**Institution: University of Kent**

**Unit of Assessment: 15 General Engineering**

**a. Overview**

Our core research base is built around three well established groups, each of which exhibits consistent research performance with focussed leadership:

- Broadband and Wireless Communications (BWC)
  Prof J Wang (Chair), Dr JC Batchelor, Prof S Gao, Dr NJ Gomes, R Oven, Dr B Sanz-Izquierdo, Dr C Wang, Dr P Young, Dr H Zhu
- Instrumentation, Control and Embedded Systems (ICES)
  Prof Y Yan (Chair), Dr P Lee, Dr G Lu, Dr G Marcelli, Prof A Podoleanu, Prof S Spurgeon, Dr X Yan
- Image and Information Engineering (IIE)
  Prof M C Fairhurst (Chair), Dr J Ang, A Bobrowicz, Dr F Deravi, Dr C Efstratiou, Dr R M Guest, Dr W G J Howells, Dr K Sirlantzis

This strong discipline-specific base has been enhanced through the REF period by involvement with a number of research centres operating at both faculty and institutional level, including the Centre for Molecular Processing, the Centre for Cyber Security and Kent Health, which brings together the region's healthcare agencies. There has been strategic emphasis throughout the assessment period at both unit and institutional level on (i) wider engineering provision than the traditional electronic disciplines at Kent (ii) nurturing increased interdisciplinary activity. This is reflected in our choice of submission to UoA 15 - General Engineering.

**b. Research strategy**

**b.i Vision and strategic plans**

Our strategy is target driven and built upon negotiated individual and group research plans which are reviewed annually. Our vision is to

- grow core capability in our three niche and established areas of engineering excellence
- expand multi-disciplinary activity through strategic collaborations with national and international academic and industrial partners as well as those within the institution
- impact positively on contemporary issues, recognising that the unique blend of technological and design expertise within the unit is at the forefront of the needs of 21st Century Society

In the period 2008-2013, we have focussed on growing the critical mass of our three groups, where the number of academic staff in the unit has grown by 50%. A further strategy has been growing the postgraduate research student population – the PGR population has grown by 23% in the assessment period. One example of our collaborative endeavour is the key role played in the design of the optical fibre network for distribution of reference signals in the ALMA (Atacama Large Millimetre Array) radio astronomy project, a partnership of Europe, North America, East Asia and the Republic of Chile which will enable scientists to probe parts of the early universe. In terms of healthcare, our optical coherence tomography (OCT)/scanning laser ophthalmoscope (SLO) research has delivered insights into eye diseases and is now being used in clinical practice. Our strategy is aligned to the University's Research and Impact Strategy (2013-16) which nurtures innovative and world-leading research striving to have a positive impact regionally, nationally and internationally. Implementation of the strategy focuses on enabling a people-centred and research-led academic environment as described in detail in Sections (c) and (d). Future group research plans follow whilst Subsection b.ii provides an analysis of our progress against the plans described in RAE 2008.

***The work of the BWC Group*** will focus on techniques and technologies to underpin future, high data rate wireless communication systems which, due to spectral congestion, will increasingly be required to operate at higher frequencies with greater spectral efficiency. Our strategic plans in the forthcoming period include:

- Undertaking world-class research in radio resource allocation and multiple access for high data rate wireless communications, this being at a critical and opportune phase, with the emergence of new international standards for beyond 4G mobile communications
- Maintaining our leading position in microwave photonics research, focusing on optical fibre transport in future mobile/wireless access networks
- Developing new techniques for future RF/microwave/mm-wave circuits and systems
- Continuing our renowned frequency selective surface (FSS) work, focusing on screening in buildings and ultra-wide-band mini antennas

- Developing wearable antennas to characterise and model the on-body channel and furthering research into the development of RFID tags for challenging operating environments
- Developing smart antennas and phased array technologies for space applications such as satellite communications and space-borne synthetic aperture radars for earth observations.

