Institution: University of Greenwich v8

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

a. Context

Under this UoA, the university is returning two research groups drawn from the School of Engineering (SoE) and the School of Computing and Mathematical Sciences (SoCMS):

- **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, RF engineering, cyber security and multi-user communication. The WMCRL is returning five ARs to this UoA (**Arshad**, **Krabica**, **Rapajic**, **Wang** and **Woodhead**).
- **Centre for Numerical Modelling and Process Analysis** (CNMPA) (http://cnmpa.gre.ac.uk/), a cross-school centre. 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 main research impact beneficiaries for both groups are a wide range of industries, with particular focus on the associated sectors of mobile communications equipment and electronics manufacturing. The types of impacts that end-users benefit from are better designs of telecommunications and other electronic equipment, improved manufacturing technologies and improved product reliability. Non-academic users of our research include companies in sectors such as mobile communications, electronics, heritage, healthcare, energy and aerospace.

b. Approach to impact

Our approach to achieving impact for our research, since 2008, has been a broad one, comprising the following highly interdependent key elements:

i. **Many of our basic research projects have been undertaken in collaboration with business and industry** and we involve such partners at the early stage of developing proposals, eg EPSRC grant no EP/C534212 in collaboration with Sun Microsystems, Unilever, BAe Systems, GSK and 18 other businesses, EU FP7 NMP EXOMET in collaboration with the European Space Agency, Volvo and Stone Foundries, and EU FP6 IMPRESS, in collaboration with NPL, Rolls-Royce and Qinetiq.

ii. **Through UK and EU government-funded collaborative projects**, we have achieved significant levels of knowledge transfer into business and industry, eg the EU FAMOBS project in collaboration with ACI Ecotech, Kepar Electronica, Freshfield, RF Com and Robler, the TSB EndView project in collaboration with GE Aviation Systems, Raymarine, NCR, Thin Film Solutions and Design LED Products, the EU iMocca project with six EU partners, KTPs 7458 and 8774 with NIC Instruments and KTP 8348 with MEP Ltd.

iii. **Through EPSRC CASE studentships** eg EPSRC grant no FS/05/01/01 with BAe Systems and EPSRC grant no EP/K504361/1 with Ford.

iv. **Contributions to and citations in patents**. The WMCRL in particular has contributed to a range of patents, for example: WO2011028646 A2 (10/03/2011), US8126096 B2 (28/02/2012), US8135088 B2 (13/03/12) and US7773498 B2 (13/03/2102).

v. **Licencing of our software tools** (eg SPHINX). These tools have now been licenced to users in more than six countries throughout the world.

The development and implementation of these approaches is strongly supported by the central Greenwich Research and Enterprise office (GRE). For example, GRE have a dedicated KTP

manager to support KTP project development and management, as well as an IP manager to support patent filing, software licencing, etc.

Examples of research driven impact

WMCRL: The work of the WMCRL (**Rapajic** in particular) has been cited in a significant number of patents, with the following being key examples:

1) Inventors: Sudhanshu Gaur; Applicant Hitachi, Ltd.; Patent Title: 'Generalised decision feedback equalizer precoder with receiver beamforming for matrix calculations in multi-user multiple-input multiple-output wireless transmission systems'; Publication number: WO2011028646 A2; Publication date: Mar 10, 2011.
2) Inventors: Dagnachew Birru, Charles Razzell, Seyed-Alireza Seyedi-Esfahani, Jun Yang; Applicant Koninklijke Philips Electronics N.V.; Patent Title: 'System, apparatus, and method for multi-band OFDM systems with receiver antenna selection per sub-band'; Publication number: US8126096 B2; Publication date: Feb 28, 2012.
3) Inventors: Aamod Khandekar, Ravi Palanki; Applicant QUALCOMM Incorporated.; Patent Title: 'Pilot transmission and channel estimation for a communication system utilizing frequency division multiplexing'; Publication number: US8135088 B2; Publication date: Mar 13, 2012.
4) Inventors: Koji Ikeda, Akio Kurobe, Gou Kuroda, Kensuke Yoshizawa; Applicant QUALCOMM Incorporated.; Patent Title: 'Transmitting/receiving apparatus, method, program, recording medium, and integrating circuit used in communication network'; Publication number: US7773498 B2; Publication date: Mar 13, 2012.

