

<p>Institution: Plymouth University</p>
<p>Unit of Assessment: 13</p>
<p>a. Overview</p> <p>Research in Electrical and Electronic Engineering is based principally within the School of Computing and Mathematics (SoCM), though staff collaborate closely with researchers in the School of Biomedical and Biological Sciences (SoBBS) and other parts of the University. This interdisciplinary orientation has developed in relation to a key recommendation of the International Review Report produced by the Royal Academy of Engineering/EPSRC Report (2004), <i>The Wealth of a Nation</i>, which argued that there should be greater interaction between engineering and both basic science and mathematics. This interaction has been further carried forward in the light of the feedback on our submission to RAE2008.</p> <p>A university-wide strategic review of research organisation and management encouraged the formation of inter-disciplinary Research Centres to build on areas of strength and to respond effectively to external drivers. As a result, our research is now focused through two Research Centres. The Centre for Security, Communications and Network Research (CSCAN) is a basis for our collaboration with computing and mathematics staff through complementary research strengths in cyber security and communications. It is aligned with national and international research agendas for digital economies. The Centre for Research in Translational Bio-Medicine (CRTB), based in SoBBS, brings together staff specialising in biomedical science, healthcare, and clinical medicine, with our own engineering specialists in diagnostics and bio-sensing.</p> <p>Our aim since the formation of the Centres has been to address key international concerns while yet remaining at the forefront of the UK agenda. Location in the South West, a region identified by the European Union as a deprived economic zone, provides both distinctive research opportunities and an ability to bring direct benefits to the local area through the multi- and inter-disciplinary research carried out by subject specialists in both CSCAN and CRTB.</p>
<p>b. Research Strategy</p> <p>The shared strategic vision of CSCAN and CRTB is to carry out internationally-leading interdisciplinary research with international collaborators in interdisciplinary teams able to deliver innovative solutions to challenging problems and to illuminate our understanding beyond existing fields of research. This vision underpins our formulation of a concrete strategy for the development of research.</p> <p>Our research strategy has five aims:</p> <ol style="list-style-type: none"> 1. To perform research of the highest quality and to continue to raise the level and ambition of our activities to world-class and world leading standards of excellence. 2. To pursue national and international research funding, and align our strategic objectives with national and international research agendas through strong national and international collaborative partnerships, in particular collaborative partnerships with researchers in Europe, USA, and BRIC countries; 3. To bring leading-edge research to research end-users, developing and utilising intellectual property, in order to contribute to the knowledge-based economy and to ensure our research has maximum impact and social benefits; 4. To foster public engagement in engineering research and innovation, and improve understanding of it, using a range of media and communication channels. 5. To embed research in the student experience, creating a vibrant environment, inspiring students to pursue innovative research, and enabling researchers to develop in their careers. <p>The review and regular monitoring of these strategic objectives, in consultation with academic and external advisors, is the responsibility of the Research Director and management team in each Research Centre, with the work of the Centres being coordinated through cross-school collaboration and the Faculty Associate Dean for Research. The Research Centres report annually to the Faculty Research Committee and performance is monitored by the University Research and</p>

Innovation Committee.

Discussions within the two Research Centres have identified the need for us to contribute towards regional economic development and security and to address the problems of an ageing population, since these are key issues of concern in our region and are areas where we know that we can make a contribution through our internationally oriented research. While we actively target issues of major concern in the south-west region, we are always mindful of their applicability and importance in a wider arena.

We scan Research Professional and other sources for research opportunities, aiming to be able to respond to new initiatives or research opportunities announced by RCUK or EU research bodies. New opportunities are discussed and refined at research away-days that enable the formation of new research collaborations and ideas for project proposals. These are organised as 'sandpits' in which concentrated effort, away from our normal work routine, has been invaluable in helping us to develop research ideas of all kinds, be they for individual or collaborative research projects.

The research strategy overlaps with several other dimensions of university activity including business engagement, commercialisation, internationalisation, estates, human resources and finance and requires continuous and close coordination with these through our representation on key committees and the work of the 'Business Partners' set up to liaise with major divisions of the university.

