Institution: University of Surrey

Unit of Assessment: UOA 13 Electrical and Electronic Engineering, Metallurgy and Materials

a. Overview

Our aim is to undertake world-leading research in our focussed areas of advanced materials and nanotechnology, communication systems, signal processing and satellite/space engineering. Since RAE2008 we have maintained our focus to build around large and critical mass research centres with a managed approach to research which has delivered on our strategy. We have produced both basic and applied research of the highest international quality, increased our publications in high quality journals and extended our integration with industry demonstrating high impact. The research output and impact was recently recognised by the Royal accolade of the first Regius Chair in Electronic Engineering being bestowed in 2013.

The research detailed in this return comprises the activities of the four Electronic Engineering (EE) Research Centres, which since RAE2008 have expanded to reflect developing challenges, alongside materials related research activities that were previously returned to General Engineering in RAE2008. Materials research thus relates to two of the organizational groupings detailed below (ATI and MSE).

Advanced Technology Institute (ATI) - Headed by Prof Ravi Silva FREng and Professors Gwilliam, Homewood, Slade and Varcoe. Academic staff - Aaen, Cai, Carey, Cox, Crean, Curry, Emerson, Forbes, Henley, Jarowski, Shkunov, Sporea, Stolojan, Trevethan, Turner.

Centre for Communication Systems Research (CCSR) - Headed by Prof Rahim Tafazolli and Professors Evans B FREng, Moessner, Sun. Academic staff - Barnaghi, Brown, Dianati, Foh, Heliot, Imran, Kelly, Ma, Nikitopoulos, Wang N, Xiao.

Centre for Vision, Speech and Signal Processing (CVSSP) - Headed by Professor Adrian Hilton and Professors Bober, Bowden, Evans P, Illingworth, Kittler FREng, Kondoz. Academic staff - Christmas, Collomosse, Fernando, Guillemaut, Hummersone, Jackson, Lewis, Mikolajczyk, Pugeault, Wang W, Wells, Windeatt.

Materials Sciences and Engineering (MSE) - Headed by Professor John F Watts and Professors Crocombe, Heggie, Kirkby, McDonald, Ogin, Smith, Webb, Yeomans. Academic Staff - Abel, Bailey, Baker, Cavalli, Grime, Hamerton, Jeynes, Lekakou, Lohstroh, Rayson, Reddy, Watson.

Surrey Space Centre (SSC) - Headed by Professor Sir Martin Sweeting FRS FREng and Professors Aglietti, Gao, Lappas, Underwood. Academic staff - Bridges, Guida, Knoll, Palmer, Ryden, Saaj.

More broadly, these research groupings sit within the Faculty of Engineering and Physical Sciences. The Faculty operates a devolved system and large research centres are separate cost centres with a considerable degree of autonomy within the aggregated overall Faculty budget. A single Faculty Research committee (chaired by the Associate Dean Research) coordinates issues such as joint and multidisciplinary bids, studentship bids, student progress and training and strategic issues linked with the University Research and Enterprise committee on which the Associate Dean Research sits. The Centres themselves provide well-managed research environments, strong leadership and sustainability of the core research disciplines. The advantage of size means that fluctuations in funding and staffing levels can be better managed than in smaller groups. All staff and researchers are also *de facto* members of a Department which organises the teaching of undergraduate and postgraduate programmes.

b. Research strategy

Delivering on the 2008 research strategy

The period since RAE2008 has been one of continuing progress and success. Our research portfolio (live grants) has increased from c. £30M to c. £40M over the period and we have secured 12 grants/contracts in excess of £1M whilst becoming the largest UK recipient of EU FP7 funds in

both the Communications and the Space areas. Our partnerships with industry have increased significantly, most notably via the recent award of £11M from HEFCE matched by £24M from industry for a new 5G Innovation Centre (5GIC), and other strategic alliances have been formed, e.g. membership of the BBC's Audio and Video Centre of Excellence. We have established, via a successful KTA grant from EPSRC (£3.6M), a KT partnership with the National Physical Laboratory (NPL), and played a key role in the formation and operation of the Satellite Applications and CDEC Catapult Centres. Surrey Satellite Technology Ltd. (SSTL) was spun-off at the start of the period for the largest cash sale (£50M) of any UK academic based company. Recently, a HEFCE Catalyst grant (£3M) was awarded to support mobile communications, and the period was crowned by the award of the first Regius Chair in Electronic Engineering in recognition of sustained research excellence over more than 30 years.

To achieve these successes we have invested strategically in staff (including 7 new Professors) to achieve a more uniform coverage and critical mass in all areas, and a new cross centre medical group has been formed to enhancing links to the NHS. The EPSRC DTA income has been invested strategically to form a new Surrey CDT to increase the UK PGR compliment. Focus has been on longer and larger research sponsorship and on strategic industrial partnerships which have enabled us to deliver in each of our key challenge areas. Materials related activities have been integrated by incorporating materials chemists researching in energy and fuel cells (and chemists working on nano and molecular electronics) alongside ATI researchers working on photovoltaics to concentrate activity on future energy research. In addition, the MSE grouping brings together researchers from Engineering, Chemistry and Physics who have a shared interest in tackling key challenges relating to materials characterisation, structural materials and materials modelling. To support the latter we have invested in instrumentation to stay at the forefront of characterisation (new equipment in ion beam analysis, surface analysis, X-Ray diffraction and electron microscopy) and extended our work on infrastructure reliability with a large grant from a public utility. In more detail:

ATI has focused activity in three critical mass sub-units: (i) the NanoElectronics Centre; (ii) the new Energy and Photonics Group; and (iii) the Theory Group. All groups are multidisciplinary in nature having EE, Physics and Chemistry staff. During the period major advances have been made in the field of low temperature growth of carbon nanotubes (CNT) and low-k dielectrics, with the spin-out company Surrey NanoSystems Ltd. driving exploitation based on holding key patents in low temperature deposited low-k dielectrics. Research into silicon photonics, supported by a £2.2M EPSRC grant (£5M in total) in 2008, has helped to establish this as a leading contender in optical technology worldwide which is poised to revolutionise short-reach interconnects and optical modulators. Significant progress has also been made in optical modulator designs, which were discussed in a Nature Photonics review authored by Surrey. A further £3M EPSRC Programme grant on Spintronics has facilitated the integration of researchers from different disciplines, and a recent £1.5M EPSRC programme involving Surrey, Cambridge and Southampton is developing next-generation materials and devices for phase-change memory and (opto)electronics.

