**Institution:** University of Greenwich

v10

**Unit of Assessment:** (UoA 13) - Electrical and Electronic Engineering, Metallurgy and Materials

**a. Overview**

The University of Greenwich is a strongly research-informed institution. The University Strategic Plan (http://www.gre.ac.uk/governance/vc/strategic-plan-2012-2017) aims to build on its success in creating this research-informed environment to increase the quality, volume, and intensity of research activity. Key themes of current and future strategies are:

- To ensure that the University has a critical mass of excellent researchers through the appointment and retention of high-quality staff;
- To develop at least 20 research groups with an international reputation for excellence as measured by the significance, originality, rigour and impact of their work;
- To develop a vibrant community of high-quality postgraduate research students;
- To increase the national and international impact of its research.

The research agenda within the University is led by the Deputy Vice Chancellor for Research and Enterprise who chairs the University Research and Enterprise Committee (R&EC). Directors of Research and Enterprise for the constituent Faculties and Institutes of the University are members of the R&EC. Each Faculty and Institute is accountable to the R&EC through an annual report and strategic plan. Each Faculty operates a Research Degrees Committee which oversees Postgraduate Research programmes in the Faculty and reports to the University R&EC. The University's research work is also guided by a Research Ethics Committee, chaired by a Dean of School.

Under this UoA, the University is returning a multi-disciplinary team of engineers, physicists, mathematicians and computer scientists from the School of Engineering (SoE) and the School of Computing and Mathematical Sciences (SoCMS). The team is drawn from two research groups:

- **Wireless and Mobile Communications Research Laboratory (WMCRL**) (http://www2.gre.ac.uk/about/schools/engineering/research/groups/mwcrl), based in the SoE. The WMCRL was established in 2005 by, and continues to be led by Prof Predrag **Rapajic**. The WMCRL undertakes research in the associated areas of communication signal processing algorithms, bandwidth usage optimisation, information theory, adaptive control, equalisation, cyber security, RF engineering and multi-user communication. The WMCRL is returning five ARs to this UoA (**Arshad**, **Krabica**, **Rapajic, Wang** and **Woodhead**). The location of the SoE on the Medway Campus facilitates close collaboration with colleagues from the University of Kent and Canterbury Christchurch University, with whom Greenwich shares the campus to collectively provide a world-leading learning and research environment.

- **Centre for Numerical Modelling and Process Analysis (CNMPA**) (http://cnmpa.gre.ac.uk/), a cross-school centre, based in both the SoE and SoCMS. The CNMPA has research interests in developing computer models for multi-physics/multi-scale predictions, numerical optimisation, failure analysis, reliability and maintenance of engineering structures. Due to the highly inter-disciplinary nature of its work, the CNMPA is returning seven ARs to this UoA, (**Djambazov**, **Kao**, **Mallik**, **Rajaguru**, **Strusevich**, **Tilford** and **Yin**) as well as five to UoA 11, nine to UoA 12 and six to UoA 15. The location of the SoCMS in close proximity to Canary Wharf facilitates strong research collaboration with the global businesses based there.

As a result of the multidisciplinary nature of the work of these groups, their research does not fit neatly into the REF UoA framework. Hence, some staff from the CNMPA are being returned under other UoAs, although, the vast majority of the research environment is common across these UoAs.

The strategic aims of this UoA are closely aligned with the research growth strategy of the University. Specific points which reflect this are as follows:

- This is the first return to this UoA by the University of Greenwich. Of the 12 ARs being returned, only five has been returned under previous RAEs. The other seven ARs have either been hired since 2008, or have significantly enhanced their research profile in the intervening period.
- With respect to refereed publications, the WMCRL has published 132 such papers over the REF 2014 assessment period, compared to 45 over the RAE 2008 assessment period. The CNMPA (including the ARs returned to other UoAs) has published 542 such papers during the REF 2014 assessment period, compared to 498 for RAE 2008.
- Over the REF 2014 assessment period, the WMCRL achieved eight PhD completions and generated £1453k in external research grants, with both figures growing from zero (over the RAE 2008 assessment period).

**b. Research strategy**

**i. Implementation of strategy since RAE 2008**

The overarching strategy for the UoA since RAE 2008 has been to grow the research endeavour. The fact that this is the first return by the University of Greenwich under this UoA is considered to provide strong evidence that this strategy has been successful. Another strong indicator is the fact that across UoAs 12, 13 and 15, the University is returning 35 ARs in REF2014, compared to 20.1 across the equivalent UOAs in RAE 2008. A number of elements have contributed to this success, as summarised below.