The three key pillars that support this strategic vision and its successful implementation are research quality, research impact, and research staff.

Research quality

Our principal aim is to undertake research of the highest quality and to continue to raise the level and ambition of our activities to world-class and world leading standards of excellence. This is exemplified in our work on the mathematics of error correction coding that has resulted in the design of error-correcting codes that have better properties than existing best-known codes, resulting in high quality research outputs and international recognition. Since 2007, the group has devised over a hundred new best-known codes, leading to significant publications in prestigious journals, such as *IEEE Transaction on Information Theory* (**Tomlinson, Ahmed**). Currently, our team is focusing on the design and use of error-correction codes for information security, and in particular the identification of new properties of codes that are relevant to security applications and their construction methods.

The university is in a unique position, with the opportunity and ability to focus on research into the healthcare of an ageing population. The South-West has the largest percentage of residents aged 65+ in the UK, comprising (2011 census) 20% of the region's population. It is also a principal destination of inward migration for retirees. Our participation in this thriving research area has seen the successful completion of the EU:FP6 BioPattern project (led by **Ifeachor**) and award of follow-on grants, including FP7:GERYON, FP7:ADAMANTIUM, and an NIHR-funded project. Several research outputs are included that focus on the topic of e-Health (**Ifeachor**) and multimedia communication (**Sun**). Advances in sensors (**Panina; Jenkins**), actuators (**Jenkins**), and fabrication (**Pan**) are also included.

Research impact

Our aim in this area is to bring leading-edge research to research end-users. We see our intellectual property and the timely application of research within local companies as an important way of maximising the impact of research and diversifying sources of research income. Staff in UoA13 have been granted ten UK patents and one US patent, and have taken out more than twenty eight patents in this REF period. Staff actively engage with the Technology Strategy Board Innovation Vouchers scheme to apply leading research to commercial products. Since its launch in February 2013 the university has a 100% success rate in having in project approval and has been successful in securing half of the total number of projects so far authorised (4 out of 8). The university is targeted with achieving a minimum of 23 projects before the scheme ends in early

2015.

We have applied coding to industrial applications, facilitated by way of Knowledge Transfer Partnerships (KTPs), and this has led to the development of innovative products with outstanding results. Bombardier Transportation Ltd., for example, has benefited from jointly-developed, error-correction coding to become the world-leader in coded track signalling. Our collaboration with Bombardier resulted in an award-winning KTP and secured a significant number of jobs for engineers based at Bombardier's Plymouth site.

Research Staff

Our second strategic aim of pursuing national and international research funding, and of aligning our strategic objectives with national and international research agendas is apparent in staff appointments that have been made to support these. This and the mechanisms through which we are achieving this aim are detailed in section (c) below.

Future Plans

The creation of the two Centres has allowed us to better focus our efforts and collaborations to advance our strategic vision. In the future we will target funding to support the merging of our security and communications research strengths featuring the mathematics of cryptography and coding. We are considering, in particular, EU funding and the *EPSRC Digital Economy* theme, where our work is firmly aligned with their priorities. We are especially concerned with the security, privacy and trust sub-themes with our work in network security and intrusion detection (**Furnell**) having already contributed to the award of projects under FP7. Key to this will also be ongoing work in relation to user authentication, enabling trusted identity in multi-device environments (**Furnell**). In view of our decision to concentrate on Quality of Experience (QoE) modelling and management, **Sun** will be targeting EU and EPSRC funding to enhance collaborations on multimedia QoE with academic and industrial partners within and beyond the EU.

We are negotiating plans with colleagues that we hope will lead to the formation of a Nanoscience Institute (NI) to unify the research of groups active in this area within Plymouth University and to establish a critical mass in this important area of technology. We believe that the re-location of the nanoscience and technology research groups within one building as the NI would bring significant advantages in terms of multi-discipline collaborations, cross-fertilisation of ideas and training of research students, particularly in graphene electronics, biosensors and spintronics. This would also create opportunities for external funding, and enable collaboration with companies and other research institutes.

c. People

Staffing strategy and staff development

Our strategy for research staff relates to recruitment, career development and retention, promotion, and leadership succession.