CCSR has pioneered work on cellular-relay hybrid architectures to achieve improvements in radio coverage, capacity and user positioning with more energy efficiency; in doing so defining the architecture that has been adopted for the LTE-A (4G) standard. A new multi cell coordination scheme (load matrix) was proposed and evaluated and this has also been adopted for LTE(4G) standards. A multiple access scheme - Low Density Signature (LDS) - was shown to provide a 2.5 times capacity increase in cellular systems and is a candidate for 5G. Further, research on reconfiguration management architecture has been adopted by the SDR Forum as the basis for SDR technology. A faster and more accurate spectrum sensing scheme was developed for use in CR HETNETS and in TVWS augmented data base systems. European research on the Internet of Things(IoT) was initiated by CCSR via EU projects SENSEI and e-SENSE and led to the first smart cities demonstrator SMARTSANTANDER. This enabled the establishment of a Surrey smart campus with 3000 reconfigurable sensor nodes which has been adopted as a platform by the TSB. In the energy area the major project EARTH on radio access won the prize for the best EU FP7 wireless project. In the satellite area research has been initiated into Terabit/s satellite involving the development of smart gateway schemes and efficient satellite payload resource management to

accommodate non uniform traffic. In the web services area a new hybrid service delivery engine which combines machine learning and logical reasoning has been developed, whilst a new ontology model for semantic sensor networks has been applied to the IoT for describing sensors and sensor platforms.

CVSSP has seen advances in research on robust visual tracking result in the award of the 2011 ICT Pioneer Prize from EPSRC and the resulting technology being licensed to Google. The use of data-mining for action recognition in internet scale datasets was pioneered at Surrey and the technology exploited for security and surveillance. The link between 3D facial shape and genealogy to identify related populations across the UK was established and, as an exemplar of outreach activity, demonstrated via the 2012 Royal Society and Big Science public exhibitions. Efficient methods for 3D video coding were researched and the first free-viewpoint video for sports TV & stereo 3D film production were achieved, which has been exploited by the BBC and The Foundry. Strategic investments have been made in Multimedia Communications Systems, combining expertise in communications (CCSR) and signal processing and resulting in advances in multi-screen delivery of multimedia content.

MSE has focussed on three strategic areas of research; materials characterisation, structural materials and materials modelling. The former is the largest and incorporates the activities of the Surrey Ion Beam Centre, Surface Analysis Laboratory, Microstructural Studies Unit and niche NMR imaging areas such as the STRAFI and GARfield systems. This has formed the focus of our highly regarded Industrial Doctoral Centre in Micro and NanoMaterials and Technologies (MinMaT), currently with some 50 Research Engineers associated with c. 30 sponsoring organizations ranging from SMEs to large multinationals (e.g. Proctor and Gamble) and national laboratories (e.g. NPL, DSTL). In RAE2008, the potential for growth and the synergy of many activities, particularly in conjunction with the ATI, was highlighted. These aspirations have come to fruition, leading to (i) much better integrated characterisation activities, (ii) expansion of research into infrastructure reliability, (iii) a shift in focus of ceramics research to ceramic armour and joining, and (iv) significantly expanded research into functional polymers and composites for aerospace and electronics. Diffusion studies by STRAFI have become an important area and form a key component of NANOCEM (consortium of 30 industrial and academic partners) leading to significant international collaboration and research income to date of over £1M.

SSC has pursued a strategy based around building very strong links to key UK and European space industrial partners, most notably EADS-Astrium, whilst maintaining a direct link to Surrey Satellite Technology Ltd. (SSTL). This has provided strong industrial focus in space engineering, in small satellite systems and applications, and for the next challenges in space, e.g. the all electric spacecraft and space debris mitigation. The Centre now houses leading academic research programmes in electric propulsion and debris mitigation, based on leveraging industrial research support with substantial European Union (FP7) funding, as well as in the area of space robotics. Significant expertise in SAR image interpretation has also been established and employed to support the UK's NovaSAR S-Band radar mission. The UK's first CubeSat mission (STRaND-1) in collaboration with SSTL was pioneered during the period and the expertise gained has been used to establish links with Caltech for the highly innovative AAReST reconfigurable space telescope demonstrator mission (in conjunction with NASA-JPL). In addition, it has also enabled involvement in the QB-50 50 nanosat mission and proved invaluable in defining the CubeSail, DeploySail and InflateSail debris mitigation demonstration missions.

Future strategy

Our future strategy is to continue our research focus around the existing challenge areas of Demography, Energy and the Environment, Global Security and the Digital Economy. With our broad coverage in advanced materials and devices, broadband communications, Internet of Things, signal processing, media, nanotechnology and space, together with our critical mass, we are well placed to address the future challenges and to adapt to the changing external funding environment. We will complement our basic research with more experimental demonstrators to maximise our research impact and link to the TSB Catapults and our networks of industrial collaborators. The new £35M 5GIC will be a catalyst and a major element in this strategy,

becoming an International Centre which will engage other Universities and industry to help regain the UK position in leadership of mobile standards. Our senior staff will also continue to shape the external research landscape via participating in setting the National and International R&D agendas. In more detail:

ATI will expand its research on next generation renewable energy devices, on advanced plastic electronics and applications to large scale terminals and machine interfaces, wireless and sensor networks, assisted living and smart cities. There will be integration of activities with the new 5GIC in green energy technologies and with wider University healthcare initiatives; graphene based nanocarbons provide major opportunities for innovation and research funding in these areas. By strengthening research in novel renewables the aim is to produce more efficient materials for solar PV. Complementary research into storage devices such as supercapacitors, organic fluid, and transportable energy and novel power generation, as well research on more energy efficient optical and spintronics devices, will continue and in the context of 5GIC will lead to efficient sensors using energy scavenging including thermoelectrics, solar and pyroelectrics. In all of the above areas there are significant opportunities for funding via EPSRC, EU, TSB and from industrial partners.