***The strategy of the ICES Grou***p is to sustain research that is beneficial to the power generation, healthcare and other industries. We will continue applied research programmes in sensing, instrumentation, imaging, robust control and estimation and embedded system design. We will further develop

- Multiphase flow metering, in particular, coal/air and biomass/air two-phase and coal/biomass/air three-phase flow metering and on-line sizing of coal, biomass and particulates
- Monitoring and characterisation of burner flames in the power generation and other industries
- Optical Coherence Tomography (OCT) and physical motion measurement for rehabilitation
- Fundamental nonlinear control paradigms applicable to both engineering and biological systems, with a focus on the control mechanisms of health and disease
- Applications of embedded system design and neural network technologies.

***The IIE Group*** will build on our strong base and increasing success in industrial collaboration, maximising the impact from existing research themes. Our focus will be:

- Developing work on intelligent behavioural analysis
- Linking work in the security domain to new analysis of user interaction and exploring new applications in virtual worlds, social networking, etc.
- Extending work which links the areas of biometrics and forensics
- Building on work in privacy-enhancing security technologies
- Continuing development of information processing platforms which embody “intelligence” to provide high performance, operating flexibility and task-optimisation
- Developing work on healthcare monitoring, diagnostics and assessment.

**b.ii Current position with reference to the research position in RAE 2008**

All three groups have undertaken the planned activities as described in RAE 2008 submission. The current standing of each group with reference to the position in RAE 2008 is given below.

***BWC Group***

The research plans in RAE 2008 have delivered:

- A novel chunk-based radio resource allocation technique for wireless OFDMA systems for multiple user environments, which was implemented in the FP7 ULOOP prototype system.
- An architecture for Radio-over-fibre (RoF) distribution in future mobile access networks which contributed to the first demonstrations of coordinated MIMO using RoF-fed antennas in the FP7 FUTON project.
- Design specifications at mm-wave frequencies for the optical fibre and other optical components used in the distribution of reference signals. These included polarization mode dispersion effects and were deployed in the international ALMA radio astronomy project.
- Work on substrate integrated waveguides (SIW) with techniques to directly integrate active devices. Switches, attenuators and switched-beam antennas have been demonstrated, formed fully in SIW.
- Methods for producing reduced size FSS elements for wide bandwidths with actively switched and convoluted element designs. Fabrication technology was developed allowing the printing of FSS directly onto building materials using conductive inks.
- Novel button and multiband antennas characterised for low power use.
- Avatars derived from motion capture yielded highly accurate representation of test subjects allowing worn wireless sensors to be analysed reliably and transmit powers reduced.
- Transfer tattoos that are the world’s first ultra-thin RFID tags capable of reading on metal and skin. Designs are being refined in collaboration with industry (e.g. DSTL) for digital fabrication.

The BWC Group has been strengthened since RAE 2008 through new staff appointments. The deliverables of RAE 2008 have thus been complemented by:

- Lightweight and smart antenna technologies for space applications.
- Intelligent radio resource allocation algorithms for future mobile systems.

The performance of the BWC group since the last RAE is evidenced by a total of £3.1m in research grants, 130+ journal papers, 160+ conference papers and six prizes and awards (part e).

***ICES Group***

The research plans in the four distinct areas in RAE 2008 have correspondingly delivered:

- Flame imaging technology capable of providing the measurement of flame characteristics such as temperature distribution, free radical concentration and stability which has been applied to quantity biomass flames, biomass/coal flames and oxy-coal flames for the optimization of large-scale coal and biomass fired and oxy-fuel combustion processes.
- New solutions to mass flow metering and on-line particle sizing of pulverised fuel (coal and biomass) using electrostatic sensor arrays and piezoelectric sensing techniques.
- An innovative multiple-path interferometer configuration for OCT, which provides multiple OCT en-face images simultaneously for use in medical instrumentation.
- New algorithms using logarithmic signal processing which have been applied to high-speed imaging, OCT and correlation. The architectures have been combined with low-power circuit techniques to improve battery life in mobile computing applications.

