMS and sensors has grown significantly, and now includes: advanced semiconductor and dielectric materials for customised SOI, MEMS and nanoscale detectors for environmental sensing and biomedical applications, (**McNeill, Mitchell**). Enhanced involvement at senior level in international networks of excellence include NEWFOCUS, mm-wave integrated dielectric focusing systems (**Fusco)**, ECONAM, Nanostructured composite materials, (**Schuchinsky)**. *Example achievements over the period include:* Two spin-offs LamhRoe, MicroSense. Creation of the world's fastest SPDT switch 5Gbit/Sec operating at V-Band, in association with Infineon Technologies AG through a €1M Marie Curie GigaRadio IIAP (**Mury, Fusco**). The world's only self-tracking mobile broadband BGAN satellite communication array, with ESA and Cobham. (**Buchanan, Fusco**). Triple band feed for Direct Broadcast Satellite HDTV, with Global Invacom (**Linton**). The world's first ultra-low loss polarisation independent micromachined FSS filter in collaboration with RAL Space, Astrium. (**Cahill, Dickie, Fusco, Mitchell)**. *Collaborations include:* EADS Astrium, Powerwave, Global Invacom, Infineon, Universities of Madrid, Cartagena, (Reflectarrays), Aalto University, Helsinki, (Metamaterials), North Carolina State University, USA (Passive Intermodulation).

Secure Digital Systems SDS (McAllister, McCanny, McLaughlin, Murphy, O'Neill, Sezer) Research addresses information and cyber security, communication signal processing and embedded systems. Since RAE 2008, the research has evolved with a particular focus on security, with the cluster playing a key role in the establishment of the EPSRC-funded CSIT IKC. *Major achievements*: the first FPGA–based 40GBit/s complex traffic analysis system for internet and cloud security, commercialised by Altera and Netronome; the world's first botnet detection system using only network traffic analysis (collaboration with IBM/QRadar) (**Sezer, McLaughlin**). Novel quantum-dot cellular automata (QCA) design methodologies and the first to illustrate QCA's potential to defend against side channel attacks (collaboration with UT, Austin). Hardware performance evaluation of Round 2 SHA-3 candidates - formed part of US NIST SHA-3 selection process (**O'Neill**). First proposed use of self-timed logic for PUFs which significantly reduces the area cost (**Murphy, O'Neill)**. The world's first real-time quasi-ML Detector for 4x4 802.11n WiFi; a platform-portable model-based design toolset for commercial off-the-shelf FPGA platforms - spun-out to Analytics Engines Ltd. (**McAllister)**. One spin-off company was formed, Titan-IC, providing content processing acceleration for network security and big-data analytics (**Sezer**). *Collaborations include:* S.Korea's Electronics, Telecommunications Research Institute (ETRI) $3M (PUF/Cloud Security), BAE Systems (zero-day attacks), Thales (homomorphic encryption), Altera (traffic classification), Cisco (intrusion detection), McAfee (mobile malware analysis), IBM (SCADA security/botnet detection), Infosys (cloud security), Xilinx Inc., National Instruments Inc., Selex Galileo, (embedded systems design processes), CyLab Carnegie Mellon (cyber security), UC Berkeley (SCADA security), RWTH Aachen (hardware architectures).

Digital Communications DC (Conway, Cotton, Garcia, Ko, Matthaiou, Scanlon, Van Walstijn, Woods) This cluster covers a selected range of activity within the digital communications theme including both fixed and wireless networks including network management, security protocols, wireless propagation and digital signal processing (algorithms and implementation, including audio applications). Main developments since RAE2008 include the establishment of a wireless communications group covering physical link and network layer research, with major focus on body centric communications (**Conway, Cotton, Garcia, Ko, Matthaiou, Scanlon**). Programmable systems research (**Woods**) has concentrated on the development of FPGA cores which provide optimally efficient performance. Three spin-off companies, Analytics Engines (**Woods**), tools and methodologies for programming heterogeneous platforms, ACT Wireless Ltd (**Cotton, Scanlon**), secure, ultra-low power active RFID technologies for personnel tracking, Traffic Observation and Management TOM Ltd, embedded wireless security, have been created. *Some major technical achievements in the period are:* Technology to enable large vocabulary continuous speech recognition to be embedded in small electronic devices; this work won the High Technology Award at the Northern Ireland Science Park 2010 CONNECT £25K competition (**Woods**). The world's first FPGA-based methodology for the complete design of a musical instrument (**Van Walstijn**). *Example collaborations include:* Xilinx Inc. who provided a laboratory within the UoA; National Instruments and University of Maryland, USA (Programming tools); University of Leiden, Netherlands (FPGA architectures); Twente University, (Short range radio), University of Michigan, USA (Musical Instruments), University of Campinas, Brazil (Channel Modelling). EPSRC eFutures XD 'Maximising the Impact of UK Electronics Research' with Manchester, Southampton, Liverpool, Glasgow, Newcastle.