Within the UoA and within both Schools, the hiring policy is to hire only academic staff who can contribute to the research endeavour of the University, and to support existing staff to develop and expand their research work.

A consistent balanced academic workload model is operated across the University which provides each academic with dedicated time for research - with goals and appropriate support agreed through the University-wide staff appraisal process. The University also operates a sabbatical programme which allows staff members to take periods of time to concentrate on particular research projects, or to develop their research experience by working at other institutions (http://www2.gre.ac.uk/about/policy).

Strong communication between academics both within and across UoAs is viewed as crucially important to developing a vibrant research environment. Both Schools therefore run a programme of internal seminars and conference days, which are open not just to members of the UoA but also to colleagues from the wider University community. Postgraduate research students from relevant groups are strongly encouraged to attend these as part of their personal development programme.

All research outputs from the UoA which are accepted externally are deposited in the Greenwich Academic Literature Archive (http://gala.gre.ac.uk), an open repository. An internal peer review system for publications is available within each UoA, and this is coupled with a mentoring system whereby members of staff with identified research development needs are 'buddied' with more experienced colleagues working in the same or related fields. In addition, the University operates a series of paper writing workshops through the year (http://www.gre.ac.uk/research/training).

Researchers in the UoA have access to the services of Greenwich Research and Enterprise (GRE) the research office of the University. GREs main function is to support researcher's efforts to gain external funding for their research (typically about five times the funding available from RAE across the University). GRE staff include Business Development Managers (BDMs) who work closely with researchers in the UoA to identify funding opportunities and create proposals to successfully access them. Both the SoE and SoCMS have dedicated BDMs, so they are physically adjacent to

researchers in the relevant UoAs. GRE runs a comprehensive series of developmental workshops targeted at meeting the needs of researchers seeking funding, (http://www.gre.ac.uk/research/training) and also administers an internal peer review college for funding bids. In addition to assisting researchers gain funding, GRE also provides a wide range of workshops as part of the University research staff development programme. These include: project management, planning and managing budgets, research survey design, media training, establishing networks/collaborations and specialist IT training.

**ii. Forward Strategy and Vision**

The overarching forward strategy and vision for the UoA is to continue the growth of the research endeavour, both by increasing the size of the two existing research groups, and by developing other research groups to the point at which they can be returned to this UoA.

This is supportive of, and consistent with, the current University Strategic Plan (http://www.gre.ac.uk/governance/vc/strategic-plan-2012-2017), which aims to increase the proportion of academic staff who are research active from 40% to 75% by 2017, whilst at the same time, increasing external research funding by 62% and increasing the number of postgraduate research students across the University from 350 to 500.

We expect this growth to be achieved through:

- Expansion of our work in the related areas of information theory, adaptive control and equalisation, to further enhance bandwidth usage optimisation in multi-user wireless communication systems.
- Development of our work in RF systems, with particular emphasis on novel amplifier architectures.
- Development of our existing work in cyber security with particular focus on malware analysis and countermeasure development.
- Further development of our multi-physics and multi-objective optimisation capabilities for materials and manufacturing processes. To embed these capabilities into our software tools such as PHYSICA, SPHINX, ROMARA and POWERLIFE.
- Further development of our reliability and failure analysis modelling capabilities in electronics product design and in particular the electronics-energy (power electronics) and electronics-bio (Medical Devices) sectors.
- Combining the latest advances in Internet-of-things and cloud computing with our modelling tools for real time prognostics and health management of engineering products in the field.
- Continued collaboration on UK Government and overseas Government (e.g. EU, DoD, etc) funded projects with leading research organisations.

**c. People, including:**

**i. Staffing strategy and staff development**

The University has committed to the goals established by the *Concordat to Support the Career Development of Researchers* developed by Vitae. To this end it is a signatory of the Concordat and has created a comprehensive researcher development framework. Plans are in place for full implementation, including comprehensive research training programmes, from Sept 2013.

Furthermore, the University has extended this work and successfully gained the *HR Excellence in Research* award of the European Commission. This involved making substantial progress towards addressing and embedding the principles of the Concordat – and this is demonstrated through a comprehensive gap analysis and action plan (http://gre.ac.uk/hr/concordat).

The University has a dedicated equality and diversity champion who has taken a leading role in the initiatives described above. All UoAs are required to observe the University Equality Framework (http://www2.gre.ac.uk/about/policy/equality). Line managers are trained in current practice and are responsible for ensuring compliance and being pro-active in identifying areas of issue. For the

REF, the University has established a comprehensive network of equality and diversity champions across all UoAs.