Recruitment to our Research Centres has been guided by the need to bridge the gap between disciplines, by bringing people with relevant expertise and shared interests to work together on new and emerging problems within EPSRC and EU priority areas, such as nanoelectronics and sensors based on graphene and other atomically thin two-dimensional materials. In order to begin the delivery of our new agenda we have made research-focused academic staff appointments at both early-career and senior levels, with the addition to our group on part-time contracts of **Dr Shakil Awan** and Emeritus Professor **Martin Tomlinson**. A number of recent postgraduate students have also been appointed as research fellows: **Dr Fudong Li**, **Dr Javier**, **Dr Mkwawa**, **Dr Jammeh** and **Mr Athanosis**.

Awan, who is an active researcher in graphene technology with Cambridge University and the Nokia Research Center, was recruited on a 0.5 FTE contract, giving him a joint lectureship position at both Plymouth and Cambridge universities. His appointment is a key part of our faculty's strategy to support graphene research, and to exploit the multi-disciplinary expertise in different

areas, such as the Wolfson Laboratory, Biological Sciences, electronics and healthcare technology. **Awan's** existing collaborations with the newly created Cambridge Graphene Centre (CGC) and industrial partners, have brought key benefits to the group by enabling our researchers to establish collaborative links with the CGC as well as access to world-class graphene production and characterisation facilities. New collaborations with leading UK and EU groups in graphene biotechnology, plasmonics and spintronics are beginning to develop.

Tomlinson was appointed to provide continuity in the area of design of error-correction coding and its application. **Tomlinson** has been a member of staff at Plymouth University for many years, and was awarded an Emeritus Professorship in 2009. He is eminent in the field of communications and code design, having devised design methods that have established his world-wide reputation for ingenious error-correction code creation. During his time at the university, he has undertaken 11 PhD supervisions and published over 100 papers in collaboration with members of the CSCAN research group.

New members of staff are allocated a research-active mentor for guidance on research and career development. This is integrated with probation and with the Performance Development Review (PDR) of all staff. Staff development for early career researchers is fully compliant with the Concordat on Support for Researchers, under which the University received the European Commission HR Excellence in Research award (2011). We participate in the Careers in Research Online Survey (CROS) biannually, and results of this are used to support further development of staff. Outcomes from mentoring and PDR are considered by Research Centre leads and inform the decisions and recommendations of the School and Faculty for promotion and for personal and professional career development opportunities. Staff in the UoA have benefitted from the University's system of promotion: for example, **Sun** was recently promoted to Associate Professor (Reader). A flexible remuneration system has enabled continued research leadership by Tomlinson and so has allowed more efficient succession planning.

Direct research support to staff is met through financial and workload mechanisms. A Strategic Research Account (SRA) system is operated, under which each member of staff can manage overheads from spending on casual research staff, travel, attending conferences, buying consumables and equipment, and paying for membership to societies. A workload allocation system ensures that new members of staff have a lighter teaching load in their first year and that research activity is fully recognised in overall workload allocation. This system makes possible periods of concentration on research activity.

The Schools and Research Centres are fully committed to the University Equality and Diversity Programme. The Faculty of Technology was awarded an **Athena SWAN Silver Award** for promoting gender equality. Recruitment, promotion, and staff development processes are monitored for equality issues and this has allowed us to recognise and address the research career issues arising from, for example, the care provided to ageing parents and disabled children by many female academics.

Research students

Research students are registered through the Graduate School, which has been restructured as a coordinating umbrella for strategically focused Doctoral Training Centres (DTC) with devolved management. The School and the two Centres cooperated in 2012 to establish a DTC for students researching in the area of this UoA. The Graduate School provides generic, transferable skills training and provides training support for supervisors, while the DTC delivers subject-specific training and provides the progress monitoring structure for our PhD students. These currently number 81 PhD students under supervision by UoA13 staff. We are fully committed to the goals of Women Into Science and Engineering (WISE) and our Equality and Diversity monitoring, referenced above, has led to action that has increased the number of female PhD students registered. Four female PhD students completed during this REF period, a similar level to that reported in RAE2008, however 10 are due to complete over the next two years .