Energy, Power and Intelligent Control EPIC (Bai, Best, Ferguson, Irwin, Laverty, Li, Littler, Liu, McLoone, Morrow, Naeem, Rafferty) Since RAE 2008 network integration of renewable power generation has been reinforced through extending strategic collaboration with Caterpillar Electric Power Division, Areva T&D, Scottish & Southern Energy, EirGrid. Further broadening of inter/multi-disciplinary research has been achieved through engagement with QUB Civil Engineering on one of the four RCUK UK China Science Bridge projects (**Irwin, Li, Littler**) and through collaboration with CSIT on the security of smart grids (**Laverty, Littler**). Other research has focused on the stability and control of transmission systems with high penetration of renewable power (**Best, Laverty, Littler, Morrow**), smart grid control and protection technologies (**Littler, Liu, McLoone, Morrow**). Eighteen funded PhD projects with top tier Chinese universities e.g. Harbin Institute of Technology facilitate knowledge transfer. Joint laboratories developed include an 'Energy and Automation' laboratory with Shanghai University supported by Shanghai

Automation Instrumentation Co. and Baosight Ltd. (**Irwin, Li**). Other major activities include HAPTIMAP, €6.6M FP7, which aims to deeply embed accessibility into digital mainstream maps and mobile location based services (**Ferguson, Naeem**, **Rafferty**) and EPSRC funded activity on thermal management and adaptive control of polymer processes (**Li**). *Sample achievements over the period include:* Industrial collaboration with ESB Independent Energy leading to six postgraduate scholarship bursaries in Power and Energy (**Littler);** Implementation by Caterpillars' Electric Power Division of a patented control system for improved load acceptance of stand-by generators (**Morrow)**; A laparoscopic surgical simulator, selected as a finalist in the 2011 IET Achievement awards (**Ferguson, Rafferty**), and an advanced automatic guidance landing system in association with Cobham Flight Inspection Ltd. and CAA UK (**Rafferty**). *Collaborations include:* University College Dublin (Charles Parsons Award €2M on network integration of wind generation); Strathclyde, Manchester, Edinburgh, Bath, Tsinghua, Zhejiang and Southeast University (EPSRC UK-China Joint Research Consortium on sustainable security of power transmission with renewable generation) and the major IET Power Academy.

Over the REF period approximately 18 *Prize winning publications* have been awarded. These include *(*2010) HA Wheeler Prize IEEE Trans. Ant. and Prop. **Cotton, Scanlon**; (2012) Inst. Measurement and Control, **Ferguson**; EUCAP Best theory paper, **Goussetis**; (2011) IET premium best paper Micro. Ant. and Prop., **Fusco**; (2008) IEEE Trans. Micro. Theory Best Paper, **Schuchinsky**.

UoA volume of outputs estimate

IEEE Journal	IET Journal	Other Journal	Books	Book Chapter	Conference Paper	Major Report	Patents Awarded	Patents Filed
165	67	178	14	32	890	39	19	8

Future vision and strategic aims for research

Through recent core appointments, see section c(i), and infrastructure investments, we have initiated a rolling process by which we are extending technical specialties in areas where we have significant superior technical differentiation with respect to other leading research groups, e.g. within **HFE** (Higher Performing Antenna/Circuits), **DC** (Context Aware Wireless), **SDS** (Cyber Security and Cryptographic Hardware), **EPIC** (Network Integration of High Penetration Renewables). Importantly we wish to actively pursue a significant expansion of the activities within ECIT such that it will provide a research forum for major cross school (UoA13, UoA11) research with external partners. This will allow us to; (i) provide research leadership through well informed structured and resourced programmes of work conducted at the highest international standard; (ii) continue and expand our role as partner of choice working with leading academic, industrial and government organisations; (iii) reinforce our operational environment in order to maximise our potential for success through increased cross-cluster/multi-disciplinary collaboration in carefully selected research topics of major significance such as identified below; (iv) be a primary destination of choice for the world's most capable researchers.