CCSR will become the research element of a new Institute which will also include the 5GIC; the University is supporting 10 new posts in the 5GIC in 2013/4. Major indoor and outdoor 5G experimental test beds will be set up and linked to an operator network; this facility will be used to drive more industrial facing projects but also link to existing research and enable additional EU bids. By such means one can bridge the industrial-University divide to accelerate innovation. Now that the smart campus IoT platform has been adopted by the TSB this will open up further opportunities to work with industry on research and demonstrations; the strategy being to link longer term research with innovation networks to create a 'win-win' situation. The breadth of expertise in communications across RF, signal processing, networking and service provision will be maintained but focus progressively towards the future internet and collaboration with colleagues at Surrey and elsewhere. Satellite communications will remain a unique specialism with the aim of promoting the integration of satellite and terrestrial systems for broadband. Staff have already influenced EU Horizon 2020 and will continue to be active in setting strategic research agendas.

CVSSP will build on existing strengths in audio and visual content production, linking with the new 5GIC in mobile communications, to realise the potential of future mobile content and EPSRC ICT/Horizon2020 priorities in big data. Research will focus on the challenges of intelligent content production, representation and search drawing on expertise in advanced visual scene analysis. It is intended to develop our medical imaging research through strategic partners across the University and with external partner organisations (Royal Surrey County Hospital (RSCH) and Institute of Cancer Research). The establishment of a School of Veterinary Medicine at the University (launch 2014) opens up opportunities for medical imaging research to exploit the link between human and animal health. Developments in audio and visual signal processing will aim to advance joint audio-visual signal processing; this is aligned with EPSRC priorities in Signal Processing and Intelligent Information Processing for huge audio-visual datasets available on the internet. Strategic partnerships with the BBC and DSTL in audio- visual signal processing will support the continued development of this area to realise advances in the automatic high-level understanding and intelligent processing of real-world sensor data.

MSE will enhance the suite of characterisation facilities, particularly those based around ion beam analysis and surface analysis. Investment will be made in cluster beam facilities for depth profiling with electron and ion spectroscopies, to extend our current work from chemical profiling to the profiling of functional material properties such as work function, in support of activities in photovoltaics and plastic electronics. Installation of confocal laser scanning microscopy for metrology is planned and the examination of sub-surface features in ceramics. Work on key medical challenges will continue using the unique vertical nanobeam facility collaborating with clinical facilities in the UK and abroad and with the CERN ENLIGHT initiative. Increased collaboration with bioscience colleagues will enable work on next generation thermostics that use carbon based materials to deliver image markers and anti-cancer payloads. The Materials focus will be developed to integrate materials research at Surrey even further, to which end the portfolio

of high capital cost characterisation equipment will be administered in a more purposeful manner by the formation of a Faculty-wide Facilities Directorate.

SSC will continue to push the boundaries of what can be achieved with small satellite technology, through funded research and the PhD programmes, to maintain our position as world leaders in this area. This will involve working ever more closely with other universities and industries to attract the significant EU and ESA funding necessary to support such research. The next strategic focus is to build a Space Robotics and Planetary Exploration capability through the establishment of the STAR Lab, which will bring together robotics expertise from across the University. Remote Sensing capability will be enhanced through a strategic partnership with the University of Reading and NPL to form the GLObal Satellite Sensing (GLOSS) virtual Centre of Excellence. Working with the Satellite Applications Catapult and other partners (RAL, CGI and SSTL), this will enable the latest advances in small, lightweight and highly innovative satellites to monitor changes to the Earth, its ecosystem and climate. Knowledge Transfer to Industry and SMEs will be supported through short course programmes and through the Surrey Space Incubator, which has already engaged with 13 SMEs to demonstrate the potential of space technology to small business.

c. People, including:

i. Staffing strategy and staff development

Our strategy has been to strengthen research activity by making appointments that fill gaps or reflect adjustments in research direction. Examples are the appointment of a Professor (Evans P) to head the cross centre medical electronics activity and build links to the RSCH via a new team in nuclear materials, and the appointment of staff in low energy system design and renewables. In all cases we have sought to use appointments to foster links between areas of activity and other cross University initiatives. Leadership succession has been seamlessly achieved in two of the research centres; Hilton has taken over from Kittler in CVSSP (2012) and Tafazolli from Evans B in CCSR (2010). Both Kittler and Evans B remain as active researchers. During the period a total of 21 staff moved to other academic positions (Gao S, Hay, Pavlou, Reed, Slater, Vladimirova, Weiss, Mashanovich, Poh, Vlachos) or industry (Acar, Pechev, Stark, Stevens, Tzarus, Worrall (3 to spin outs) or retired (Free, Rumsey, Sermon, Sweeney, Zhdan), but a total of 39 new staff joined, reflecting a significant expansion of activity;

ATI - Aaen, Cai, Crean, Henley, Jarowski, Shkunov, Sporea, Stolojan, Trevethan
CCSR - Barnaghi, Dianati, Foh, Heliot, Imran, Kelly, Ma, Nikitopoulos, Quddus, Wang N, Xiao
CVSSP - Bober, Collomosse, Dogan, Evans P, Guillemaut, Hummersone, Jackson, Lewis, Pugeault
MSE - Bailey, Heggie, Lohstroh, Rayson, Watson
SSC - Aglietti, Bridges, Guida, Knoll, Ryden.