The research students in both Research Centres are primarily funded through external government scholarships from countries such as Iraq, Saudi Arabia, Malaysia, and China. Some students are recruited by way of research grants, while a minority of students are self-funded. SoCM also

provides three fully-funded scholarships every year to support the recruitment of high calibre MEng and MSc students onto our PhD research programmes.

In addition, CSCAN has established research nodes in Germany at the University of Applied Sciences Darmstadt (since 2004) and at the University of Applied Sciences Furtwangen (since 2010). These provide a means of supporting remote students (31 at present) who are completing their PhDs on a part-time basis, whilst undertaking employment in the sector. This programme differs from a traditional part-time route, in that it allows academic staff at the remote locations to become lead supervisors, with Plymouth-based academics providing additional supervisory input and expertise based upon research synergies with the CSCAN team. All of the researchers are registered as Plymouth students, and CSCAN provides the hub for the activities, enabling an extension of our capability-base alongside an associated broadening of research activity, doctoral completions and published outputs. All of the node-based academics are given appropriate supervisor training by our Graduate School.

d Income, Infrastructure and Facilities

Staff have received over £1.9 million in research-grant income in this REF period. Knowledge Transfer Partnerships (KTPs), short KTPs (sKTP) and EU FP 7 projects have formed a substantial proportion (90%) of research income. FP7 projects and KTP form 37% and 40% of research income respectively. NiHR research income accounts for 13% of research income.

Plymouth University remains one of the largest providers of KTP in the South-West region with national recognition as a UK-leading KTP Office and a reputation for high funding-success rates. Members of the Unit have been rewarded with three wins at the national KTP awards: two with GOSS and Zoefitig for best regional partnership in 2009 and 2010, and the best business impact award for the Bombardier KTP in 2011.

A multimedia communications and networking laboratory is built around VoIP/IPTV/IMS test beds, which include a Cisco routers/switch/voice gateway, network emulator (Shunra Storm), open IMS Core server, video streaming server, and Asterisk server. We also utilise the Faculty's High Performance Computing facility with 432 cores using Intel Xeon E5650 processors for video signal analysis and Quality of Experience (QoE) modelling and evaluation. We aim to strengthen our research on QoE with a focus on novel QoE modelling and QoE management schemes for new and emerging multimedia applications such as mobile HDTV and online gaming, and also for multimedia QoE in emergency communications and eHealthcare applications. To this end, we will target EU and EPSRC funding to enhance collaborations on multimedia QoE with academia/industry partners within and beyond the EU. European Union FP7 projects have already focused on multimedia communication, particularly on QoE assessment and monitoring for the delivery of multimedia services over fixed and mobile networks for both conventional and emergency communications.

We have built upon the successful completion of the EU FP6 project (NMP4-CT-2003505282), coordinated by Pan, for exploring spin-transport in nanoscale devices and the DTI MNT project (CHBS/004/00033C) for building the world's first 300mm BIBD deposition tool for MRAM applications. As a result we have achieved world-leading outputs in a number of areas; in particular we are the first to report the transfer-free production of graphene on insulator substrates by sputtering, which is a key step forward for realising industrial scale application of graphene (Pan).