HFE Activity focus will be on microwave, millimetre through sub-millimetre enabling technology supporting high data rate communications and advanced imaging systems. The objective is to develop novel electromagnetic materials, monolithic circuits and antennas, together with strategies for their integration. These will then be used to facilitate the development of innovative space and terrestrial systems that can perform better and at higher levels of functionality than current systems. **DC** Focus will be on transformative research in wireless communications which demonstrably addresses the major challenges of spectrum, energy, security and privacy. Activity will be driven by the development of new theoretical perspectives which incorporate real world constraints such as propagation channel effects, interference and radio hardware limitations. This approach will lead to advances in emerging applications such as massively MIMO, context-aware, self-aware and self-organising networks, body centric communications and ultra high bandwidth mobile network architectures. **SDS** Future research will centre on cyber-physical, mobile and cloud security. In particular, research on critical infrastructure security SCADA will be extended into broader cyber-physical security applications. Research will include the hardware acceleration of homomorphic encryption for cloud security and the definition of embedded cyber security architectures as an integral part of the future cloud computing fabric. Research will be carried out

into emerging mobile security challenges in Android and iOS and the protection of mobile devices directly within the cloud. Advanced techniques for embedded device authentication using PUF technology will be investigated. Research will also be carried out into the security of wireless communications using novel DSP techniques. **EPIC** Renewable integration is a global challenge with, due to its size, the Irish grid being recognised as a world class test bed. Privileged access to data from various sites will allow innovative research on PMUs for power system monitoring. Activity in wind integration and innovative smart grid research in-conjunction with key commercial stake holders both in Ireland and the UK (SONI, NIE, Eirgrid, Kelvatek, SSE) will be extended. We intend to build on our strong record of fundamental and applied research in data driven process monitoring, modelling, control and optimisation applied to manufacturing and energy systems (manufacturing and energy informatics). Working with partners such as Intel, Seagate and Pfizer our informatics expertise, strengthened through recent academic appointments will enable us to work across a number of application areas with primary focus on developing decision support systems for advanced manufacturing and smart grid applications.

c. People:

i. Staffing strategy and staff development

The UoA has a formal rolling three-year strategic plan created through the assimilation and integration of annually updated inputs from each research cluster. These identify areas of focus, new research topics, resource requirements and objectives. Monitoring is performed through relevant key performance indicators generated by the UoA in discussion with the University. Overall staffing priorities are determined by a senior management committee comprising the HoS and research cluster directors (each a Professor), reporting via the Dean and Pro-VC to the university management board. Considerable effort goes into ensuring staff engagement takes place at all planning stages.

The UoA currently has 1 FRS, 4 FREng, 3 IEEE Fellows, 7 FIET, 3 MRIA (Royal Irish Academy, Fellow equivalent) and 1 FIFAC. Sixty percent of staff have professional registration with IET and 85% with other professional bodies such as the IEEE. Over the REF period the UoA hosted 6 Marie Curie Experienced Research Fellows and 4 EPSRC/RAEng Fellows. Uniquely through ECIT and CSIT 22 engineers are tasked for technology transfer. These personnel are on industrial style contracts. The UoA has an active and continuously on-going academic staff recruitment policy which aims to recruit only the highest quality staff with proven track records to senior positions, and those with clear leadership potential to more junior positions. Targeted recruitment was aimed at, Smart Grid, Communications Signal Processing/Engineering, High Frequency Electronics and Network/Malware Security. At July 2013 the academic staff within the School is diverse in terms of its international make up, approximately 21 UK, 6 EU, and 8 other. During the REF 2014 census period, measured at July 2013, 9 new academic staff had joined the UoA, 5 academic staff had retired and 5 had left. Two staff were promoted to Senior Lecturer, 3 to Reader, 4 to Professor and 2 visiting Professor appointments created, **Appleby** (millimetre wave imaging), **Bai** (advanced process control). New academic appointments were targeted specifically to replace lost, or to develop expertise in thematic areas directly relevant to the UoA strategic research plans, for example a chair in the **EPIC** cluster to provide research direction leadership, **McLoone**. The new academic appointments include early career researchers, **Cotton** (body worn antennas and on-body propagation), **Ko, Matthaiou** (Wireless networks)**, Best** (distributed power system monitoring), **Laverty (**Smart Grid), **Thian** (mm-wave MMICS), **Mc Laughlin** (SCADA security), **Murphy** (advanced Crypto hardware). These appointments add to our increase in highly research active academics, help succession planning and reduce overall UoA age profile.