The former IES Group has been augmented since RAE 2008 to include the closely related discipline of control. This has significantly enhanced our strengths and stimulated opportunities for interdisciplinary collaboration. The deliverables of RAE 2008 have thus been complemented by:

- Fundamental theoretical research relating to robust control of systems with limited plant measurements and/or subject to delay as well as stabilization of nonlinear and discontinuous systems in finite time. This has been supported by EPSRC throughout the period with funded international collaboration with Mexico, France, Israel, India and the USA.
- Applications work, including diverter control for MAST (Mega Amp Spherical Tokamak), the UK's fusion energy experiment at Culham Centre for Fusion Energy.

The ICES Group are founding members of the University's Centre for Molecular Processing, which was established in 2009 with funding of £2 million to link systems and modelling expertise across the institution with experimental scientists. The progression in the period is evidenced by the total income generation of £4.5m, the quality and volume of research publications (140+ journal papers and 250+ conference papers) and the six awards and prizes by professional bodies (part e).

***IIE Group***

The objectives set in RAE 2008 focussed on security and healthcare themes underpinned by continuing generic research in multi-source and multi-dimensional data processing and pattern recognition. The five work strands articulated in RAE 2008 have delivered:

- Intelligent classifiers based on agent-mediated negotiation. These offer advantages over conventional classifiers in unpredictable data environments and are especially effective in multiclassifier combination.
- Work on security/encryption where issues of security and the relationship between biometric identifiers and their analogues in hardware/software processes improve system assurance and integrity in cloud computing.
- In terms of adaptive multimodal biometrics applications, understanding of the effects of physical ageing in biometric systems, particularly for the iris and handwriting modalities. Information about the relationship between biometric features and other measures of identity have been integrated within a model of "SuperIdentity" across physical and cyber domains and a novel method for the assessment of biometric usability, the Human Biometric Systems Interaction model enabling an exploration of human and systems error components has been developed.
- Integrating work on handwritten data reading with forensic applications of handwriting analysis has delivered developments in handwritten signature analysis in relation to work on signature quality and standards and a new approach based on the "grapheme spectrum" concept for textual word spotting in handwritten documents such as analysis of historical documents.

The planned focus on healthcare applications articulated in RAE 2008 has been complemented by strengthened skills from new appointments in on-line user analysis and has been very productive:

- Multimodal biometrics have been integrated into flexible remote healthcare delivery platforms within the CallerID project. Methods for generic drawing-based medical assessment have been developed and introduced into the clinical environment. A novel intelligent wheelchair design has been developed. Work to support older people and intelligent behavioural assessment has led to a major EPSRC project investigating communication behaviours of role transitions.

Over the assessment period the IIE Group published 60+ journal papers, 120+ conference papers and was awarded a total of £1.3m in research grants.

**c. People**

**i. Staffing strategy and staff development**

Underpinning our strategy to nurture our core capability and given statistics on the unit's demographic post RAE 2008 showing an ageing academic population, the staffing strategy in the current period has been to focus on vitality and succession planning and to this end seven appointments have been made at lecturer level across all three research groups. One appointment replaces Haxha who left in 2010 to become CEO of an international telecommunications company with six posts representing new investment in the unit. Two additional strategic appointments at professorial level have been used to facilitate increased opportunities for interdisciplinarity and strengthen and broaden our stakeholder base. Following RAE 2008, a strategic decision was taken to include the discipline of control within the former Instrumentation and Embedded Systems Group. The appointment of Spurgeon (Professor) who joined the University of Kent in 2008 from Leicester to the post of Chair in Control Engineering was followed by the appointment of X Yan (Lecturer, 2010) and Marcelli (Lecturer, 2011) to add critical mass to the activity. In 2012 strategic investment brought the appointment of Prof. Gao from Surrey. Gao has brought extensive experience in smart antennas and space RF technologies to complement the unit's established strengths in the antennas area as well as considerable experience of research collaboration with industry. The appointment of Gao was also strategically aligned with infrastructure developments which provided a multi-functional millimetre-wave anechoic chamber in 2011. The appointment of early career researchers C Wang (2013), Zhu (2012) and Sanz-Izquierdo (2013) has provided depth and succession planning across the BWC Group. The IIE group has been strengthened by the appointment of Ang (2009) and Efstratiou (2013) both of whom provide considerable experience in human computer interaction and mobile computing. The unit has expanded by 50% to 24 FTEs in the assessment period.