The focus within CRTB is on post-genomics equipment. This represents an investment of more than £3 million and will bring next-generation proteomics and DNA sequencing into a purpose-built facility, which will be used extensively by researchers in the school and collaborators at the Peninsula College of Medicine and Dentistry. Our state-of-the-art facilities include a cleanroom-based laboratory, the Wolfson Nanomaterials and Devices Laboratory. This hosts a number of researchers, supporting leading-edge research into nano-functional materials for applications in nano-electronics and biotechnology. Notably, we are the only university in the UK with an ultra-high vacuum and six-target deposition facility for device-scale spintronic film production. New laboratory facilities, at a cost of £2.5M, have been earmarked for the relocation of the clean room, nano-characterisation tools and some of the nano-toxicology and biomedical systems. The new

laboratory, with over 500 square metres, will be shared by many of the nano-technology groups at Plymouth University, but will be self-contained in purpose-built modules for the different fields of work. The Class-10 Cleanroom, and the Wolfson Laboratory will complement this facility and advances in graphene based biosensors that will utilise these facilities will create a strong basis to compete for research funding. Our facilities enable a variety of research projects, such as the large-scale production of graphene, high-frequency graphene electronics, nanomagnetism, spintronics, and label-free biosensors, all of which are in line with the *EPSRC Nanotechnology and Healthcare Technology Challenge* themes.

The research seminars organised by CSCAN and CRTB provide the opportunity to hear invited external speakers, as well as presentations by staff and research students. Talks are disseminated using iTunes U via our Networks and Security collection and this has proved to be extremely popular, receiving more than 500,000 downloads to date. Research students give presentations on their research in the final stages of their PhDs, while all staff participate in the seminar programme, which aims to share new research initiatives and project results.

e. Collaboration and contribution to the discipline

Participation in research collaboration networks

Panina has been a specialist lecturer at the School on Magnetism (La Coruna, Spain, August 2009), the School of Nanotechnology (Moscow University, September 2011), and San Sebastian University, Spain (2008). In 2010, she was Ikerbasque Fellow at the Basque Foundation for Science. In 2011 she was research professor at Nagoya University and Aichi Steel Corp., Japan and is currently collaborating with the National Technological University and Lebedev Physical Institute RAS in Russia. **Jenkins**, currently works as an invited Research Professor on 1 to 3-month sabbaticals at the Institute of Electronics, Microelectronics and Nanotechnology which is one of the nano-poles in France. This collaboration has led to over ten joint publications in the REF period and a one-week doctoral workshop entitled, *Functional Piezoelectric thin films: Fabrication, characterisation, optimisation and application*. **Pan** is Guest Professor of the Nanotechnology Centre at Fudan University China. **Tomlinson** has served as an international advisor for the advancement and direction of telecommunications research in Portugal. **Tomlinson, Ahmed, Grassl** (National University of Singapore) and **Bezzateev** (Saint Petersburg State University of Aerospace Instrumentation, Russia) are working on the design of error-correction codes, and have published new codes superseding some of the best-known codes. **Ambroze** and **Tomlinson** collaborate with Martin and Taylor (University of Canterbury, New Zealand) on the application of error-correction coding for satellite and ultra-wideband communications. This has led to a joint UK patent being granted and a number of publications. **Tomlinson** and **Ahmed** are working with a start-up company combining Goppa error-correction codes in a post-quantum public key encryption method able to correct transmission errors. **Tomlinson** and Rosnes (University of Bergen) collaborate on evaluating the distance parameters of classes of Low-Density Parity-Check codes, resulting in two publications so far. **Tomlinson** and **Ahmed** collaborate with Rodrigues (formerly with the University of Porto, now at University College London) on the application of coding to the wire tap channel, and that asymptotically reduces the information gained by an eavesdropper to zero. **Furnell** collaborates with colleagues from Nelson Mandela Metropolitan University in South Africa, with whom he has jointly published seven papers, comprising five on security awareness and culture and two on authentication and access control. Furnell also works in an interdisciplinary context with the Democritus University of Thrace (Greece), VEGA IT GMBH (Germany), Space Internetworks Ltd (Greece) and National Observatory of Athens (Greece) as part of the Space Data Routers STReP call. Plymouth is working on the design and development of a novel application that receives and disseminates data from the space devices. The application handles the latency aspects of the Delay Tolerant Networks, as well as providing appropriate security mechanisms to protect the data. **Sun** has engaged in interdisciplinary collaboration with NCSR Demokritos and University of the Basque Country, which has resulted in several joint publications including 2 book chapters, 3 journal papers and 6 conference papers, on multimedia QoS/QoE. The collaboration has also led to two successful bids for EU grants (i.e. ADAMANTIUM and GERYON). The collaboration involves Rohde & Schwarz GmbH & Co. KG, Thomson Grass Valley France, Vodafone Panafon Hellenic Telecommunications Company S.A., Ericsson, Viotech