Individual staff progress monitoring is carried out via the staff appraisal process. All staff, including staff on probation, are appraised twice yearly with objective setting and mentoring towards objective realisation and career progression planning taking a primary role. Support is provided to any member of staff who, through appraisal, has had an area identified for improvement or has needs for specific training. This support is provided through additional personal development and/or one-to-one mentoring from a more senior staff member. Arrangements are the same for all categories of full time and fixed term staff. Financial support for UoA specific training activities is provided through the School Training and Development Plan. The plan is jointly funded by the

University Staff Training and Development Unit (STDU) and the School. SDTU also provide a range of central courses in skills development, and provide conference and networking event participation funding. Approximately £150K per annum is budgeted by the UoA for staff training.

QUB has HR Excellence in Research certification (2012-) which links to the Concordat for the Career Development of Researchers and to the QAA Code of Practice for Research Degree Programmes, that acknowledges alignment with the principles of the European Charter for Researchers and Code of Conduct for their Recruitment. In January 2012 Queen's agreed a Concordat Implementation Plan, which outlines a range of tasks and targets, central and UoA based. The University, an Equal Opportunities employer is committed to the promotion of equality of opportunity and to creating and sustaining an environment that values and celebrates the diversity of its staff and student body. The University, through its gender initiative, has actively sought to improve the working experience of women on a range of issues, and is the only EEE department in the UK to be awarded a SWAN silver award (2011). This recognizes good employment practice for women working in science, engineering and research. In 2011 two females within the School were promoted to Professor **Maire O'Neill**, the youngest and first woman ever to be made Professor in EEE at QUB, and **Weiru Liu** the first woman to be made Professor within QUB Computer Science, UoA11. In 2012 the ECIT institute was the first QUB and one of the first UK University units to be accredited to the national standard Investors in People**.** In 2013 the School (UoA13, UoA11) was also accredited. Between Jan. 2008 and Feb. 2013 the UoA employed 106 Post-Doctoral Researchers, 22 ECIT Engineers, 15 Technical and 12 Clerical staff.

Prestigious Fellowships Honours/Prizes/Awards: **Appleby** Fellow RAEng (2009), Senior Fellow QinetiQ (2010). **Buchanan** ESA young engineer of the year (2010), RAEng Enterprise Fellow (2012). **Cotton** RAEng Sir George McFarlane Award (2011), Phillip Leverhulme Prize (2011). **Naeem** Denny Medal (IMarEST) 2012. **Fusco** IET Senior Achievement Award the Mountbatten Medal (2012). **Irwin** Fellow of the International Federation of Automatic Control, (2009), Inst. of Meas. and Control Sir Harold Hartley Medal (2010), IFAC Outstanding Service Award (2008), **Li** Shanghai S&T industrial prize (2009), Creation prize China international industry fair (2010). **McCanny** Royal Irish Academy most senior award the Cunningham Medal (2011).

Personal Fellowships won in open competition: EPSRC/RAEng Research Fellowship, **Cotton, Goussetis, O'Neill, Shitvov,** EPSRC Leadership Fellowship, **O'Neill.**

UoA staff holding visiting/adjunct Professorships: **Appleby** Glasgow University 2010-2013, **Fusco** University of Paris-Est 2011, UPCT Cartagena 2012, **Goussetis** UPCT 2011, **Li** Harbin Institute of Technology, 2011-2013, Ningbo Institute of Technology, 2010-2013, **McCanny** Shanghai University 2011-.

We have an active *Visiting Professor* scheme typically attracting 2-3 top tier international persons per year, e.g. 2011 **Prof. S. Haykin**, McMaster University, Ontario, pioneer in adaptive signal-processing in radar and communications, 2010 **Prof B. Madahar**, Chief Scientist DSTL.