**Career development support**

Career development needs of academic staff are identified through the annual appraisal and promotion cycle and individual research planning and performance review processes. Through these processes individuals develop research and enterprise plans and also articulate problems or training needs. Engagement of the Heads of School and Research Groups with these processes ensure realistic plans that deliver both for the individual and the unit are established which are supported appropriately. All new academic staff enrol on the University's PGCHE programme, which embraces research-related training and each is supported by a mentor and a probation supervisor. Our workload model modulates teaching, research and administrative commitments to ensure availability of time for research and scholarly activity. Newly appointed staff and early career researchers are given a reduced load (50% in year 1, 75% in year 2 rising to a full load in year 3) to enable them to establish independent research careers. In line with the university policy, the unit established an efficient internal peer review system in 2011 to help staff producing higher quality grant proposals from EPSRC First Grant to large proposals for EU funding. The University of Kent has established the Grants Factory programme for staff applying for research funding which includes regular mock panels to advise less experienced staff in external funding. Over the assessment period three members of staff (Bobrowicz, Guest and Lu) were promoted from lecturer to senior lecturer and three (Batchelor, Gomes and Howells) from senior lecturer to reader.

Additional support is provided to RAs through the development in 2012 of the Early Career Researcher Network. This provision integrates a range of training and development opportunities in research-related and transferable skills and specialist careers guidance with an opportunity to network and share best practice across the institution. The University of Kent attained the European Commission's HR Excellence in Research Award in May 2013 in recognition of its commitment to and compliance with the principles of, the Concordat to Support the Career Development of Researchers. School Research Conferences are organised biennially (http://www.eda.kent.ac.uk/research/conference.aspx) and internal research workshops and regular School Research Seminars are attended by all academics and RAs (http://www.eda.kent.ac.uk/research/seminars.aspx). Staff attend external and internal training events organized by the University of Kent and information days provided by funding bodies. The Faculty of Sciences has ring-fenced annual research funds to pump-prime investigation and scoping of new research opportunities in addition to the provision of a research support officer who works closely with academics in the formulation of grant proposals.

**International staff appointments**

In the assessment period we have appointed nine members of staff (Ang - Malaysia, Efstratiou - Greece, Gao - China, Marcelli - Italy, Sanz-Izquierdo - Spain, Spurgeon - UK, C Wang - China, X Yan - China, Zhu - China). Throughout the audit period we hosted more than 40 visiting scholars from overseas, including Brazil, Canada, China, France, Japan, India, Indonesia, Israel, Italy, Korea, Mexico, Russia, Spain, New Zealand, Poland and USA. These scholars undertook research or scholarly work with us from a couple of weeks up to two years. Fourteen of the scholars were funded by the Royal Academy of Engineering (Distinguished Visiting Fellowship), the Leverhulme Trust (Visiting Professorship), Newton International fellowships, KC Wong Foundation, and the remaining were funded by their home institutions or governments.

**Equality and diversity**

The unit has an action plan to show its commitment to equality and diversity. All academic staff are required to attend equality and diversity training. A staff member was appointed as the unit's Equality, Diversity and Inclusivity Representative. An Athena SWAN Committee, which was established in 2012, includes male and female academic staff, PGR and RA members from a range of ethnic backgrounds and contracted working patterns. The University made an Athena SWAN Bronze application in 2013 and the unit's action plan is aligned with applying for an Athena SWAN School award in 2014. Comparative data on the balance, grade and level of achievement of academic staff, RAs and postgraduate research students with different protected characteristics is reviewed and compared with the national position on an annual basis as part of the University Planning Round. Female representation on staff appointment panels is ensured by University policy. The unit provides mentoring from senior staff for staff seeking promotion or developing promotion cases. The unit hosted two Daphne Jackson Fellows, a Newton Fellow and a KC Wong Fellow in the assessment period. These fellowships were all awarded through open competition.