Communications and Thomson Telecom as part of the ADAMANTIUM FP7 project, and with COSMOTE Mobile Telecommunications S.A., GRUPO CYS, ITELAZPI, NCSR Demokritos, University of the Basque Country and VIOTECH COMMUNICATIONS as part of the GERYON project.

Other collaborations with research users

Panina has undertaken work on behalf of Nestlé Nespresso S.A. and Adaxys Ltd (Switzerland), in the field of developing magnetic coding for packaging applications, and also Aichi Steel Corp., Japan, in the field of high-sensitivity magnetic sensors. **Ahmed** has served as an expert commentator on a rail safety case with Bombardier Transportation. **Ifeachor's** work involves collaboration with clinical centres (Plymouth Hospitals, Imperial College, Oxford and Aberdeen Universities), and NHS Devon IT Department and Health economists at Exeter University. Ahmed works in an interdisciplinary context with the Marine Biological Association of the U.K. on applying digital-signal-processing techniques to data collected from marine organisms. This has led to greater insights into the data and resulted in a number of high-impact co-authored publications (e.g., *Nature*, 2008, doi:10.1038/nature06518).

Journal editorship and conference organisation

Pan has served as a committee member of the UK Magnetic Society and is Editor of the journal *Graphene Spintronics and Nanostructures*. **Furnell** is the Editor-in-Chief of *Information Management Computer Security*, and an associate editor for *Computers and Security* (Elsevier), *Security and Communication Networks* (Wiley), and *The Computer Journal* (Oxford Journals). **Ifeachor** is (Co) Editor-in-Chief of the journal *Source Code for Biology and Medicine*, and serves on the editorial board of the IET Journal *Science, Measurement and Technology*. **Sun** was the guest editor for the *IEEE JSAC special issue on QoE-aware wireless multimedia systems* (August 2012) and *International Journal of Telecommunications Systems*, Springer, special issue on *Quality of experience issues in multimedia provision* (June 2010).

Panina is a member of the international committees for a number of conferences (JEMS, AES, MISM, DICNMA) and the organiser of special symposia within major international conferences (Magnetic wire workshop 2008; PIERS 2009; AES 2012; PIERS 2012). **Sun** was Chair of the QoE for the Multimedia Communications Interest Group of IEEE MMTC (2010 - 2012). She has been the Publicity Co-Chair of IEEE ICME 2011, Post and Demo Co-Chair of IEEE Globecom 2010, and will serve as Symposium Co-Chair for the Communication Software, Services and Multimedia Application Symposium (CSSMAS) of IEEE ICC 2014. **Furnell** has served on the programme committee of over 180 international conferences, 85 within this REF period, and has established and co-chaired the annual Human Aspects of Information Security & Assurance (HAISA) symposium since 2007, and the biennial International Network Conference (INC) series since 1998.

Other Professional Contributions

Furnell is regional Branch Chair of both the British Computer Society and the Institute of Information Security Professionals, and also chairs the Academic Partnership Committee of the latter. He is the UK representative to Technical Committee 11 (Information Security and Privacy) within the International Federation for Information Processing (IFIP), as well as an active member of related working groups on Human Aspects of Security (of which he was the founding chair), Information Security Management, and Information Security Education. **Ifeachor** has served as Chair of the Executive Team of the IET PN on Healthcare Technologies and currently leads a theme in an NIHR-funded project on methods for clinical trials for neurodegenerative diseases. **Sun**, together with her colleagues, has authored a book: *Guide to Voice and Video over IP: For Fixed and Mobile Networks* (Springer, Feb 2013).