Of the above, 4 are at Professor level and 17 are international appointments. We have deliberately appointed younger staff to balance the demographic profile and 10 are Early Career Researchers (ECRs). In the ATI, Aaen was appointed (from Freescale in the USA) to enhance microwave and RF research; Henley and Stolojan are experts in the field of applied nanotechnology (materials processing and devices); Crean and Jarowski specialise in molecular electronics and Trevethan and Cai provide nano and multiscale modelling capability to the team. In CCSR, Dianati, Ma and Xiao were appointed to strengthen the physical/MAC layer research area in communications and Barnaghi to open up a new area in new web and semantics plus big data processing. Foh's appointment strengthens our core networking expertise, whilst Heliot, Kelly, Nikitopoulos and Quddus have been appointed to the 5GIC. In CVSSP, Evans P was appointed as Professor of Medical Radiation Imaging with expertise in imaging sensors to complement existing expertise in medical image analysis and modelling. This appointment will provide leadership in our new cross centre medical applications group and strengthen collaborative links with the Physics radiation group and the Royal Surrey County Hospital. Collomosse and Guillemaut were appointed in video media to support the continued growth of research in 3D content, visual interaction and retrieval and to strengthen collaborative links with UK creative industries. In MSE, Heggie, supported by Rayson, has been appointed to enhance first principles computer modelling of materials, especially nanomaterials such as graphene. Bailey was appointed to increase activity in forensic analysis and

makes extensive use of facilities in both the Ion Beam Centre and Surface Analysis Laboratory, Watson is a surface scientist with interests in heterogeneous catalysis and makes use of international synchrotron facilities, whilst Lohstroh has a background in radiation detectors and now focuses on structure property behaviour in such devices. In SSC, Aglietti was appointed as a joint RAEng/SSTL chair, specifically to ensure the research strategy of SSC and SSTL is closely aligned. He is an expert in spacecraft structural design, analysis and testing and in particular structural dynamics and has collaborated with all the important UK companies operating in the space sector. Ryden was appointed to set up the Centre of Excellence in Aerospace Radiation Environment and Effects Research, Knoll to boost our work on electric propulsion and Guida to support our work on remote-sensing/radar. Bridges has been the driving force behind the STRaND-1 CubeSat mission working in conjunction with SSTL.

Research Assistants and Postdocs

We have maintained the Postdoc researcher cohort across all activities (c.100) with a deliberate policy of creating Senior Researchers responsible for key areas and projects. For example, the EPSRC visual media platform grant in CVSSP provides long-term underpinning of key post-doctoral researchers bridging gaps in grant contract funding, supporting career development through extended collaborative visits to leading international research groups and allowing flexibility to pursue adventurous new research directions outside the scope of existing projects. In CCSR a cohort of Senior Researchers help coordinate the large number of EU projects and engage with academics through a structured bidding process. The strong post-doctoral research base provides the foundation and practical know-how to operate specialist facilities such as the multiple camera 3D broadcast studio in CVSSP, the campus wide IoT sensor network in CCSR, the fabrication and clean room facilities in the ATI and the satellite integration labs in SSC.

Fellowships

We have a policy of encouraging staff and talented students and post-doctoral researchers to apply for prestigious fellowships and support then fully in doing so. The Fellowships awarded during the period are as follows:

- RAEng Fellowships (Sporea, Tsakmakidis)
- Royal Society Research Fellowships (Abel, Mashanovich)
- Royal Society Industrial Fellowship (Hilton)
- Royal Society/Leverhulme Trust Senior Fellowship (Bowden)
- RCUK Fellowships (Acar, Dianati, Henley, Stolojan, Xiao)
- Leverhulme Fellowships (Gurbich, Shiozawah)
- NPL Fellowships (Allam, Cox)
- EPSRC Leadership Fellowships (Sweeney, Varcoe)
- ERC Advanced Researcher Fellowship (Homewood)
- EPSRC Doctoral Prize Fellows (Beliatis, Jayawardena, Li)

Visitors

Visiting staff, either from Academia or Industry, play a vital role in ensuring research programmes remain vibrant and focussed on the needs of the user community. During the period the following have contributed significantly in this capacity (the list is not exhaustive):
ATI - Andreev (Hitachi), Ashley (QinetiQ), Cain & Hussain (NPL), Carter (Oclaro), Haq (BAE), Shannon (Philips), Coleman (Trinity), Dosanjh (CERN), Elliman (ANU), Hess (Imperial), Jena and Kelly (Cambridge), Milosavljevic (Vinca), Neri (NEC), Reed & Mashanovich (Soton), Rose (Dundee), Shiozawa (Vienna);
CCSR - Selby (Nokia), Short (Telefonnica), Smith (Astrium), Walker (Vodafone), Webb (OFCOM-Nuell), Kim (ETRI Kor), Ma and Rajasegrer (Melbourne Aus), Nakata (NEC), Presser (Alex Inst Den), Sohaib(UET Pk), Shakir (KAUST SA), Stavroulaki (Pir Gr), Suga (Fujitsu Jp), Wang (NUDT, Ch);
CVSSP - Grau (Intel), Hadden (Panther vision), Hisatomi (NHK), Sperrin (NHS), Thomas (BBC);
MSE - Fernie (AWE), James (DSTL), Sims (NPL), Clarke and Kadour (Qinetiq);
SSC - Dyer (ex DSTL), Hodgart (ex SSTL), Mackin (NPL), Stavrinidis (ESTEC), Qing-Xi Tong (China Ac Sc), Van-der-Ha (Kyushu Jp), Vladimirova (Leicester), Wie (Iowa State US).

Staff Development

Every staff member has a formal appraisal with a line manager annually in the Staff Development Review process. Targets are set for publications in top quartile journals, submission of research proposals, income generation and PhD student progression. For probationary staff this is conducted through the University Staff Development system and overseen by a Faculty committee who monitor progress and recommend completion of probation, normally after 3 years. The University runs a Graduate Certificate in Learning and Teaching (GradCert) which is a two year accredited qualification including research, teaching and enterprise which is taken by all new staff and is a requirement for completion of probation. We have a policy to lightly load new staff during this period so that they can establish their research credentials. New staff join a research team and work with a senior member (mentor) who introduces them as a co-investigator in early research proposals, ensures that the first grant application is made and that they are preferentially allocated research students. Sabbaticals are available for all staff on the recommendation of their line manager and Dean of Faculty with an individual case being made by the staff member to demonstrate the corporate and personal advantages.

Overall strategy for researcher development is led by the Deputy VC (Research and Innovation) with input from the Faculties and the units responsible for career development and transferable skills training. Surrey's Researcher Development Programme (RDP) is delivered by a central specialist team (five staff) coordinating transferable skills training working with input from the Careers Service, Staff Development, Research and Enterprise Services, and the Dept. for Higher Education. A training programme and support are provided for ECRs in post-doctoral research (PDR) posts integrated with staff development provision for academic staff. This has recently been augmented by a series of drop in lunchtime sessions where staff from across the University can discuss issues. The PDR programme consists of 16 workshops, covering research project management, publication, funding and impact. In 2011, Surrey developed an action plan and undertook gap analysis to support the implementation of The Concordat to Support the Career Development of Researchers. The University continues to invest in initiatives to improve the areas indicated in the gap analysis and the RDP is fully compliant with the Vitae RD Framework. As staff progress in their careers they will attend leadership and management courses prior to taking on more responsibilities. Special funds are available to bridge PDR's between contracts and to build a sustainable career path. Our success overall in this programme is evidenced by the large number of PDRs who have moved on to an academic position during the period.