**ii. Research students**

**Recruitment**

The training and management of postgraduate research students (PGR) is led by the Director of Graduate Studies. Our PGR recruitment is efficient and decisions are normally made within one month from receipt of online applications. The vibrancy and attraction of the unit provision is demonstrated by the fact that applications for postgraduate research have grown by more than 80% over the assessment period. New PGRs can start their registration any time throughout the year, though most of them register at the beginning of a new academic year. There are currently 64 PGRs registered with the unit, an increase of 23% compared to our PGR population in 2008.

**Training and support mechanisms**

Our postgraduate training environment offers a high level of resourcing, personal direction and group support. The Graduate School champions the strategic development of provision for graduate education and research at the University of Kent and offers a formal Researcher Development Programme for all PGRs and RAs. This is provided partly at Faculty level (transferable skills) and partly at University level and is complemented through the School's specialist training programme. Each student is overseen by a Supervisory Panel consisting of First and Second Supervisors and a Supervisory Chair. Newly appointed early career staff are trained in research supervision and associated student care. All PGRs attend regular research seminars organized by each research group, give internal seminars at least once a year and attend the biennial School Research Conferences. Each student is financially supported by the School to participate in at least one major international conference. Students benefit greatly from increasing numbers of international visitors in the unit, broadening their horizons and enhancing opportunities for cross-topic discussion. The IEEE Student Branch at the University of Kent has organised various technical meetings and social events since its formation by PGRs at the submission unit in May 2013. We also provide opportunities for students to undertake laboratory or small-group teaching with appropriate training. The results of the Postgraduate Research Experience Survey (2013) demonstrate the quality of our training and supervision provided: areas substantially above the national position include responses to 'My department provides a good seminar programme for PGRs' (84%, 21 percentage points above the sector level), 'My supervisor/s provide helpful feedback on my progress' (97%, 18 points above the sector level) and 'As a result of my experience so far I feel confident about managing a research project' (91%, 17 points above the sector level). PGRs are represented on key management committees within the unit.

**Progress monitoring**

We have implemented a strict progress monitoring system. Each student must have an induction review at the end of the first month of their registration, a probation review by the end of the tenth month of registration and a review at both the end of years two and three. In the writing-up year, students may request an extension from a few months to one year. Only under exceptional circumstances is an extension given for more than one year. Progress is monitored with assistance from the institutional Student Data System which sends email reminders to students and supervisors of deadlines for submission of reports and outcomes of assessments.

**d. Income, infrastructure and facilities**

**Infrastructure and facilities**

The unit strategy is to resource a well-founded laboratory infrastructure across its three research groups concentrating more substantial infrastructure investment in its leading and niche experimental areas. The University of Kent allocated £3.492 million for the provision of specialist research infrastructure over the assessment period. A significant upgrade (£350,000) was made to five key research laboratories in 2008. A state-of-the-art anechoic chamber operating at up to 110 GHz (now one of the best university facilities in Europe) was established at a cost of £650,000 in 2011. The area of antennas has been well established at Kent for over 40 years and the unit is committed to preserving the experimental facilities that are essential to this research area. Maximising value for money from the investment has been ensured by the appointment of Gao (Professor) and Sanz-Izquierdo (Lecturer) during the assessment period. A further investment of £110,000 was made in the Photonics Laboratory of the BWC group in 2013 for high-speed, real-time measurement capability, supporting the work of a newly appointed lecturer as well as extending capabilities for the established radio over fibre research. In line with our strategy to impact on significant challenges, the unit has expanded the Combustion Instrumentation Laboratory (£115,000), including the installation of high capacity compressed air systems and high-capacity, high-flow $CO_2$ systems and construction of industrial test rigs for flow and combustion measurement and analysis. From 2011 to 2013 the Medical Instrumentation Lab received an equipment investment of £200,000 from the university, including an ultrafast camera and specialist optical analytical tools. As part of an ERC Advanced Grant (COGATIMABIO 249889) awarded to Podoleanu, equipment funding of £250,000 was obtained to purchase optical instruments, lasers and digital measurement electronics.