The hiring policy of the University is that all new academics are research active. There is a requirement that all new hires should either already have a PhD or to be near completion. Several hiring initiatives have been undertaken over the past five years – including the introduction of new-blood research-active staff, research professor schemes, and high-profile PhD student scholarship schemes. The small number of existing staff who do not have a PhD are encouraged to work towards such a qualification and a defined support scheme exists to provide both time and financial support to enable them to do this. Potential leaders for research groups and departments are identified at an early stage and are encouraged to undertake several of the leadership development programmes offered by the HR Learning and Development team and the Leadership Foundation for HE.

Early career researchers (ECR) are identified on joining the University and provided with support via a comprehensive ECR network. The network supports the career development and management of ECR staff and contract researchers within the University. It was set up in 2009 as a direct response to the aspirations of the Concordat and in accord with the previous Roberts Report and funding stream. In order to allow a maximum number of appropriate staff to benefit from internal training and opportunities, criteria for ECR classification at Greenwich are inclusive. In addition to access to specific training and mentoring initiatives, the network facilitates communication and networking between ECRs across the University creating a strong and cohesive support community. The network runs an annual competition to identify ECRs with particularly high potential and the winners are given high-profile early career research excellence awards which include financial support for their research. Seven early career researchers are being returned to this UoA.

The research group directors manage the groups, providing a coherent approach to staff development within the groups and infrastructure investments to support the research strategy detailed above. Each group is a cost centre with directors having overall responsibility for managing research income/expenditure and investment of RAE, RCIF and external funds.

Both groups have developed specialist MSc programmes (MSc Wireless and Mobile Communications Engineering for WMCRL and MSc Applicable Mathematics for CNMPA) and the ARs being returned contribute significantly to the delivery of these programmes.

The main achievement of this UoA team is its ability to maintain a strong, rich and multidisciplinary research environment including a network of links with laboratories worldwide. In a highly competitive research environment, they attract UK government, EU, industry and international funds, from SMEs to multi-nationals without sacrificing their main goal of research quality.

**ii. Research students**

The University aims to increase the number of postgraduate research students (PGRs) by 40% over the next five years. There is an active programme to recruit high-quality students internationally, supported by a high-profile competitive Vice Chancellor's PhD scholarship scheme which provides generous stipends.

Greenwich provides high-quality training of PhD students in an interdisciplinary environment. This is driven by a culture of shared resources, expertise, and facilities. Student progress is regularly and formally monitored by the Faculty Research Degrees Committee. Each student is expected to present their work – and have it subject to peer review and feedback - either at a Faculty research seminar or a postgraduate research day. This provides the opportunity for them to test their emerging work on a critical but supportive audience. Students are supported in their needs by both generic training provided at University level, and also specific training provided within the UoA, such as specialist programming skills and training in the use of specific laboratory equipment.

Within the UoA, PhD students typically attend the appropriate MSc modules or other appropriate short courses as part of their initial studies. Presentation of their work in internal seminars and conferences hones their presentation skills in front of peers and supervisors, prior to making external presentations. A regular programme of invited external speakers enhances awareness of relevant research beyond the University. All PhD students have access to state-of-the-art computational and laboratory facilities supported by RCIF and business/industry funds.

As is common across the sector, each student has a supervisory team with at least two supervisors – one of whom is fully accountable for progress and training of the student. Supervisors are required to have undergone a specified training programme within the University and have specific experience in research student supervision before becoming lead supervisor.

Within the UoA, we project continued increases in PhD student recruitment, with particular emphasis on international collaborations. The University has recently strengthened its entry criteria for doctoral programmes and this is expected to result in an increase in the quality of publications being produced by PhD students and their supervisors.

**d. Income, infrastructure and facilities**

The research culture of the UoA is supported through both external income (Research Councils, EU, government agencies, consultancy, and licensing of software) and internal investments. Annually, the University allocates RAE income to established research groups by competitive internal bidding. The groups bids for RAE funding to underpin their main activities and supplement research grant and enterprise income. This funding is used to: support active researchers with travel and equipment, provide funding for RA's and provide bursaries for PhD students. RCIF funding is apportioned to research groups to provide state-of-the-art research infrastructure. Within the Schools there are also Directors of Research and Enterprise who sit on the School Management Committee, bringing the research and enterprise agenda to the highest levels of School governance.