Distinguished lectures. These normally occur on at least a monthly basis and are given by major international visiting scholars. Examples include: **Prof M. Tentzeris** Director for RFID/Sensors Georgia Institute of Technology, **Prof M. Flynn,** Stanford University, multiple international award winner for his major contributions to computer architecture design, **Prof. C. Wu,** Former Chinese Chief Scientist Automation Technology.

ii. Research students

Research Student Recruitment Strategy

The UoA has a dynamic recruitment strategy and employs a dedicated research student marketing and recruitment officer, also a number of School staff act as international champions. Targeted links with China, India and Malaysia have been formed and have resulted in funded initiatives to support international research student recruitment, e.g. with Harbin IT, a top 10 Chinese university, funded through the QUB International Engagement Fund. Also split site PhD programmes e.g. with China under the EPSRC Science Bridge initiative have been formed. Plans for the

internationalisation of research and education activities place particular emphasis on the development of strategic international partnerships implemented via a School based International Collaboration Task Group set up for this purpose.

The central University Postgraduate Office provides support in terms of research opportunities and studentships. Widely advertised postgraduate open information sessions are held each year. Research opportunities and PhD studentships are advertised on School and University dedicated web sites and in the press. UG and PGT students are actively encouraged to consider research opportunities. All PG candidates are subject to the International Code of Conduct administered by the School student progress research committee which handles all PG related issues including progression and discipline. The University is required to monitor Tier 4 international students, and all research students are required to maintain regular contact with their supervisors. Academic staff have been successful in obtaining PhD studentships through EPSRC, EU, DEL, GCHQ industrial sponsorships e.g. McAfee, Diageo, Thales, Schrader, and from overseas universities for the development of their own academic staff, e.g. University of Tun Hussein Onn, Malaysia, as well as through self funding routes. Over the REF period approximately 65% of graduating PhDs went into industry, 20% into national and international full time academic posts and the remainder into university research posts.

Research student environment

QUB (2011) completed a £1.3M International Postgraduate Support Centre which provides dedicated support and facilities to all of the Universities postgraduate students, a new £50M library was opened in 2011. Our Postgraduate Researcher Development Programme (PRDP) which links directly with the National Researcher Development Framework supports PGR students in the development of their research and transferrable skills, career development and employability. QUB has a dedicated PG training team as well as state-of-the-art facilities within the PG student centre. An online 'Personal Development Planner' tool has been developed to facilitate training and development needs analysis. A Researcher Plus award, an initiative welcomed by business, provides accreditation for the development transferrable skills. In 2011 the School launched a dedicated research society whose mission is to enhance the quality of research students and post doctoral workers experience by providing a voice for the research community within the School and to promote opportunities for career advancement, personal development and social interaction. The School also provides financial support to research clusters to run specialist programmes and clubs (e.g. the HFE Research Seminar Programme and Journal Club). Research students are invited to attend internal development sessions (for instance the IET run an annual in-house course on 'Technical Paper Writing'). All new 1st year Postgraduate Research Students are assigned a mentor in order to support them with the transition to the research environment.

d. Income, infrastructure and facilities

Since January 2008 the UoA research funding portfolio consists of a healthy balance of EPSRC to other (EU FP7, Industrial, other government/charity/philanthropic), in the ratio 2.2:1. Future plans related to generating research income involve several major strands. Enhanced industrial revenue will be pursued through our in-house business development personnel who will develop jointly with industry activity roadmaps on a per research cluster basis so that alignment of need can occur and thus better facilitate leverage of new research income. We intend to continue to significantly increase our engagement with relevant EU programmes. QUB is one of 11 universities who in terms of research funding drawn from EPSRC hold between them 30% of the portfolio. Consequently we have a strategic relationship with EPSRC with whom we work closely together, sharing information and strategies, and spreading best practice. Through this relationship the UoA has leveraged an EPSRC Doctoral Prize, 2 international PhD studentships, 5 summer internships as well as funding for developing pathways to impact. In addition to refining our industrially funded portfolio we wish to enhance government research funding through increased high quality applications which are centred around Horizon 2020, EPSRC, BIS, strategic aims and which are relevant to the needs of the UoA range of research activities. Such activities include Secure IT for the consumer and commercial sectors, advanced high data rate and on-body communications, as well as sustainable energy integration into the smart grid.