The unit provides an in-house Technical Support Centre, including an IT service which is highly responsive and tuned to researchers' needs. For example, a number of specialist processing systems have been constructed to support antenna simulation. All RAs and PGRs are provided with desks and PCs and recurrent unit budgets are used to replace PCs on a three year cycle. The unit benefits significantly from a well-resourced Engineering Workshop which services research and consultancy projects requiring high-level mechanical engineering as well as surface mount electronic assembly. The Engineering Workshop produced the prototype instruments that were successfully tested on coal, biomass and oil fired power stations. Nano-ID, a nanoparticle spectrometer marketed by Naneum Ltd. which won the Inaugural Innovation Award from the Institute of Physics in 2012, was manufactured in the Mechanical Workshop. The ICES Group maintains a long-term working relationship with power generation organisations which provide access to industrial-scale combustion test facilities and full-scale power plants. The Technical Support Centre has recently received £1.25m of institutional investment which will benefit the research unit. There are also on-going annual investments to support and maintain high-end server, network and data storage facilities.

**Research funding portfolio and future plans**

Over the assessment period we have been awarded in excess of £10million from a diverse range of external funding bodies and industry, in particular, EPSRC, ERC, EU FP, TSB, KTP, BCURA/BF2RA, The Royal Academy of Engineering, The Royal Society, The Leverhulme Trust and leading industrial organizations such as DSTL, NTT DOCOMO, RWE npower etc. Over 40% of our funding is from EPSRC and other UK research councils and 36% of our funding is from the European Union. Podoleanu (ICES Group) was awarded an ERC Advanced Grant of over 2m Euros. We have maintained a 100% success rate with the EPSRC First Grant scheme since 2008. In view of the current challenges in research funding, the unit seeks to maintain a varied portfolio of funding, ranging across UK research councils, EU funding programmes, charitable organisations

and industry. Collaborations with our established academic and industrial partners in the UK and Europe is key to our future funding plans. We will continue to establish industry-linked projects such as those funded through KTP and TSB with the support of Kent Innovation and Enterprise (KIE), the University's commercial arm. Consultancy activities beneficial to staff career plans and supporting impact will be encouraged. In addition, smaller grant proposals will be submitted in response to external and internal calls for funding. The unit will continue to use the established internal peer review system to support staff producing proposals of the highest quality across the range of funding sources.

**Consultancies and professional services**

Our research environment is closely linked to outward-looking enterprise activities, and we interface strongly through our School Enterprise Committee to KIE. Our Enterprise Committee also oversees our Electronic Systems Design Centre (ESDC), which has an impressive track record of promoting technology transfer (e.g. DSTL, Post Telekom Kosovo, Identity and Passport Service, RWE npower etc.) and Knowledge Transfer Partnerships (e.g. EMS Ltd., C-Scope Ltd., Timeplan Ltd. and Martec Ltd.). We have a well-established School Industrial Panel (senior industrialists from a diverse range of industrial sectors) which typically meets biannually and attends our biennial School Research Conferences, ensuring that our research and career-support planning is industry-aware and externally responsive. Over the assessment period the unit filed and maintained 40 patents and supported the formulation and operation of four spin-out companies (Metrarc Ltd., VisionMetric Ltd., Optopod Ltd. and MioBand Ltd.).