Equality and Diversity

As a public body, and in order to develop its reputation for quality and excellence, the University is committed to meeting its responsibilities under the Equality Act 2010. In support of embedding equality across the University, an Athena SWAN Bronze University Award was achieved in April 2013. The HR Excellence in Research Concordat encourages the recruitment and retention of researchers from the widest pool of available talent, including those from socially and ethnically diverse backgrounds. The University endorses this and actively monitors diversity in the workplace. The Faculty also subscribes to the WISE campaign on gender balance. All staff are provided with equality and diversity training as part of the staff development training programme. In our appointments of lecturers and professors, we advertise widely and encourage applications from under-represented groups, particularly women. Support for part-time staff, and those whose career has been interrupted, is addressed in the University flexible working policy.

ii. Research students

Research student numbers have increased by 15% since 2008 and now number c. 250, which is ~ 4 per FTE. Support comes from many diverse sources (Research Councils, Industry Overseas Governments etc.) and many internal research scholarships are also available. The Faculty has created its own DTC to attract students and particularly to promote a cross disciplinary approach to research. In addition, we have 50 research engineers in the EPSRC funded IDC (MinMaT) plus others supported by the CDT in applications of next generation accelerators (ANGA).

Student recruitment, training and development

We interview all new PhD applicants in person or by video, with each student invited to present a personal research plan for discussion. All procedures connected with the admission of PGRs are

subject to the University's Equality and Diversity Policy, the Race Equality Policy and Code of Practice, and the University Student Disability Policy. Each student accepted to PhD probationer status is allocated two supervisors with defined responsibilities. Within research areas the students are provided with specialist technical training and given a wider view of other students' research; they all will make presentations of their work to their peers at various points in their studies. There are also extensive programmes of research Seminars. Students see their supervisors weekly but there is a formal requirement to complete a monthly report. Progress is monitored by 6 monthly reports and interviews at which targets are set. After 12 months students present a confirmation report on their achievements and plans together with a literature survey paper. A viva is held with two examiners and based on this a decision is made to confirm PhD status or to resubmit. All students attend a conference to present their work at some point of their studies. The Faculty Graduate School provides an environment where students can mix with those from other disciplines both socially and in general seminars and their progress is monitored via the Graduate School Director. Oversight of postgraduate researcher (PGR) recruitment, training, progress monitoring, and quality rests with the Research Degrees Committee, chaired by the Deputy VC (Research and Innovation), which reports to the University Senate.

The University wide Research Development Programme (RDP) is the primary source of research and transferable skills training. Five trainers (with PhDs) offer c. 200 workshops per year with content compliant with the Vitae Researcher Development Framework. Two RDP workshops are compulsory for all PhD students: "Welcome to YOUR PhD" and "The Confirmation Process." At the "Welcome" workshop there is an on-line analysis of training needs, delivered by Surrey Action Planner, which allows skills assessment against the areas of the RDF to produce a customised list of recommended training courses. 89% of PGRs reported the Planner to be helpful; 87.5% said that the workshop had a positive impact. In year three, students are prepared by an RDP course on 'The Viva Examination' and by a suite of training on advanced project planning and writing ('Finishing Up and Moving On'). Thesis Writing Retreats are offered to overcome hurdles. 'Success Beyond Surrey' prepares PGRs for careers. Off-campus support uses online resources, Skills Portal links, and social media.

d. Income, infrastructure and facilities

Research income

Income has increased over the period (£9.1M in 08/09 to £12.4M in 12/13) despite sponsors being hit by the recession and the exclusion of SSTL R&D income. The average income per FTE per year has been c. £140k for the whole Unit; this figure is considerably larger if recent appointments are 'discounted'. Of particular note is our high EU income of £26M, whilst EPSRC awards over the period amounted to £18M. MSE in addition received £6.2M from EPSRC for the establishment of the MinMaT IDC. Our £6.7M Integrated Electronics Portfolio Grant from EPSRC (2003-2009) contributed to many of our activities and found a natural continuation in the £3.8M EPSRC KTA grant (2009-12) in which much of the early research was extended and taken to exploitation. The £5M EADS-Astrium endowment (2009-2014) arising from a strategic engagement with the company has also supported activities across research areas in the Unit. The National Ion Beam Centre received continuation funding via a £2.27M EPSRC grant (2007-2011) and ticketing income has generated a further £0.4M per annum. A Wolfson Foundation grant of c. £1M enabled a vertical scanning focussed Nanobeam tower to be added to the facilities enabling ion beams to be applied to medical applications. Of note in industrial funding was a contract of €1M from E.ON for research on hybrid organic-inorganic solar cells, €1M from Huawei, their largest UK academic support for future mobile networking, and £1M from Thames Water for continuation of research related to asset management.

A strong presence has been built in EU framework research programmes over many years and our staff have been instrumental in contributing to the drafting of the future research and development agendas in ETP's and now for Horizon 2020. We are thus well placed to continue and extend our EU research funding income by utilising this expertise across all our activities. A number of EPSRC programme and platform grants have been secured (including the recently awarded £5.4M for 'Future Spacial Audio for Immersive Listener Experience at Home') and will underpin our basic research portfolio, and we are again well placed in the strategic areas prioritised by EPSRC to

continue this income stream. Recently, as mentioned in Section b, a major success has been the award of £35M from HEFCE and UK industry for the formation of a 5G research and innovation centre (2012-2017). Our extensive industrial partnerships via the 5GIC, the BBC Audio Visual Partnership, the EADS- Astrium foundation and our close involvement in two of the UK Catapults will help secure our future industrial income stream.

