Institution: QUEEN MARY UNIVERSITY OF LONDON (QMUL)

Unit of Assessment: B11 Computer Science and Informatics

a. Overview

Staff in this UoA are members of the School of Electronic Engineering and Computer Science (EECS). The School was formed in 2008 from the merger of the two then Departments of Computer Science (CS) and Electronic Engineering (EE). EECS is run as a single administrative entity with no formal distinction between the two pre-existing departments. Our vision is that research in the discipline speaks to both fundamental science and the engineering of large-scale technological systems, and that linking these activities in the same academic unit benefits both, even though they remain reportable separately at REF, and are recorded separately by HESA. This view is supported by the continued rapid development of EECS, which now has 66 research active staff (50 submitted to REF), 217 PhD students, and a grant portfolio of £37.5m (stats @Oct 2013). EECS maintains a single vibrant research environment, and much of the work within this could be submitted under either CS or EE UoA's. Research in EECS is organized into 8 groups: Antennas & Electromagnetics (*Antennas*); Centre for Digital Music (*C4DM*); Computer Vision (***Vision***, concentrating on image and video analysis, submitted in this UoA); Multimedia & Vision (*MMV*, covering media applications, submitted in UoA 13); Networks (***Networks***); Computer Theory (***Theory***); Cognitive Science (***CogSci***); Risk Information Management (***RIM***). EECS also leads two formally constituted QM Research Centres (*qMedia* and the *Centre for Intelligent Sensing – see section b*). These bring together research activities across the wider QM community (all three of its Faculties), as well as industry, media and the performing arts. The majority of the research activities of the School fit within the EPSRC ICT theme, covering the wide spectrum of activity from theoretical computer science to antenna engineering.

For this UOA staff outputs associated with Networks, Theory, CogSci, RIM, Vision are submitted (FTE=30.5). Staff FTE submitted to EE UoA = 19.

b. Research strategy

The success of the School is built on following through the strategy outlined at RAE2008. Over the next period the school does not plan to change its approach in fundamentals, but to follow through natural organic changes, allowing us to further enhance the societal relevance of our work while maintaining and improving core academic quality.

In 2008 our CS RA5 narrative said that we would:

- *Work on interdisciplinary and collaborative research and encourage groups to work on large-scale problems that go beyond the scope of their original disciplines.*
- *Work to increase direct collaboration with industry and increase industry funding.*
- *Support a broad-based alliance with Electronic Engineering and Mathematics, and mentioned the use of SRIF infrastructure funding to support cross-disciplinary work.*

Groups from this UoA continue to work on large-scale interdisciplinary problems, notably in:

Digital Media: supported by RCUK our Doctoral Training Centre and two successive EPSRC Platform Grants). We founded qMedia (2010) a QM research centre of more than 20 academics and over 100 researchers bringing together the work of the C4DM, MMV and **CogSci** groups plus links to QM researchers in Commercial Law, Drama, Geography, Business & Management. Work ranges from using advanced signal processing and machine learning to automate processing of media information (**Purver**, Plumbley, Dixon), to using sophisticated computer techniques for innovative studies of audience interaction (**Healey**).

Security: QM is one of only three institutions involved in both the GCHQ/EPSRC Research Institutes in the Science of Cybersecurity. Security-related research spans **Theory**, **Vision** and Mathematics Dept, and covers areas as disparate as quantitative information flow (**Malacaria**), verification of binary code (**Tautschnig**), network reliability (**Mondragon**) and subject tracking on video (**Gong, Xiang, Cavallaro**).

Software Reliability: (**Theory) Distefano** won the Needham Award for his work on making verification practical. **Curzon**'s work using formal methods to reason about the safety of medical equipment is supported by EPSRC CHI+MED Programme Grant. **Honda**'s work on *Session Types*

for software concurrency theory led to their use in the *NSF Ocean Observatories* project and as a basis for EPSRC Programme grant "Data Types to Session Types: A Basis for Concurrency & Distribution".

Intelligent Sensing: the new Centre, launched in 2012, has attracted 18 industrial collaborators including Philips, Thales, IBM, Ocado, Google, BBC and Honeywell. Research on which it is built covers key EPSRC priority areas such as Data to Knowledge, Next-generation interaction technologies, Autonomous systems and robotics, and Engineering for Life and Health. The Centre will host a new doctoral training programme. Membership includes staff from all EECS groups.