In addition to academic staff on teaching and research contracts, revenue enables the UoA to engage three research fellows, who enjoy significantly reduced teaching loads, thereby enhancing the capacity of the research groups.

Research infrastructure is continuously being renewed and enhanced. All research staff/students have their desk-top computers upgraded as part of a rolling programme.

During its foundation in 2005, the WMCRL attracted SRIF/RCIF funding of £150k, to develop a 70$m^2$ dedicated laboratory, incorporating a 112$m^3$ industrial standard RF anechoic chamber, with a working frequency range from 400MHz to 18GHz. This funding was matched by equipment donations from industry. Since that time, further investments have included two network analysers (working frequency up to 18GHz) (combined value circa £100k), as well as a 2-3G mobile telephone base station and numerous other small items of equipment, including signal generators, spectrum analysers, etc. Under the iMocca project (awarded in 2011), the laboratory saw further investment of £100k, to develop two competence centres in industrial communications and embedded systems. In 2013, the laboratory received a further investment of £65k, to purchase equipment to support its work in the application of mobile devices for industrial control, and to develop a cyber-security test bed. Over the REF 2014 assessment period, the WMCRL has gained research grants valued at £953k, mainly from the EU.

The School-based computer networks are continuously upgraded by the addition of equipment e.g.: in SoCMS the 6 Tb SAN storage has been upgraded to 10TB this year, off-site backup/replication for maximum resilience of storage area, 1GB network back-bone has been upgraded this year to 10GB, 1GB switches and dedicated research servers. Other facilities include a dedicated server room space in Dreadnought Library which has been enhanced to cater for HPC servers, two distributed memory high performance clusters, a 40 processor system and a high performance shared memory 64 processor Linux cluster, implementation of Virtual Desktop

Environment and Virtualisation of servers enabling research groups the ability to demonstrate software to clients and development of their specialised software. These provisions have been made available via RCIF expenditures of £1.5million since Jan 2008. Additionally, a small grid cluster has been purchased to support parallel and distributed computing research in the Greenwich campus. A ubiquitous computing software-hardware lab has been built and equipped at Greenwich using University and RCIF funds. A mobile computing lab, forensics lab and MAC lab for film, TV and animation work have been equipped. Additionally, £160K has been spent on specialist software to support research activities within the groups.

The Drill Hall Library at Medway and the Dreadnought Library at Greenwich are each open for over 100 hours per week for the majority of the year and offer access to over 600,000 volumes, as well as 1,000 PCs, laptop drop-in zones, printers and photocopying.

**e. Collaboration or contribution to the discipline or research base**

Collectively, the groups engage with many leading Universities across the world (eg. US, Australia, Singapore, China), as evidenced by the co-authors of many publication outputs (see http://gala.gre.ac.uk). For example, the WMCRL is represented at the vast majority of the leading conferences in the field, including IEEE ISIT, IEEE PIMRC, IEEE Globecomm, IEEE VTC (as maybe evidenced from the publication outputs of the laboratory). Colleagues take part in may "side meetings" at such events. A specific example of more local collaboration is the €4.5M iMocca project, which constitutes a consortium of seven EU partners, including two from Belgium and four from France.

We have also been involved in initiatives such as Marie Curie (e.g. Pb-Free project which supported close collaboration with City University, Hong Kong) and the Prime Ministers International Research Collaboration Initiative which supports staff exchange visits between CNMPA and Kyoto University, Japan. We also engage with the wider community through our Visiting Professorships which include Professor Peter Mason (Royal Academy of Engineering Visiting Professor at Surrey University) and Professor Nihal Sinnadurai (President IEEE UK &RI Reliability and CMPT Societies).

Another example is our collaborative work in the Innovative Electronics Manufacturing Centre (http://www.lboro.ac.uk/research/iemrc/), where we are undertaking interdisciplinary work with a number of universities and companies. This has supported a number of joint university/industry research projects including the Power Electronics Flagship project, PEMREL and FAMOBS which led onto a EU-FP7 project with four research organisations and 10 SME associations. Another project to note is the EPSRC Grand Challenge project – 3D-Mintegration which involved seven Universities and 23 companies where CMRG led the design, modelling and simulation activities.

In addition to our subject specific research, a considerable body of the work being carried out in this unit of assessment, is focused on broad topics that have an impact on a large number of cognate areas. For example, the work of the CNMPA in computational mechanics and reliability, although originally focused on electronic components, is now being adopted for conservation of heritage structures, and as part of our strategy is being developed towards healthcare and renewable energy systems.