In-kind support
In CCSR, Rhode & Schwarz have contributed DVB S-RCS (S2/SH) transmission and receiver equipment and performance measurement equipment valued at £0.5M to the satellite networks lab. Avanti have contributed a Hylas Ka band terminal plus free satellite time. In CVSSP research equipment has been donated by Mitsubishi to the value of £1M and the BBC are providing support costed at £450k for collaboration with Surrey under the BBC Audio Partnership. In SSC, EADS-Astrium donated an electric propulsion lab valued at £2M. SSC also have the use of SSTL's multi million pound specialised systems facilities on the research park.

Consultancies and Professional Services
Staff have served as expert witnesses in several cases. Evans B served in an international industrial tribunal for noncompliance of satellite performance and in US commercial court for patent infringements in multibeam satellites. Kondoz served as expert witness in four cases of patent infringement in the mobile devices and smartphone area and Slade in disputed manufacturing problems in industrial materials. Heggie was consultant to EDF Energy Nuclear Generation. Staff have had consultancies with Roke Manor Research, Arqiva, EDF, SS-Loral, Interdigital, SEEDA, ETSI, BBC, Samsung, Imaginer, Ikonisys, Home Office, Swarm systems, Omniperception, MulSys, UNESCO, SurreyNanoSystems, BAE Systems, Carbon Trust, Intel and Bookham. We are committed to allowing industry to access our facilities and have recorded significant income (c. £1M) for use of the ion beam facilities, microstructure and surface analysis equipment, anechoic chambers and channel sounders.

Infrastructure
Research activities are located across six buildings. CCSR and SSC share a bespoke building and the ATI has a stand-alone purpose built building; all funded by a mixture of HEFCE and University funds (£30M). CVSSP occupies refurbished accommodation in the main Faculty building to which the University has contributed c. £0.5M. MSE is split across Engineering, Physics and Chemistry buildings with the majority of its laboratories located in the main Faculty of Engineering building. During the current REF period significant investments have been made as follows:

- CCSR/SSC have increased accommodation and labs as a result of SSTL moving to purpose built accommodation on the research park; University investment c. £0.5M.
- CVSSP had investment from JIF/SRIF in the previous period of £4.2M for a digital film quality multiple camera studio facility for 3D content; the University has invested a further £0.5M on upgrading to allow portable outdoor acquisition.
- MSE saw the refurbishment of general laboratory space, installation of a state of the art angle resolving XPS system in The Surface Analysis Laboratory and commissioning of a FEG-SEM with triple analysis Facilities (EDX/WDX/EBSD) in the MicroStructural Studies Unit (total c. £2M).The vertical Ion Beam facility funded by Wolfson and the University (£2M) was established; Chemistry has also had a £2M upgrading of its laboratory provision.

Facilities

ATI has an extensive microfabrication clean room used for processing of different substrate types and sizes from individual die up to 150mm wafer e.g. compound semiconductors, silicon, glass, ceramic and polymers. A Nanofabrication and Nanoprobe Laboratory contains two electron microscopes and a dual-beam electron/ion microscope. A Plasma Laboratory allows for the formation of novel nano-materials, e.g., the development of the optical deposition head that facilitates the growth of high-quality aligned carbon tubes at process temperatures that are compatible with silicon CMOS devices. Extensive microwave characterisation facilities up to 210GHz are also available, together with a high performance computing cluster.

CCSR has a variety of test beds, laboratories and state of the art computing facilities which can

also be integrated using a Future Network Platform (FNP). The latter can be accessed both internally as well as externally via secure interfaces and is being used by industrial collaborators. The IoT test bed consists of 3000 flexible indoor and outdoor sensors around the campus and gateways to the FNP to create smart environments. Other facilities are; satellite network and security test beds, a fully equipped RF laboratory with test gear up to 30GHz and an anechoic chamber with automatic antenna measurement equipment, latest edition Elektrobit wideband MIMO channelsounder (Propsim), a traffic engineering test bed consisting of 9 Linux machines for multimedia resource management, and a cognitive radio test bed with WARP and USRP nodes for spectrum sensing, routing and mesh networking applications.

CVSSP has a digital film quality multiple camera studio facility for 3D content production and high-performance video-processing and storage. A further capital investment of £350k was made in 2010 in HD video capture and storage infrastructure and incremental upgrades, including a 16 camera portable system for onset production for research in 3D content production including c. £1M industry investment. This infrastructure is complemented by similar investment in the ILab including a self-contained audio-visual signal processing laboratory, subjective testing facilities with an extensive range of 2D-3D display technology and speaker setups for spatial audio, and end-to-end communication system emulators.

MSE Facilities at the Ion Beam Centre (IBC) consist of three accelerators, two primarily used for ion implantation and one for analysis. The Surface Analysis Laboratory (SAL) contains the largest cluster of instrumentation for surface analysis by electron and ion beam analysis in the UK and is one of best equipped laboratories of its type anywhere, also providing a complete array of electron microscopes for thin foil and conventional specimens, together with a number of STM and AFM microscopes and variants based around scanning probe microscopy. A new FEG-SEM with triple analysis facilities (EDX, WDX and EBSD) has been installed very recently. A suite of magnets are available for NMR imaging (STRAFI and GARfield) and chemical NMR includes high resolution work with solids. A state of the art range of electrochemical and electrical characterisation techniques are also available in house. Researchers also benefit from facilities elsewhere in the Faculty such as the recently refurbished Mechanical Testing Laboratory.

SSC has specialist facilities to support space science and satellite production including a Mission Control Centre with a full VHF/UHF capability to command control and receive data from University/amateur-radio class satellites. A Robotics Laboratory has been constructed in collaboration with the Departments of Mechanical, Civil, and Chemical and Process Engineering; this has extensive facilities that can be utilised for the classification of the mechanical properties of particulate materials, and for robotics research. The equipment includes a mars surface simulant facility and a robotic arm, infrared camera based motion capture system (including high speed cameras) and air-bearing tables. Clean Manufacturing Facilities are also available; a 140m2 class 10,000 clean room for space system manufacture and 3 Vacuum Chambers, a Thermal Chamber having a working volume of approximately 170cm x 170cm x 170cm and has a temperature range of -30 degrees Centigrade to +70 degrees Centigrade. Other facilities include an RF lab equipped with RF simulators (HFSS), signal generators and spectrum analysers up to S-Band, and an optics lab with a vibration isolated optical table and Class IIIb frequency doubled Nd:YAG laser. In addition SSC has use of the extensive satellite production facilities in SSTL on the research park.

e. Collaboration or contribution to the discipline or research base

Industrial collaborations

ATI has close collaborations with NPL, BAE Systems, EADS-Astrium, E.ON, Philips, Intel and Freescale. Participation in SUPERGEN programmes has also involved collaboration with Johnson Mathey, Jaguar Land Rover and Sharpe EU.