We also have a host of smaller interdisciplinary exemplars in which our work is applied to less wide-ranging but still societally important problems, where we are working with:

- Psychologists: developing mathematical models of human vision, gaze analysis, predicting patient adherence to treatment from dialogue transcripts, music perception & cognition and human errors in software (**Theory**, C4DM, **CogSci**)
- Biologists: decoding genome data, evolutionary biology, bee vision and understanding cell deformation, applying information theory to ecological networks (**CogSci**, **RIM**, Antennas)
- Chemists: developing radio frequency assisted chemistry (Antennas)
- Musicians and Actors: producing better music and performance, (**CogSci**, C4DM).
- Mathematicians: developing theories of network traffic and complex interacting systems (**Theory**, **Networks**).
- Clinicians & Medical researchers: new monitoring techniques, assistive technologies for healthy living in elders, safety pharmacology and decision strategies (**RIM**, **Vision**, Antennas, **Theory**, **CogSci**).
- Lawyers: to find ways to simplify risk and probability to juries (**RIM**).

The level and scale of our interaction with industry has increased significantly (active grants @Oct 2013= £633k), and further exemplified by the commitment of £3.4m industrial support (cash, +£2m in kind) for our new Centre in Intelligent Sensing. Since 2007 our academics have founded five companies based on our research, which have between them generated more than £6.5m in start-up funding, and whose client list includes the defence and security establishment as well as governments and major companies. One of them (Monoidics) has gone from foundation to sale to Facebook in this REF period. Another (Actual Experience) was the 2012 IET Innovation award winner (Information Technology category). A full list can be found in REF3a. We have pioneered placement programmes for research students in both our Media & Arts Technology (MAT) DTC (a standard part of the training), and our KTA, whose programme was shortlisted for the 2011 Times Higher Education Awards in the category "Outstanding Support for Early Career Researchers".

We have pursued a strategy of engagement with the local Digital Economy. The current Head of School is also the QM's Strategic Lead on Tech City, supported by a designated Tech City Coordinator (Michelle Clement). QM is also a founder member of Digital Shoreditch.

The "broad-based alliance with EE" has been developed into a formal merger, creating EECS, while the collaboration with Mathematics has been maintained with strong collaboration on research grants (Security, Networks), on-going support for the Centre for Statistics and support for new cross-disciplinary Centres in Digital Media (qMedia, led by us), Discrete Mathematics (led by Maths), Intelligent Sensing (led by us) and Science and the Law (led by Law). We have benefited from approximately £1.25m of QM infrastructure funding specifically to enhance our research laboratories. This provided the Media & Arts Technology Studio, an entirely new comprehensively instrumented performance space, primarily supporting our MAT theme, and also enabled us to enlarge and re-instrument our Antennas Laboratory. The MAT studio includes the Performance Lab, a large soundproofed space (10x8m) used for a variety of applications including full 3D motion capture of music performance/dance, audio and video recording, interactive art installations, film/video sound stage and general performance. In addition during 2009 Cisco donated gigabit switch router (GSR) equipment (global list price was in excess of $1m) to support Networks group research into Quality of Service in IP networks. The work these facilities supports covers both the EE UoA (Antennas, C4DM) as well as this UoA through the CogSci and Vision groups and the new focus of our Networks group on addressing the challenges around "smart networks".

➢ Our CS RAE2008 narrative said that we would work on: *Attracting and retaining a blend of*

experienced and promising researchers into the research groups

We have undertaken major new investment in staff, with 18 new academic staff appointed over the period giving an overall increase of 11 posts. Most new appointments are early career, but they include 3 established researchers at professorial level. Part of this investment supports our decision to refocus the direction of the Networks group towards addressing the challenges around "smart networks", with the recruitment of a new Group Head (Uhlig) and ECR lecturers (Cuadrado and Haddadi) as well as the joint lecturer appointment of Elkashlan to build stronger links with Antennas. This investment has also enabled us to add weight to our activity in the Cognitive Science area, enabling our decision to formalise it as a formal research group. We have increased our population of individually funded research fellows, having had 10 PDRA's (Postdoctoral Research Assistants) and 6 academic staff on Fellowships in the REF period. We have a strong track record in enabling researchers' career development at all levels, evidenced through promotion and destinations of departing staff (in the last 5-years any faculty member who has moved on from QM has gone to Oxbridge or another Russell Group institution).