Current and planned investment in specialist infrastructure and facilities

Specialised infrastructure and facilities within the UoA are continually upgraded e.g. in 2012/13 the Ashby Institute housing the **EPIC** cluster was extensively refurbished, £525K, additionally research laboratories (mirrored at Shanghai and Harbin) were constructed. Recent **ECIT** upgrades include: 24 x high end servers including HBA connectivity to 4 x Fermi class GPGPU (Tesla C2070s) for single- and parallel- mode GPU calculations, 38TB of scalable backup for research continuance and assurance; **DC** New capability in propagation simulation tools and measurements including hardware accelerated full-wave electromagnetic modelling parallelised PC-cluster ray-tracing (8 x Core i7 workstations) installed and a custom-designed BlueTest reverberation chamber for channel and body-centric antenna measurements commissioned. **HFE** far field anechoic chamber coverage was extended to 110GHz, and quasi-optical measurements extended to 850 GHz. CST EM computational environments were expanded to include multiprocessor capability. ESA and industrial funding, £490K, has enabled our MEMS manufacturing capability to be extended to the 300mm diameter substrates required for future space missions, making our MEMS facility the primary ESA sub-millimetre wave FSS manufacturing facility in Europe. **SDS** have significantly upgraded high-performance and specialist computing infrastructure for larger scale chip design, (synthesis and simulation), malware analysis and cyber threat/cyber-attack simulation. A state-of-the-art test network, comprised of high-performance network nodes (routers/switches), over 50 networked PCs and servers, traffic capture and analysis equipment and software packages for emulating small to medium size corporate network infrastructures has been commissioned. This was funded by industrial donations from Mentor Graphics, Q1Labs, QosMos, to a value of $3M US.

Planned infrastructural boosts 2013 and beyond include: Full ESA certification of our MEMS facility and expansion of its remit to include commercial as well as research service provision. Development of a competence centre in the area of Capital Markets (with UoA inputs on high speed hardware for data mining). Expansion of CSIT to second phase majoring in the security of cyber-physical systems.

Provision of UoA facilities to external organisations Both large companies and SMEs lease UoA13 facilities, examples include Plextek, OMMIC, QinetiQ. The HFE cluster provides transfer standard calibration for the universities commercial EMC pre-compliance testing service (30 SMEs over the REF period). Training and technology evaluation for industry is routinely undertaken. Such activities are often funded through Knowledge Transfer (KTS) or Innovation Voucher schemes.

Staff consultancy The UoA views consultancy as an activity that complements our ambitions in research and further enhances our impact on society and the economy. We have in place a consultancy scheme whereby staff are permitted to undertake up to 30 days paid consultancy per year. The scheme is managed through the Universities Knowledge Exploitation Unit.

UoA Spin off/in Company Directorships UoA spin-offs are actively encouraged as is spin in activity. Recent academic staff spin-in founders or directors include **Scanlon** ACT Wireless Ltd., **Appleby** MMW Consulting, **Fusco** LamhRoe Ltd., MicroSense Ltd, **McCanny**, **Sezer** Titan IC Systems Ltd., **Woods**, **McAllister** Analytics Engines, UK.

e. Collaboration or contribution to the discipline or research base

The UoA uses programme specific industrial advisory boards, e.g. ECIT International Advisory Board, includes 3 FRS, 6 FRAEng, 6 IEEE Fellows, to review current research and provide focus for strategic research effort direction, as well as to provide advice on the creation of spin-off companies. Also our partnerships within CSIT have enabled confidential review by senior personnel indicating the priorities from government in the areas of cyber security. Through EPSRC and EU networks, e.g. EPSRC eFutures and eFuturesXD (2009-15), we aim to form opinion within the academic community in a variety of aspects of electronics research in a bid to address major future challenges, e.g. collaboration with the DTI resulted in the DTI strategic renewable energy strategy UK report DT/E0066450/1, 2008 **(Littler)**. This work has directly influenced UK renewable energy integration policy and has set the scene for EPIC cluster future work on secure smart grid technology. International collaborative research projects also play an important role. The **SDS** cluster is developing secure communication modules for use in national Korean Electric Vehicle (EV) charging infrastructure trials. To date, a novel security protocol for EV charging has been licensed to LG-CNS. Queen's Academy in India sponsors academic researcher up-skilling, and

UoA agreements with major India Industry such as InfoSys are in place.

The UoA via its ECIT Institute has pioneered the development of a substantive Capital Markets Engineering collaborative research program. Companies who pay a substantial annual membership fee include Citi, NYSE Technologies, Fidessa and Kofax. This funds 10 PhD inter-related multi-disciplinary studentships. The results of the research are shared with all member companies. CSIT founded and hosts the invite only World Cyber Security Technology Research Summit which brings together global representatives of government, academia and industry to discuss the state of cyber security technology, horizon scan, and establish agreed priorities for research activities and articulate the impact of emerging/existing technologies. 2012 participants included the chief scientific advisor UK Home Office and the cyber security division director, US Homeland Security.