CCSR has worked for 12 years with 20 companies in the UK Mobile Virtual Centre of Excellence and is now moving to work with a similar number of companies in the 5GIC. There are also collaborations with over 50 companies throughout Europe in EU projects. ETRI in Korea and NICT in Japan have long standing research collaborations and in 2012 HuaWei (China) and Interdigital (US) inaugurated major research collaborations.

CVSSP is the lead academic partner in the 5 year BBC Centre of Excellence in Audio/Visual Processing and the Programme Grant in collaboration with the BBC. There are also collaborations

with 40 partner companies in EU projects and an endowed post from Bang & Olufsen in the Sound Recording Institute. In addition, there are joint projects with many SME media companies including Imagination, Framestore, DNeg, Filmlight, the Foundary and Imagineer.
MSE has longstanding (> 10 years) research collaborations with Thames Water, Becker Industrial Coatings, PlasmaQuest, Thermo Fisher scientific and EoN. In addition, the National Ion Beam Centre has over 70 companies that use the facility on a regular and recurring basis.
SSC has very close ties with SSTL and also with EADS-Astrium, and is a major recipient of the £5M research foundation fund set up post the sale of SSTL.
As a whole, the Unit has a thriving CPD portfolio of twelve one week courses for industry which attract an average of 200 industrialists per year. Some are assessable as part of a modular MSc programme.

International collaborations
ATI has bilateral agreements, under the auspices of the University Global Partnership Network programme and funded by Santander, with the Universities of Sao Paulo and Shanghai Jiao Tong to research large area electronics and systems for display and energy applications. There are also a large number of international programmes with the IAEA (Atomic Energy Agency), Academy of Engineering (solar deployment and manufacture of functional materials), CNRS (International nanotechnology initiatives) and UNESCO (Research park development, Sri Lanka). Future energy projects include links with India and China supported by the Royal Society and British Council.
CCSR is a major partner in the £10M (EPSRC/DST) UK-India Centre of excellence in Next Generation Networks with 6 UK universities and 6 IIT's working with BT/Toshiba in the UK and 6 Indian companies. It was also a partner in the UK-China Science Bridge project in mobile communications, and 12 MoUs with institutes around the World provide regular visitors.
CVSSP has collaboration with leading research institutes in the EU (INRIA, EPEL, UPF, HHI, MPI) and internationally (Kyoto and MIT) and with international broadcasters.
MSE has undertaken research in collaboration with the Universities of Columbia, Tel Aviv, Cyprus, Bourgone, Sao Paulo, Seville, Catalonia, Karlsruhe, as well as with the EU Inst. of Health and Protection, Ispra, CERN, PSI, EDFL, NCR Canada and CNR It.
SSC has well established strategic collaborations with Mississippi State University and Caltech (Nasa-JPL), as well as with Astrium and DLR.

Interdisciplinary collaborations
ATI and **MSE** have had extensive collaborations with medical colleagues at the Gray Institute and Addenbrookes in relation to use of the vertical ion beam for radiation effects on living cells. The Ion Beam facility has also been used by archaeologists to date samples. Multidisciplinary energy research includes collaboration with colleagues in Microbial and Physiological sciences.
CCSR has collaborated with the Department of Psychology and the Centre for Environmental Strategy in an £1M EPSRC funded project on user involvement in energy conservation in buildings (REDUCE). In the public infrastructure area there is collaboration with Birmingham City Council in an EU project on city transport (OUTSMART).
CVSSP has collaborated extensively in the medical imaging area with the NHS (Royal Marsden, Royal Surrey and Cambridge University hospitals) and also involving the Departments of Psychology at Surrey and QMUL. Collaborations with the Faculty of Arts have included visual recognition in the AHRC Digital Dance archive with the Dance Department and in usability research with the Digital World Research Centre. Related was the iWare EPSRC bridging the gap grant for 3D capture in relation to choreography.
SSC has activities in remote sensing together with Reading and the MET office concerned with climate research and in collaboration with Aid agencies regarding disaster relief.

Recognition and awards
- In 2013 a Regius Professorship was awarded in recognition of excellence in research in Electronic Engineering.
- Elektra award for the best EE Department in 2013.
- In 2012 HEFCE awarded £11M which was matched with a further £24M from industry to set up an International 5G Research Centre to collaborate with industry and help restore the UK's premiere position in wireless communications.

- Kittler was awarded the IET Faraday Medal in 2008 and an Honorary EURASIP fellowship from the European Signal Processing Society for his contributions to pattern recognition, image processing and computer vision.
- Evans B was awarded the IET Ambrose Fleming Medal in 2013 for his contributions to information and communications systems.
- Hilton was awarded the Royal Society Wolfson Research Merit Award for his work on '4D computer vision for real-world dynamic scene understanding'.
- Silva gave the Royal Society Kan Tong Public Lecture in Hong Kong in 2009 and was awarded the Clifford Paterson medal and lecture in 2011. He was elected a Fellow of the National Academy of Sciences in Sri Lanka.
- Sweeting was awarded; the von Karman Wings Award (2012) (Caltech); the Faraday Medal by the IET (2010); the Elektra Lifetime Achievement Award by the European Electronics Industry (2010); the Arthur C Clarke Lifetime Achievement Award (2008).
- Watts was made Docteur Honoris Causa of l'Université Paris Diderot (2011) and received the Adhesion Society Award for Excellence (2008); the British Vacuum Council Senior Prize and John Yardwood Medal (2008); and the UK Surface Analysis Forum Rivière Prize (2010).
- Yeomans received the Verulam Medal and Prize of IoM3 (2008).
- Heggie received the outstanding leadership award from the British Carbon group.