- Our CS RAE2008 narrative said we would concentrate on: *Creating excitement around the Department's research by a campaign of public awareness*

We have followed a strategy concentrating on public awareness of the discipline as a whole, including our own research only as appropriate. This mirrors QM's overall strategy, led by a member of the School (McOwan), and coordinated through the Centre for Public Engagement. Major strands of the activity include:

- cs4fn (www.cs4fn.org): an integrated campaign involving a magazine (hard-copy and on-line materials); schools talks, science festivals and other outreach events; spin-off magazines (ee4fn and Audio!), books and special editions. The cs4fn website received over 1M visits with >890k PDF downloads since Jan. 2008, and the special issue on women in computing has now been downloaded >75k times. Nationally we were founder members of the Computing at School initiative. See *Impact Template* for fuller details on cs4fn.
- Participation at the Royal Society Summer Exhibition – three times since 2005, most recently featuring research from one of our Programme Grants: QUEST
- qMedia Open Studios showcasing staff and student research at the Digital Shoreditch Festival
- Music and concert series including "Inspired by Digital" a partnership with the London Chamber Orchestra, including a workshop at Queen Mary and a concert at Cadogan Hall.
- Hosting (Fenton, Neil) the public engagement website http://probabilityandlaw.blogspot.co.uk/

External recognition includes the IET Mountbatten Medal for excellence in communicating Computer Science to diverse audiences to McOwan (**Vision**) and the 2011 British Science Association's Isambard Kingdom Brunel Award for outstanding science communication to Alomainy (Antennas).

Future Strategy: EECS research strategy is led by the *School Management Team* and is disseminated via the Director and Deputy Director of Research to heads of research groups and EECS's *Research Committee*. QM's Strategic Plan for 2010-15 has headline aims that include ranking within the top 10 broadly based UK universities, according to research quality, and within the top 20 according to research power. A significant step towards this aim was Russell Group membership in 2012.

EECS's headline strategic aims are to broaden and deepen our major research strengths. A significant part of our research is integrated within, and a contributor to an innovative cultural sector, and we want to make QM the premier institution for digital economy research. Through continued investment we will orientate more of our research activity closely with the creative industries exploiting our position in London, a world centre for cultural interaction (the sector contributes £21 billion per year to the capital's economy and provides one in five of all new jobs in London; the city also employs one-third of the UK's creative work force (more than 500,000 people)). The Media and Arts Technology DTC, Tech City and *Creativeworks* are expected to lead to further collaborations between EECS researchers and the cultural and creative industries. We will also exploit and encourage assistance from QM structures (Public Relations, CPE, QMI, Business Development Team). We will widen our interdisciplinary reach through the creation and participation in new centres and institutes such as our Centre for Intelligent Sensing and QM's new

Life Science Institute, covering key EPSRC priority areas of Data to Knowledge, Next-generation Interaction Technologies, Autonomous Systems & Robotics, Engineering for Life & Health. To get early access to industrial thinking to "shape" our research we will widen the activities of our Industrial Board and our industrial visiting academic body as well as increase (through such mechanisms as appraisal) the already significant input from EECS academics on standards bodies, professional societies, and funding bodies. These aims will be facilitated by the future strategies of our research groups and these are articulated below for those submitted to this UoA:

Vision: Our long-term goal is to produce effective and widely used computational models for understanding and analysing perception, human actions and interactions from visual data. As part of this we will be contributing to the development of machine learning for large-scale vision problems. Our ground-breaking mathematical modelling and algorithmic work on behaviour and face recognition has already been used in business intelligence, security, crime prevention and consumer-video content analysis. Over the next five years we will build on major national and international funding to develop work in multi-view scene analysis, visual sensor networks and behaviour recognition, and on industrial funding to further develop existing work in human detection and interpretation of interactions.

CogSci: This is a newly focused research group (2013), with researchers from our former group in Interaction Media and Communication at its core, whose development was enabled through strategic investment as mentioned above. The group's work centres on understanding the architectures underpinning intelligent human behaviour in areas such as natural language understanding, musical cognition, social computing and creativity. Its strategy is to build on existing expertise to solve hard problems such as building computational language systems that can cope with normal human conversational mechanisms, and understanding the computational mechanisms at the heart of higher-order human functions such as creativity and musical appreciation.