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

**Research collaborations**

Both nationally and internationally we have an excellent record of developing strong partnerships with institutions through EU, EPSRC and Royal Academy of Engineering funded projects. For instance, the ICES Group has established partnerships with prestigious Zhejiang, Tianjin and Xi'an Jiaotong Universities in China through two EPSRC funded projects (EP/F061307/1 and EP/G063214/1) and a major exchange project funded by The Royal Academy of Engineering (Ref: 5502). We have participated in FP7 projects (e.g. FUTON: ICT-215533, ULOOP: ICT-257418) through collaboration with numerous EU partners. Benefitting from our geographical location, we have worked with many institutions in France and other European countries through Interreg and similar EU funded schemes (e.g. DocExplore: IVA 4043 and 4117, NOBA: IVA 4051, TECS: IVA 4081, SYSIASS: IVA 06-020-FR, COALAS: IVA 4194). At national level we have established partnerships with research groups at Cambridge, Dundee, Edinburgh, Exeter, Imperial College, Lancaster, Leeds, Manchester, Nottingham, Royal Holloway and UCL through EPSRC funded projects. Staff are visiting professors at a number of international institutions, for example, Y Yan (Tianjin University and North China Electric Power University, China), Guest (Universiti Teknologi Malaysia and Purdue University, USA). Over the assessment period the unit has developed links with academic and industrial institutions in Australia, China, India, Japan, South Korea, Malaysia, New Zealand, USA and more than ten countries across Europe. We have signed formal collaboration agreements with several institutions (e.g. UCL, UK and Tianjin University, China).

**Interdisciplinary research**

Encouraging interdisciplinary working has resulted in joint projects with the School of Biosciences (systems and modelling), the School of Physical Sciences (medical instrumentation, optoelectronics, biometrics) and the School of Psychology (human computer interaction, energy consumption). The University has established Research Centres to promote working across Schools and Faculty boundaries. We contribute to the Centre for Molecular Processing and Centre for Biomedical Informatics, Centre for Cognitive Neurosciences and Systems and the newly formed Centre for Cyber Security. We have forged interdisciplinary links with Kent Health (http://www.kent.ac.uk/health/about/index.html) and our research in multi-parameter assessment of upper limb movement and automatic facial gesture recognition has led to a close working relationship with local NHS consultants.

**Industrial and end-user collaborations**

The majority of our research activities are applied and hence collaborations with industrial and end-users of the technologies are a crucial element of our research endeavour. For instance, the BWC Group has collaborated with DSTL to advance ground detection capabilities in military operations, body centric technologies to investigate body armour with electromagnetic bandgap screening

between worn antennas and human operators and covert RFID tags for security services and health providers. Work with Mitsubishi VIL developed internal antennas for Digital Terrestrial flat screen TVs. The Group collaborated with Surrey Satellite Technology Ltd. and Polar Imaging Ltd. on the development of space remote sensing instruments (SGR-ReSI) and with EADS (Germany), IHP (Germany) and Ericsson (Sweden) on the development of mm-wave smart antennas for mobile satellite communications through FLEXWIN funded by EC FP7. The ICES Group has established strong partnerships with leading power generation organizations including Alstom Power, Datang Corporation (China), Drax Power, Doosan Babcock, E.ON, RWE npower and SNET (France) through projects funded by EPSRC, TSB and EU. Interactions with the industrial partners have influenced the ICES Group's research directions and strategies. Examples of this include biomass/coal/air three-phase flow metering, on-line fuel tracking, and oxy-fuel flame imaging, which are new research activities inspired by the industrial partners. We also work closely with a wide range of SMEs locally and nationally through our Electronic Systems Design Centre (ESDC). The unit has built up a strong partnership with NHS hospitals and SMEs. For example, the unit and East Kent Universities Hospital Trust undertook two projects over the assessment period.

**Research leadership**

***Advisory board membership:*** Fairhurst: member of Government Biometrics Assurance Group; Home Office IPS Experts Group. Spurgeon: member of the UK's Defence Scientific Advisory Council (DSAC). Y Yan: member of the Innovation Metrology R&D Metrology Working Group and the Engineering and Flow Working Group of the UK National Measurement Office.