Leadership in the academic community and beyond

- Tafazolli, Kondoz and Evans B all led European Technology Platforms during the period and Tafazolli was an advisor to the EU on the Future Networks and 5GPP programmes.
- Tafazolli was scientific advisor to the Boards of Vodafone, Telefonica, and Samsung and was a Board member of UK Future Internet Strategy group.
- Silva and Tafazolli represented the UK on Trade Missions to India, Japan, China and Sri-Lanka and Varcoe represented UK on a scientific delegation to Thailand and Singapore.
- Moessner was founding chair of the spectrum sensing interfaces IEEE DySpan committee and of IEEE 1900.6 standards committee.
- Evans B was a member of the OFCOM Spectrum Advisory Board and an International member of the Italian Research Assessment Panel for Electrical Engineering.
- Evans B and Sweeting were part of the ITG team that shaped the UK space strategy and founded the Space Agency.
- Underwood contributed to the formation of the Satellite applications Catapult.
- Lappas was a member of the EU Space Advisory group for H2020 and Tafazolli for the ICT group.
- Sweeting served on the UK Government Office of science foreign office review, Royal Academy of Engineering International, UK Space Agency leadership council, Royal Society science policy, UK Space Agency advisory, ESA Advisory Committee on human spaceflight.
- Silva served on the scientific advisory board of Netscientific, International review ctte Zhejiang China, advisor to Science Minister Sri-Lanka, Royal Academy of Engineering cttee chairs International Fellowships, member of EPSRC TOP, Nanotech review panels—EPSRC, Singapore, Saudi Arabia and Hong Kong. He was advisor to Unesco and CNRS.
- Slade represented the UK on UKTI energy-related missions to Germany and the USA.

Editorships of Journals

Evans B continued as the Chief Editor of the IJSCN; Watts continues as Editor in Chief of Surface and Interface Analysis; Yeomans as Editor of the Journal of Materials Science to 2009; Dianati as Associate Editor IEEE VT, IET Comms and WCMC; Foh as Associate Editor for IJCS; Hilton as Associate Editor CVIU; Collomosse for CGF; Bowden for ICV, Evans P for Med Phys, BJR and PMB; Lappas for AIAA Guidance and Control.

Academic conferences

Staff contributed as Chairs of organising committees and TPCs for hundreds of conferences during the period and we mention here only major contributions. Over 100 best paper awards have been received across the disciplines and over 50 invited plenaries presented.

- Tafazolli was founder and chairman of the Wireless Green conference 2008 and overall

conference chair of European Wireless held at Surrey in 2013.
- Moessner was chair of TPC for IEEE-PIMRC, VTC and EW 2013.
- Barnaghi was chair of EuroSSC in 2009.
- Smith has had a sustained period of service with the International Conference on Composite Materials (Senior VP 2007-2009; 2011-2013, Europe VP 2009-2011; President 2013-2015) of IoM3, Crocombe also through the IMechE.
- McDonald is on Steering Committee and International Scientific Advisory Committee of the Magnetic Resonance in Porous Media Division of the Groupement Ampere 2008-2014 (Chairman 2008-2010).
- Heggie was chair of the annual NanoteC series, and the international conferences Carbon (2006) and Extended Defects in Semiconductors (2000 and 2010).
- Chairs of international conferences: BMVC (Bowden, Collomosse, Mikolajczyk); CVMP (Hilton); 3DIM (Hilton); SGA (Bowden); NPR (Collomosse); TPCG (Collomosse); AES (Jackson); ICIG (Kittler); MCPR (Kittler); Biometrics(Kittler); GCIS(Wang).

Committee service
- Slade serves as a member of the steering committees of the Nano4energy Initiative (nanotechnology KTN) and of the EPSRC Energy Fellowship and on the Council of the Materials Chemistry Division of the Royal Society of Chemistry.
- Watts has served the Adhesion Society (USA) as President (2008-2010) and VP (2006-2008) and immediate past President (2010-2012).
- Yeomans is a member of EPSRC Strategic Advisory Team for Engineering (2008-2013).
- Ogin is on the council of EU Society for Composites (2006-14) and chaired the British Composites Committee of IOM since 2010.
- Heggie was founder and former Chair of the British Carbon Group (joint Roy. Soc. Chem. and Inst. Phys.) and is a consultant to the nuclear industry (specifically EDF) as a member of the Graphite Core Committee that advises on the science of graphite moderators.
- Homewood served on Irish Research Council, US Department of Energy Committee and the Finnish Academy of Sciences Committee.
- Underwood served on the COSPAR panel for radiation belt monitoring, and the AIAA study group on distributed space systems.
- Silva served on the Royal Academy of Engineering Solar Deployment Committee.
- Ryden edited the Royal Academy of Engineering study on extreme space weather.

Contributions from junior staff
- Lohstroh has already delivered invited lectures at three international conferences.
- Bridges and his team were recognised by the Times Higher Education (THE) Awards Outstanding Engineering Research Team of the Year 2011 for STRaND-1 (runner up).
- Imran as a new lecturer was awarded £1.2m EPSRC grant for REDUCE and led the EU project EARTH which was awarded a prize as the best FP7 wireless project.
- Guillemaut was named 2012 University Researcher of the Year in recognition of his contributions in 3D computer vision enabling technologies for free-viewpoint video in sports TV production and stereo production from monocular cameras in film.
- Wang W won the Best Solution Award in the DSTL Challenge Workshop for the signal processing challenge "Under-sampled Signal Recognition".
- Mikolajczyk won the UK ICT Pioneers Award in 2011 for his research on visual tracking introducing robust methods for tracking in complex real-world scenes.
- Wells received the IET Innovation Award for medical imaging research entitled ‘A Motion Prediction and Modelling Framework for Reducing the Planning Target Volume Margin in External Beam Radiotherapy’, in the Software Design category.
- Saaj was awarded an industrial secondment award by the Royal Academy of Engineering.
- Varcoe was appointed lecturer in 2006 and progressed rapidly to Chair and EPSRC Leadership Fellowship based on his work in alkaline electrochemical energy and related technologies.
- Sporea was appointed to a Royal Academy of Engineering Fellowship in 2011 and has significantly developed large area electronics exploiting Surrey patented technology.