Theory: The theory group's strategy is to concentrate on areas where potential application helps motivate and guide top-quality foundational research. Over the next period we will be concentrating on applications in cybersecurity, systems engineering, computational linguistics and the structure of social interaction. We will seek to maximise impact through our industry links (e.g. Facebook, IBM, Microsoft, BAE Systems and Google), and our involvement in both EPSRC/GCHQ research institutes in Cybersecurity (one of only three UK institutions). We will strengthen our wide-ranging research team, working on Logic, Combinatorics, Information Theory and Game Semantics, applying our research to solve crucial problems such as the quality and certification of software, the security of cyberspace and the logical analysis of big data. Our paradigmatic exemplar is the development of separation logic, and its application through our spinout Monoidics, recently bought by Facebook.

RIM: The group will focus on its key contribution, which is its unique combination of data centric methods with hypothesis-driven approaches. In its work, the power of advanced computing is combined with the insights of human expert judgments to support better inference and decision-making. Its strategy is to continue to develop its capacity in a wide range of application domains, including medical, legal, systems engineering, bioinformatics, security, risk and safety, focusing on problems of decision-support under uncertainty and using methods from computer science, statistics, machine learning and psychology, to solve problems and challenges presented by scale, complexity and variability, as laid out in Fenton's successful bid for an ERC Advanced Grant.

Networks: The group's strategy centres on the shift in networking towards smarter infrastructures (cognitive and context-aware), and the increasing requirements of networked devices and applications. It plans to address this by contributing in three key areas: (1) Internet of Things (IoT) and cognitive/cooperative wireless, (2) Next Generation Networks, including Software-Defined Networks (SDN), Cloud and Big Data, and (3) Quality of Service (from measurement, through modelling, to performance evaluation). Work in the area of IoT and SDN/Cloud will be validated and showcased through the development of experimental platforms in collaboration with Cisco and supported by funding from EPSRC and the EU. Work on Big Data is enhanced by EECS expertise in machine learning and data mining.

c. People, including:

i. Staffing strategy and staff development

The excellence of the support we provide for staff has been assessed and recognized at both unit and individual level. At the unit level, we were one of the first six CS departments to be recognized by the Athena Swan Bronze Award (Imperial, QMUL, UCL, Soton, York), only one has the higher Silver (Belfast). Two EECS members are shortlisted for this year's WISE awards (Martin and Brown). Martin's 2012 CBE citation includes her work on assisting early career researchers and women in Computer Science. Our success in gaining individual fellowships is built on the support we offer our staff in career development.

Commitment to Research Staff: The *Vitae* Concordat is fully supported at QM through the *Centre for Academic and Professional Development (CAPD)* which works in partnership with QM Careers, the Doctoral College and EECS to provide both tailored and bespoke researcher development activities that align with QM's commitment to the Researcher Development Statement (endorsed by RCUK, QAA and Hefce). Two full-time staff in *CAPD* (Cordy & Forristal) coordinate this support, plus a dedicated Careers Officer (Bussoli). QM has been recognised for its Concordat Action Plan and its programme to support research staff and their career development, with the European Commission's prestigious award: HR Excellence in Research. In 2011 QM was shortlisted for the *Times Higher Education Award for Outstanding Support for Early Career Researchers*. In 2012 the College established a Doctoral College to support both PGR students and postdoctoral researchers at QMUL. Within EECS the *Research Liaison Group* coordinates both PhD and postdoctoral activities, and includes a designated PDRA representative from each research group with both Cordy and Forristal as members (see also (ii) below). EECS fully supports a very active IEEE Student Branch which has hosted at QM both the biennial *IEEE Region 8 student Branch and Gold Congress* in 2008 (the largest event in the world for young engineering students), and the *IEEE UKRI Student Branch Congress* in 2011.

Support for PDRA's includes participation in the same annual individual appraisal scheme as permanent staff, covering career progress and developmental needs. QM's CAPD support includes: Career Pathways days, with follow-up individual support and consultancy; an annual Fellowship Day with speakers from Research Councils, the Royal Society and the Leverhulme Trust; S&E Postdoc Network with representatives from each school offering a partnership approach to developmental activities; Grant Funding Masterclasses & Mock Panel Days; a suite of 3 Institute of Leadership & Management-endorsed Academic Leadership and Research Management programmes. The QM Careers events "Careers Beyond Academia" supports STEM researchers who are considering alternative careers options especially the transition from academia into industry.