***Learned societies or professional bodies:*** Spurgeon: Chair of the Technical Committee on Variable Structure and Sliding Mode Control (2009-2013) elected by the IEEE Control Systems Society's Board of Governors; Chair of UKACC (UK Automatic Control Council) (2008-2011). Y Yan: member of Executive Committee of the Coal Research Forum (CRF). J Wang: Officer of the Radio Communications Committee of the IEEE Comm. Society. Deravi: member of BSI and ISO committees on biometric standardisation. Fairhurst: Vice-Chair of COST IC1106, Member of the IAPR Education Committee and Member of the IEEE International CBP Committee.

***Conference programme chairs:*** Batchelor (2010) and Gao (2013) were General Co-Chairs of Loughborough Antennas and Propagation Conference; J Wang was Technical Programme Chair of IEEE WCNC 2013; Podoleanu was Chair of the 1st Int. Symp. OCT and Adaptive Optics 2008; Y Yan was Co-Chair of 8th Int. Symp. Meas. Tech. Multiphase Flow 2013 and Technical Programme Co-Chair of IEEE I2MTC 2011, IEEE I2MTC 2012, IST 2012, ISTMTMF 2011 and ICEMI 2011;

***Invited keynote lectures:*** Gao: LAPC2008; Batchelor: LAPC2009; J Wang: ChinaCom2012; Podoleanu: ICO 2008; Lu: IST 2012; Y Yan: IEEE IST 2010, INFUB 2011, ISTMTMF 2011, IFRF-MC 2012, EUROCON 2013, IEEE ICSIMA 2013; Fairhurst: IET IPR 2012 and IGS 2013.

***Fellowships:*** FREng (Spurgeon); FIEEE (Y Yan); FIET (Batchelor, Deravi, Gomes, J Wang, Spurgeon, Y Yan); FInstP (Podoleanu, Y Yan); FInstMC (Spurgeon, Y Yan); FIAPR (Fairhurst); FIMA (Spurgeon); FOSA (Podoleanu); FSPIE (Podoleanu).

***Journal editorships:*** *IET Image Processing* (Deravi); *IET Biometrics* (Fairhurst); *Pattern Analysis and Applications* (Fairhurst); *Radio Science* (Gao); *Optics* and *Advances in Optoelectronics* (Podoleanu); *IMA Journal of Math. Control and Information* (Spurgeon); *IEEE Trans Comm. (*J Wang*); China Information Science* (J Wang); *IEEE Trans Instrum. and Meas.* (Y Yan).

***Editorial board member:*** *Space Science and Engineering* (Gao); *IET Circuits, Devices and Systems* (Gao); *Photonics Sensors* (Podoleanu);*Journal of Intense Pulsed Lasers* (Podoleanu); *Advanced Applications in Physics and Optoelectronics and Advanced Materials* (Podoleanu); *Systems Science (*Spurgeon*); Robust and Nonlinear Control* (Spurgeon); *IET Control Theory and Applications* (Spurgeon); *Flow Meas. Instrum.* (Y Yan); *Meas. Sci. Instrum.* (Y Yan).

***Awards, prizes and other recognitions:*** Batchelor: IET Innovation Awards - Highly Commended (2011). Deravi: Best Paper Award for Real World Applications at ESTC 2011. Gao: Best Paper Award at LAPC 2012; Japan Society of Promotion Science Award (2013). Lu: Best Poster Prize at Int. Conference on Sensors & Applications (2009). Spurgeon: Honeywell International Medal (2010) by the InstMC; Distinguished Lecturer by the IEEE Control Systems Society (2011). C Wang: Best Paper Award at IEEE MWP 2010. J Wang: Distinguished Lecturer by the IEEE Comm. Society (2013). Y Yan: Distinguished Lecturer by the IEEE Instrum. Meas. Society (2012); the Alec Hough-Grassby Award by the InstMC (2011); Industrial Award at the IEEE I2MTC 2012. Zhu: Best Paper Awards at IEEE GLOBECOM 2011 and IEEE VTC 2011.