BIS/EPSRC/Other major consortia involvement: **Irwin** leader of UK-China Bridge in Sustainable Energy and Built Environment, advisor Portugal national research programme**; Littler** BIS Consortium: Smart Grid Oscillation Management; **McCanny** Centre for Secure Information Technologies, CSIT, 25 national/ international companies and government organisations, TSB Emerging Tech. Strategy Group, EPSRC Chief Exec. Advisory team; **Morrow** EPSRC Supergen V, Power Network Research Academy; **Scanlon** Director WirelessLAB–all Ireland trade association; **Sezer** leads EPSRC Network of Excellence in Internet and Mobile Malicious Software. **Woods** MIDAS Ireland, Microelectronic Industry Design Association.

EU FP7 Programme leadership: **Fusco** FP7 ESF NewFocus NoE UK representative, 2009/10, Marie Curie IIAP Gigaradio 1.2M€ 2009-2013, **Goussetis** Management committee RFCSET COST action, **Linton** FP7 Handhold, BeWiser 2011-14, **Schuchinsky** FP7 PI M Curie Industrial doctoral project ARTISAN 1.2M€, FP7 ECONAM, NoE Metamorphose Steering Committee, Board of Directors.

Such activities help enable the UoA to develop its strategic research direction in the area of next generation of disruptive technologies in manner tightly coupled with the needs of industry and universities/research institutes through road mapping, commercialisation and knowledge transfer.

Staff have major substantive national/international professional involvement, steering strategy, and influencing major funding decisions. Some exemplars are elaborated below.

Learned Society Engagement: **Appleby** RAEng 2011/12 Eng. leadership award panel chair; **Fusco** Royal Irish Academy Comm. for Engineering Science, Comm. for Engineering Science Education; **Irwin** Royal Academy of Engineering Research Fellowships Panel 2011; **McCanny** Royal Society, Hooke Comm., 2010-13, Fellowship Comm.2011-14, Chair Cyber Security Research Policy Steering Group 2013-. RAEng Council, 2008 -11, Int. Comm., 2009-12. RIA Council 2013-.

Academic staff are involved in high level international/national advisory at national, international level and with the EPSRC Peer Review College. Some examples are: **Linton** DSTL/MOD Cyber Exchange Spectrum Member (2010-2015); **McCanny** International Advisory Board, €32M, Excellence Initiative, Centre for Ultra High Speed Mobile Information and Communication, University of Aachen, 2007-, Board National Tyndall Institute 2004-11, Deputy Chair 2006-11, UK Cyber Security Growth Partnership; **O'Neill** Young Advisors Group to EU Digital Agenda Commissioner Kroes, 2010 –; **Scanlon** Chair Comms Advisory Panel Academy of Finland 2012. *Professional society committee membership* is very strong, e.g. **Fusco** URSI RoI National Representative Commission B, Executive Comm. IEEE EDMO UK/RoI (2005-), IET Exec. Comm. for Microwaves Antennas and Propagation (2009-); **Irwin** Council of the Institute of Measurement and Control (2007-09), IFAC Publications Management Board (2011-14), IFAC Technical Board (2011-14), IFAC Presidential Task Force for High Impact Paper Award, (2009), Chair IFAC Awards Committee (2008-11); **Laverty** N Ireland IET Young Members' Chair (2008-10); **Li** Chair, IEEE Control and Communication Chapter Ireland, (2009-); **Linton** IET Executive RF and Microwave Engineering (2008-), IET TPN Steering Committee member (2008-); **Littler** IET Power Academy

Scholarships and Peer Review Committees, IET Power Academy Executive (2009-10); **McAllister** IEEE Signal Processing Society Technical Committee; **McLoone** member IFAC Technical committee Cognition and Control, (2005-); **Rafferty** Chair IET NI Branch (2011); **Scanlon** IEEE Intl. Comm. on EM Safety (2009); **Schuchinsky** Board of CIMTEC-12 Conferences; **Woods** Board IEEE Signal Processing Society Technical Committee Signal Processing Systems (2009).