Equality and Diversity: In 2012 QM established its equality objectives for the next four years, for each protected characteristic (gender, race, disability, religion/belief, gender reassignment, sexual orientation, pregnancy/maternity, and age). EECS has a very strong record on equality and diversity, encapsulated in its achievement of an Athena Swan Bronze Award, which, not only endorses our existing state, but commits us to continuing work and monitoring. We are committed to increasing the proportion of female research staff (currently just over 20%), and encouragingly, statistics show that female applicants have an equal chance of appointment success. To add to this our PhD student population of 217 is 24% female. Later in career, promotion statistics also show that female applicants have a better chance of achieving promotion than male (50% as opposed to 41%). Two EECS staff (Chew and Agapito) attended QM's 2013 'Women in Leadership' Programme, which was created in partnership with Ashridge Business School, to develop female leadership potential. At the senior staff appointment level, since the creation of EECS, we have made 3 external appointments at Professorial level. Of these, one is female (Chew), another openly gay (Wiggins) and two have never previously been employed in the UK university system (Chew, Uhlig). EECS hosts and supports an active women's group, the exuberant G-Hack which has close links with Digital Shoreditch, runs a series of hack events across London. We also support Women in Science and Engineering (WISE@QMUL), and helped found and run the Annual London Hopper Colloquia for Women in Computing along with other similar events (recently FLOSSIE 2012 & 13). In the 2013 national WISE Awards EECS PhD student Nela Brown was "Highly Commended" in the "Wise Leader Award" category, and **Martin** "Shortlisted" for the "Lifetime Achievement Award".

The School has an exemplary track record that demonstrates its commitment to improving access to the discipline of Computer Science at all levels. Our CS4FN outreach activity (www.cs4fn.org) is a pioneer in presenting serious computer science to school students, and as a matter of policy makes clear the contribution of women and minorities. This is backed up within the School by a wide range of other activities including active participation in the Computing at School initiative, including running CPD courses for local teachers (3 courses with a total of 66 participants run in 2013). In Autumn 2013 this work received a substantial grant (£450k) from the Mayor of London's School Excellence fund (in collaboration with the Education Department at KCL) to support CPD and CS4FN.

Fixed Term and Part-Time Staff: The College's default position is that all policies and procedures apply as widely as possible, and so most apply equally to fixed term and part-time staff. Examples include appraisal, promotion and benefits, such as sickness benefit. In the School, staff have been promoted while working part-time at QM because of business interests (Neil, Bryan-Kinns) and caring responsibilities (Curzon). During the RAE2008 period, one staff member (Kanovich) was promoted from Lecturer to Reader and then Professor whilst on a fixed term contract.

Promotion and Research/Sabbatical Leave: QM has clear procedures for promotion of academic staff, with criteria detailing "Assessment of Contribution" and "Career Progress". Feedback on eligibility and possible applications is available from appraisers and Heads of School, and feedback on results from sectorial management teams. RA's do not have a formal promotion scheme, but any who take on significant additional responsibilities can apply for their post to be re-graded. Staff not ready or eligible to apply for promotion can apply for the annual Staff Bonus Scheme, which gives recognition to staff whose contribution is deemed to be over and above the normal expectations of their role. QM also operates a standard sabbatical scheme, whose criteria are the academic merit of the application within an envelope of one in seven. Since 2011 four EECS academic staff undertook the College wide 'High Potential Leaders' programme (residential workshop, masterclasses & coaching) to support their development. Since 2008 13 staff have been promoted to Senior Lecturer or Reader, 2 from SL to Reader, 6 promoted to Professor.

Early career support: QM has detailed procedures for the support of early career staff, including a 3-year probation with lighter teaching and administrative duties than non-probationary staff, plus a senior academic as mentor. Initial EECS teaching loads are normally 50% of standard and duties usually involve co-teaching with an experience academic. New staff undertake induction and QM's PGCAP training scheme. Our ImpactQM KTA was runner up in the Times Higher Awards Exceptional Support for Early Career Researchers in 2011. The Schools quota of external (EPSRC Doctorial Training Account) and QM PhD studentships are prioritized to provide support for new staff (typically one studentship) and grant applications are supported by research groups as well as the EECS's internal review system. Since 2008 10 staff have made the probationary transition to established academic posts, with 6 currently in their 3-yr year probation period. Since 2008 ten PDRA's have obtained independent researcher fellowships.