CNMPA: In the electronics reliability area, the first EPSRC project on developing a multi-physics model for the formation and reliability of microelectronic interconnects has led to a large number of future projects in the area of computational mechanics and reliability funded by EPSRC GR/M09292 (1998), GR/N14095 (2000), GR/R09190 (2002), EP/C534212 (2005), TSB TP/3/SMS/6/I/15880, EU (Projects: Flex-No-Lead & FAMOBS), and DOD (USA) and industrial projects. These projects involved collaboration with over 100 companies in sectors such as aerospace, automotive, electronics, telecommunications, healthcare etc. A recent example is the TSB funded project which developed novel displays for use in harsh environments. The designs and knowledge generated using the modelling results from the Centre are now being used by GE-Aviation, Raymarine, National Cash Register (NCR), Design-LED, and the National Physical Laboratory. Knowledge transfer to industry has also taken place through KTP programmes. For example, a KTP project with Flomerics Limited developed a multi-physics version of the award-winning FLOTHERM software that provided thermal design engineers with the ability to predict stress in electronic components at the early design stage. We have also undertaken many projects directly with industry, examples including SELEX (investigating the feasibility of lead-free interconnects for avionics equipment for the Eurofighter), TRW (investigating the reliability of solder joints for automotive applications), BOC (investigating new environmentally friendly furnace designs for electronic component assembly) etc. Our work has also been disseminated to industry through a number of short courses sponsored by the IEEE-Reliability Society. In terms of the defence sector we have received funding from DoD (USA) in collaboration with Rolls Royce, General Dynamics, SELEX, and Micross Limited which has identified new processes that provide a route to incorporate commercial off the shelf components into high reliability defence systems.

Within the materials area, the thrust of work has been the development and use of unique multi-physics software (PHYSICA) for the development of new high performance materials and processes for manufacturing components. This activity has been continuous, as evidenced by a succession of EPSRC grants: GR/G36265 (1990), GR/K42370 (1994), GR/L97483 (1998), GR/N14316 (2001), EP/D505011 (2006), EP/K00588X/1 (2012). On the international arena, collaboration in the pan-European IMPRESS project (2004-2009) contributed to the processing, design and use of intermetallic materials in important (from the point of view of the environment) applications, such as □-TiAl turbine blades for the next generation of Rolls-Royce aeroengines and

novel Raney (NiAl) catalysts for use in hydrogen fuel cells and bioreactors (end user Johnson Matthey). A strong vain running through this research features the application of magnetic fields to control the melting, flow and solidification of highly reactive alloys (Ti, Si, Al, Zr,…). The unique software created for this purpose (SPHINX) has been used by ArcelorMittal (Fr) and Corus (UK, NL) in steel making, and Rusal (Ru), Dubal (Dubai) and GAMI (China) for aluminium electrolysis cell production. Our ability to model the dynamic interaction of externally imposed electromagnetic fields and levitated metals has attracted the metrology community involved in the thermophysical property measurement of high temperature melts under terrestrial or microgravity conditions. This led to collaborations with NPL (UK), DLR (Germany), MADYLAM (Grenoble Fr), Tohoku Univ. (Japan) and Northeastern University (China). We are currently the only UK institution taking part in the European Space Agency ELIPS materials programme (projects PARSEC, Thermolab-ISS, SOL-EML) in the distinguished company of NASA, Japan Aerospace Exploration Agency (JAXA), DLR and a number of universities. Our TSB activity (project COLDMELT) in collaboration with PSI Ltd, aims to give UK the lead in the production of powder titanium for use in aerospace. Again, electromagnetic fields are used to produce a clean, inclusion-free melt for gas atomization.

c. Strategy and plans

A key strategic aim of the UoA is to continue and expand the impact-generating activities set out under 'b' above.

Over the coming years, our expansion plans include the following elements:

- to expand our world-leading electronics reliability and materials research;
- engage further in EU, TSB, EPSRC CASE and KTP projects to help transfer our research outputs into industry;
- improve reach and market penetration of our IP through patents and software tools;
- secure £2.5M in collaborative R&D funding from UK, EU (eg Horizon 2020) and international government and industry organisations to support collaborative work with business and industry.

Our plans to achieve the above goals are:

- to support staff to join EU networks to further expand our impact into Europe;
- develop an impact plan (using the *RCUK Pathways to Impact* categories) at the inception of each new significant research activity;
- disseminate our research findings widely and to a mixed audience, beyond academic journals;
- expand our involvement in standards bodies such as ISO and IEEE, by joining standards-setting committees.

d. Relationship to case studies

Electronics reliability research within the CNMPA is the theme characterising the impact described in case study 1. The case study demonstrates how, employing approaches i, ii and iii in particular, as set out in 'b' above, our research into microsystems assembly technology, and the design of stencils to support the use of isotropic conductive adhesives, led to impact in the following areas: (i) the establishment of a spin-out company – MicroStencil Ltd; (ii) the provision of key technology to DEK Printing Machines Ltd and Henkel Technologies Ltd; (iii) the development of international standards, (iv) provision of highly trained human resource.

Multi-physics modelling of materials within the CNMPA is the theme characterising research and industrial outreach in case study 2. Once again, employing approaches i, ii, iii and v, as set out in 'b' above, the case study demonstrates how our early work in multi-physics modelling for materials processing and manufacturing has led to impact in a number of areas including (i) design of new lightweight alloys for transport and aerospace; (ii) new intermetallic powders for catalytic applications and hydrogen fuel cells; (iii) new casting methods for turbine blades and (iv) new melting processes for reactive materials.