UK/ Other Government Funding Review Examples: **Fusco** 2011- Czech Science Foundation, 2009 Irish Research Council, Royal Society Fellowships 2010, UK Leverhulme Trust 2010; **Irwin** Science and Engineering Research Council (SERC), Singapore (2009); **Rafferty** National Research Council Canada 2010, Evaluator Marie Curie Awards for the FP7 programs (2008).

Staff are heavily involved in high quality conference organisation and presentation as well as journal editorship and peer review, for example.

Eighteen keynote and twelve plenary addresses. Including *Keynote:* **Appleby** 2012 SPIE Defence Conf.; **Littler** IEEE Power Technology (Norway), IEEE Power Eng. (US) 2011; **Mc Canny** 2012 Irish Academy of Eng./Intel lecture, 2012 UKTI Tech World lecture, IEEE Int. Conf. on Intelligent Computing for Sustainable Energy 2010; **Schuchinsky** 2013 11th Conf Ferrites, Okinawa. *Plenary:* **Cahill** 31st ESA Wkshp, 2010; **Scanlon** IEEE Intl. Wkshp on Ant.Tech. (2010); **Woods** 17th European Signal Processing Conf., 2009. *Invited:* Approximately 71 invited talks were delivered at high profile international conferences and at important knowledge transfer workshops such as the European Trading Summit and NATO strategy events; e.g. **O'Neill** UK delegation which spoke at the UK-Japan 2008 Symposium on Privacy and Security, Tokyo. *27 Staff have acted as Chair / Co-Chair for major international conferences, examples are;* **Naeem** IEEE Int. Conf. Intelligent Computing Sustainable Energy (2012); **Scanlon** 3rd European Wireless Tech. Conf., (2010); **Schuchinsky** Int. Congress on Advanced EM Materials (2011/12); **Woods** Asilomar IEEE Conference on Signals, Systems and Computers (2011).

Conference Organisation: About 24 staff have been involved in the organisation of over 118 major international and national TPC / Programme Committee / Steering Committee activities sponsored by the IEEE, IET, SPIE, IFAC, etc. All academic staff have been actively involved as session chair or as special sessions organisers.
Academic staff currently serve on the editorial boards of 18 Journals as well as journal editors/ associate editor, examples include; **Irwin** IFAC Journal, Control Engineering Practice; **Li** Trans. Inst. of Measurement and Control (Sage); **McAllister** Ed. IEEE Signal Processing Society tutorial library; **McCanny** Journal of Signal Processing Systems, Springer; **McLoone** Trans. Inst. Meas. And Control**; Schuchinsky** Metamaterials Journal Elsevier.
Staff serving in the role of guest editor include: **Appleby** Optical Engineering, 2011; **Cotton,** 2012 Annals of Telecommunications, Springer; **Li,** Trans Inst. of Meas. and Control, 2006, 2007, 2010; **McCanny** Journal of Signal Processing, Springer, Editor Multi-Media Processors, 2008; **Schuchinsky** Elsevier Journal Metamaterials, 2009.

Example research agreements signed with high profile universities for bi-lateral staff and research student exchange, include IIT Delhi, Beijing Electric Power Research Institute, China, Shanghai Jiaotong University, ETRI, Korea, Hangyang, Korea, National Chaio Tung University Taiwan, Harbin Institute of Technology, China.
Examples of academic collaborations funded through EPSRC, EU, NSF, other include: **UK**:UCL, Imperial, Sheffield, Warwick, Birmingham, Newcastle, Manchester, Glasgow, Southampton, Royal Holloway, Bristol, Heriot-Watt: **ROI:**UCD, UCC: **EU:**Darmstadt, Chalmers, Twente, Oviedo, Madrid, Lund, Louvain, Roma Tre: **USA:** Berkeley, Austin, Irvine, Georgia Tech: **Far East:** Zhejiang, Tsinghua, China, TaiChung Taiwan, (ETRI) South Korea, IIT Delhi India.
Examples of funded industrial collaborations include: **CASE studentships:** Space Engineering SpA, FG Wilson, Powerwave, Global Invacom: **Funded industrial contracts:** ETRI South Korea, £4.5M, Security Threat Response (**O'Neill** 2012). National Instruments, Xilinx Inc., QinetiQ, Selex, Orange Labs, Seagate, Zarlink, Andor, BAE Systems, WrightBus, Infineon, Astrium, Alstom, Caterpillar, Adidas, Thales, Analog.