Interchanges with industry: EECS has significantly increased the depth and range of its exchanges with industry, as outlined above. Academics have been allowed reduced hours in order to work with individual companies (Fenton, Pitts, Roelleke) and 12 industrial contacts have been appointed to "Visiting" and on occasion part-time academic positions (Cook). The QM's Knowledge Transfer Account (impactQM - run from EECS) was used to support 3-month periods of "industrial contact" time for academics (Alomainy, **Malacaria**, Reiss), alongside industrial applications projects (staffed almost entirely by current RA's on break from existing contracts), as well as research student project placements (see below).

ii. Research students

EECS has a large and vibrant population of research students which has approximately doubled since RAE2008 (2008=103, 2012=217.5, HESA data for CS plus EE), whose split into two categories by HESA data does not reflect the position on the ground. Accommodation is mainly organized into research labs housing both RA's and PhD students, so that on occasion the same lab contains PhD students, early career PDRA's and highly experienced late career researchers on part-time appointments post-retirement (Harrison) or from industry (Arthan). This means that research students form part of a single integrated population with RA's. Research groups run regular seminars and reading groups and EECS sponsors an annual PhD student conference at

which all second year students present their work, organized and run by the students themselves, with academic staff excluded! Third-year students present their work at EECS's annual Research Open Day, to which our external industrial partners and representatives from the IEEE and IET attend. PhD students are also encouraged to develop their teaching skills through demonstrator roles working with undergraduates, for which they receive rigorous in-house training. Students are empowered to run other activities (e.g our highly successful student branch of the IEEE) with our Media and Arts Technology students being most active (G-Hack, but also a sequence of experimental concerts and performances). QM operates a points-based training system to support delivery of our College-wide training strategy for PhD students, based on the Vitae Researcher Development Framework.

Our students are funded through: Direct provision from central QM funds; EPSRC, via QM block Doctorial Training Account (DTA) and through the RCUK grant to our Media & Arts Technology (MAT); EU grants; EECS grants; Research grants; International studentships; China Scholarship Council (CSC) scholarships; Erasmus Mundus; as well as self funded students. A summary of funding source is provided in the table below for our current PhD student body (@July 2013).

	QM Funds	DTA & MAT	EU	EECS	Res. Grant	International	CSC	Erasmus Mundus	Self
CS UoA	15	9	3	4	8	3	25	12	6
EE UoA	10	10	10	8	6	3	20	0	10
EPSRC MAT	4	42	0	0	0	0	0	0	0

Recruitment to studentships is covered by the College's Equal Opportunities policy and is assessed and monitored as for our Athena Swan submission. All studentships are advertised on jobs.ac.uk plus relevant subject lists, short-listing and interview undertaken by two academic staff, and offers authorised by DGS (Director of Graduate Studies - Research). The whole process is overseen and administered by the EECS Research Student Coordinator (full-time grade 4).

Each of our research students is supported by a first and second supervisor. Progress is monitored by the Graduate Research Studies Committee, which appoints a monitor to each student to check progress independently of the two supervisors, who are responsible for academic progress and regular formal review meetings. Performance monitoring includes main reviews at 9 months: (confirmation of suitability for research degree); 24 months: (suitability for PhD degree or MPhil) both being based on a dissertation and viva with supervisors and monitor. Failure at any stage can result in resubmission, and finally deregistration. Our PhD submission rate has improved from 2009/10 when 53% of the 32 graduating students submitted within four years, to 80% of 35 graduates in 2012/13. The total number of degrees awarded during the REF period by EECS is 163.5=3.3/FTE (based on CS+EE submission= 49.5 FTE). For RAE2008 the combined number of awards for CS and EE UoA's was 99=2.0/FTE. For the research groups associated with this CS UoA submission the total number of awards is 63=2.1/FTE, compared to 22=0.8/FTE for RAE2008.

d. Income, infrastructure and facilities

EECS has a current (@Oct. 2013) grant portfolio of £37.5m, of which £20m is RC funding (2007 RC portfolio: EE=£6m, CS=£5.6m). The annual spend per year over the REF period shows a strong upward trend, see HESA based table below. The combined (CS+EE) RAE2008 figure for full year 2006/7 was £2.95m. EECS total spend in REF 5-yr period (HESA REF4b data) is £37.2m= £150k/FTE/yr compared to combined RAE2008 figure of £13.4m= £41k/FTE/yr.

EECS RESEARCH GRANTS	**2008/9**	**2009/10**	**2010/11**	**2011/12**	**2012/3**
HESA RESEARCH SPEND	£5.47m	£6.82m	£8.08m	£8.31m	£8.50m

EECS supports research grant and PhD administration through its Research Services Team of 3 full-time staff. Central QM facilities from the Joint Research Management Office provide costing and pre and post award support plus specific EU grant application support. Major grants held over the assessment period include:

- 3 EPSRC Programme grants (2 as lead institution) and 3 EPSRC Platform grants, one of which renewed in 2013. As a result QM is a one of the 11 EPSRC strategic relationship universities.
- A £6m RCUK Doctoral Training Centre (DTC) in *Media & Arts Technology (MAT)*, recruiting on

average 12 students per year for 5 years.
- Participation in the 2012 GCHQ/EPSRC funded (£3.8m) Research Institute in the *Science of Cyber Security* (one of three universities in both Institutes).
- A research cluster "London's Digital Economy" within Creativeworks London (£4M), a newly awarded AHRC Knowledge Exchange Hub for the Creative Economy
- ImpactQM: a £2.9m Knowledge Transfer Account, held and managed on behalf of the College

We have benefited from approximately £1.25m infrastructure funding for research facilities from QM and a further $1m from Cisco, see section (b) above. QM has committed to a £36M Graduate Centre which will include the provision of dedicated space and infrastructure for doctoral cohort training to provide a 'one-stop-shop' and is expected to be completed in 2016. EECS is supported by a state-of-the-art IT system as a result of the £21M invested in QM's IT strategy.

Analysing EECS's PDRA portfolio for the period 1/8/2008 to 31/7/2013 we have supported 290 PDRA FTE years over this 5-years which equates to 1.2 PDRA's/ submitted EECS staff FTE/year.

e. Collaboration or contribution to the discipline or research base

Contributions to the discipline have been recognized at an individual level by (**bold** for this UoA):
- **Martin** (CBE for contributions to Computer Science, 2012)
- Parini (Fellow of the Royal Academy of Engineering, 2009)
- **Distefano** (BCS Needham Prize, 2012)
- Y.Hao, **O'Hearn** (Royal Society Wolfson Research Merit Award Holders)
- **Honda** (ETAPS Award 2012) – Deceased 2012.
- **O'Hearn**, **Ishtiaq** (POPL Award 2011, "*the most influential paper 10 years on from 2001*")

About ten per cent of our academics have held individual fellowships during relevant periods:
- EPSRC Fellowships:- Leadership: Plumbley**;** Established Career: **Martin**; Advanced: **O'Hearn**, **Yang**; Career Acceleration: **Sadrzadeh**, **Brotherston**.
- Royal Society Research: **Oliva.**
- European Union ERC: **Fenton**, **Agapito**.
- RAEng: **Distefano**, **Tzevelekos**, Mauch, Robertson (EPSRC/RAEng).
- RAEng Enterprise Fellowship: Reiss.
- US National Science Foundation: McPherson.
- US National Academy of Sciences: Chew.

Others (Belov**-**Antennas) have held similar fellowships, but not combined with faculty positions. During the period EECS staff have guided RA's to fellowships at other institutions (Marie Curie (3), EU (1), RAEng (1), EPSRC (1)).

8 EECS staff are FIET (Y.Hao, Parini, Izquierdo, **Gong**, Sandler, **Cuthbert**, Plumbley, **Martin**), 2 are FIEEE (Y.Hao, Sandler), 7 are FBCS (**Bryan-Kinns, Gong, Fenton, Martin**, Sandler, **Robinson**, **Curzon**).

23 EECS staff are current members of the EPSRC College, and staff are also on the equivalent colleges for NERC (UK), NSERC (Canada), MURST (Italy), Research Grant Council of Hong Kong, General Secretariat of Research and Technology (Germany), Swiss National Science Foundation, Agence Nationale de la Reserche (France), Netherlands Organisation for Scientific Research. Izquierdo is providing significant leadership within the European Commission: Invited panellist for R&D calls under IST-FP7 (2010+2008), Member Future Internet Task force, leads EU funded project strengthening cooperation between Latin-American and the EU with partner institutions from Mexico, Brasil, Uruguay and Colombia. Other staff members have acted on selection panels for EU Framework and ERC programmes, (**Martin**, **Wiggins**, **Poslad, Uhlig**).

Other significant leadership roles by staff include (those in **bold** in this UoA):
- Membership of UK Defence Science Advisory Council (**Martin**)
- UKCRC Executive Committee & BCS Research Committee (**Martin**)
- President, International Society for Music Information Retrieval (Dixon)
- President of the International Community for Auditory Display (**Stockman**)
- EPSRC Strategic Advisory Team (SAT) Member (Y.Hao)
- Member Council of Professors and Heads of Computing: 2012-2014, Deputy Chair

Information Group 2013-2014 (**Robinson**)

Awards to ECR staff:

- Cozzarelli Prize 2012 for "Evolution of Music by Public Choice", Proceedings of the National Academy of Sciences of the USA (Mauch -C4DM)
- Isambard Kingdom Brunel Award, British Science Festival, Bradford (UK) 2011, awarded to outstanding science communicator at an early stage of their career (Alomainy-Antennas)

Since 2008 staff in **this UoA** have been newly appointed to the following journal activities:

Consulting Editor: Music Perception (Wiggins)

Area editor: IEEE Signal Processing Magazine (Cavallaro)

Associate Editor: IEEE Trans. on Image Processing, IEEE Trans. on Signal Processing, IEEE Signal Processing Magazine, IEEE Trans. on Multimedia (Cavallaro); Music Performance Research (Pearce); Journal of Audio Engineering Society (Stockman); Formal Aspects of Computing [Springer] (Martin);

Editorial board member: Springer's Cultural Computing book series (Bryan-Kinns); Journal of New Music Research (Wiggins); Central European Journal of Computer Science, ISRN Software Engineering journal (Distefano); PLoS ONE (Fernando), IET Networks (Schormans); Journal on Multimodal User Interfaces (McOwan); e-Informatica Software Engineering Journal (Fenton); International Journal of Pervasive Computing & Communications (Poslad);

Journal appointments first taken up pre-REF and active during the REF2014 period for **this UoA**:

Editorial board member: IET Communications (Schormans); Software Quality Journal (Fenton);
Associate Editor: Musicae Scientiae (Wiggins); ACM Computing Surveys (Malacaria);

Guest Editorship: from 2008 EECS staff have undertook guest/special edition editorship of 15 journals (0.3/FTE). Here and in subsequent headings FTE is for the whole of EECS (CS + EE REF submission) = 49.5 FTE.

International Conference activity: From 2008 EECS staff have:- acted as conference general chairs for 17 international conferences (0.3/FTE); acted as Programme, area or co-chairs for 66 international conferences (1.3/FTE); presented 107 keynote lectures at international conferences (2.2/FTE). In addition our staff and PhD students have been awarded best paper/best student paper at 26 international conferences (0.5/FTE).

Patents: From 2008 EECS staff have:- been awarded 15 Patents; have currently 13 further patents applied for. EECS staff currently hold a total of 29 Patents (0.6/FTE).

Collaboration:

Industrial Collaboration: From 2008 EECS staff have:- Undertaken industrial collaborations with 117 different organisations (2.4/FTE) and have entered into 83 direct industrial contracts placed through QM (1.7/FTE). Total EECS industrial grant spend for Aug 2008 to July 2013 is £1.13m.

International Academic collaboration: From 2008 EECS staff have:- undertaken collaboration with 214 international academics (4.3/FTE); hold a total of 28 visiting positions in international universities (0.6/FTE). In addition we have acted as hosts to 104 international visiting scholars (2.1/FTE) (stays in excess of 1 week). EECS has a major partnership with the Beijing University of Posts & Telecommunications (BUPT), an original research link leading to a joint teaching programme (the first of its kind to be approved by the Chinese Ministry of Education, now with close to 2000 students), now feeding back into stronger research links (e.g 18 China Scholarship Council studentships/yr since 2009/10, QMedia joint research laboratory in 2013). These include joint laboratories and a future (2014) nascent joint PhD programme (dual award degrees with BUPT). The collaboration has won numerous awards: Right Partner Category of the British Business Awards organised by the British Chamber of Commerce in China, 2009; New Horizons category in the Cathay Pacific China Business Awards, 2011. EECS also runs a joint laboratory in Macao and is a member of the Indo-UK Advanced Technology Centre (IU-ATC) of Excellence for Next Generation Networks, Systems and Services.