Institution: University of Aberdeen

Unit of Assessment: 11 (Computer Science & Informatics)

a. Overview

In the period 2008-2013 Computing Science has grown significantly in size, international research profile, and scope of collaboration. Building upon our successful RAE 2008 outcome, we have further developed and clarified our research strengths. Our Agents, Reasoning and Knowledge (ARK) theme (led by Norman) brings together research in Semantic Web and Multi-Agent Systems to contribute leading research both within and across these substantial international communities. Under the leadership of Mellish we continue to be leaders in Natural Language Generation (NLG) research excellence and impact. Ground-breaking theoretical and applied research in the Systems Modelling (SM) theme (led by Pym) is a key influence in new thinking internationally in the economics of information security and in the modelling of complex socio-technical and natural systems in general. All these research themes contribute substantially to strong interdisciplinary collaborations, and have effective partnerships with industry, government and other users. Coghill (Head of Department) provides overall leadership within the unit, representing Computing Science within the University. The theme leaders are the primary research leaders, driving and enhancing our research strengths, and supporting junior members of staff. Director of Research (Norman) provides the interface to University research governance, influencing policy and strategy.

The three themes reflect our core research strengths, each contributing to both theoretical and applied research. Across these themes, however, both fundamental theoretical research drivers and application contexts bring together researchers. Challenges such as how to support human decision makers to make sense of situations are addressed through complementary strengths in knowledge representation and automated reasoning (ARK), accessible information presentation (NLG) and sound models of systems and processes (SM). Collaboration with other disciplines and strong links with industry and other users serve to broaden the relevance of our research. Interdisciplinary collaborations span the sciences (e.g. physics, biology, psychology), social sciences (e.g. economics, human geography), humanities (e.g. music, linguistics), engineering and medicine. This culture of collaboration within and across themes and of collaboration with other disciplines and research users best characterises Computing Science at Aberdeen.

b. Research strategy

RAE 2008 vision and its execution. At the time of writing the RAE 2008 submission, we considered ourselves to be a single coherent research group in intelligent systems, with key strengths in natural language generation (NLG), knowledge technologies (KT), and intelligent agents (IA). We also supported a number of special interest groups, including one in systems modelling. The strengths of all of these areas were built upon effective collaboration across the unit, fruitful links with other disciplines, and some strong links with industry and government partners with scope for longer-term development. Our vision for the unit through the current REF period was threefold. First, *to broaden the intellectual base to encompass more foundational, systems-oriented, and socio-economic perspectives*. With existing strengths, this increased breadth enables us to address the key challenges presented by a world in which complex, intelligent, systems of systems dominate every aspect of society. Second, *to develop the depth and breadth of collaboration with other disciplines and other, non-academic, modalities of research*. Only in this way can an adequate understanding of relevance and a sufficiently rich mix of approaches be ensured. Finally, we identified the need *to increase the scale of our activities, the diversity of our interaction with the users of our research, and the depth of our partnerships with industry, government, the third sector, and the public*. This strategy has driven the development of each of our themes.

Systems Modelling (SM). A major challenge was to establish a research theme that would integrate foundational and systems-oriented work. To this end, we recruited Collinson and Pym to enhance the diversity of our intellectual base with expertise in relevant areas of mathematics, economics, and management. This builds upon existing systems strength in qualitative modelling and reasoning, and in modelling natural systems, to which we have also recruited Pang. This theme has strong, funded interdisciplinary research links, particularly with physics and biology, economics and management, and with music. This theme's development has extended our engagement with industry, particularly in cyber-security, complementing those established through ARK. Collaborations have influenced the outputs of this research, both in terms of inspiring novel modelling methods [Coghill1,Pang1,Pym3] and in research that spans disciplines [Pym2]. The core

contributors to this theme are Coghill, Collinson, Guerin, Pang and Pym.

Agents, Reasoning and Knowledge (ARK). Work in knowledge technologies and intelligent agents was already closely integrated. Moreover, the prevailing intellectual dynamic was driving the combination of their approaches, with numerous funded research projects spanning these RAE2008 themes. We therefore took the opportunity to establish a combined theme, and invested in new staff (Kollingbaum, Lin, Oren) to extend our natural interactions with both NLG and SM through strengths in norm-governed reasoning, data mining and argumentation. As with other themes, collaboration with industry and government partners is strong. The authorship of [Kollingbaum2] (with a colleague from the US Army Research Laboratory) and [Oren2] (with a colleague from IBM) illustrate this. Similarly, interdisciplinary collaboration with experts in the social [Edwards3] and environmental sciences [Edwards4] have led to important, jointly authored outputs, where other research has academic impact on other disciplines [Sycara4]. The core contributors to this theme are Edwards, Kollingbaum, Lin, Norman, Oren, Pan, Sycara and Vasconcelos.

Natural Language Generation (NLG). During the RAE 2008 period, we invested in the NLG theme to establish it as a world-leading centre, and since 2008 it has been further developed through junior appointments that broaden and complement the scientific base (Siddharthan, Wyner). The theme has a long track-record of collaboration with disciplines as diverse as medical sciences [Reiter2,Sripada1] and ecology [Siddharthan3] in the use of NLG technologies in real-world contexts, again leading to jointly authored publications. As with other themes, this more application-oriented, interdisciplinary research is underpinned by strong theoretical [vanDeemter3] and empirical contributions [Mellish2,Reiter1]. The insights that come from tackling real-world research problems provides a key route to research impact, both in economic and societal terms [REF3, case studies 1 and 2]. The core contributors to this theme are Masthoff, Mellish, Reiter, Siddharthan, Sripada, van Deemter and Wyner.

Given our track-record in effective interdisciplinary and user-led research, the RCUK Digital Economy initiative provided an opportunity that Aberdeen was uniquely well placed to grasp. Edwards, Mellish and Norman led a bid for a Digital Economy Hub that built upon collaborations with geography and healthcare, extending these to include transport, sociology, ecology, and engineering. The successful bid enabled the *dot.rural Hub* (EP/G066051/1) to be established, addressing challenges around robust, accessible healthcare, transport, and social systems, and supporting sustainable economic development in rural and marginal contexts. From its core collection of disciplines, the Hub has enabled additional collaboration with economics, management, and geology, and joint working with a wide range of industry (local, national, and multinational) and public sector bodies (NHS, local authorities, and government agencies).

These developments form the core of the delivery on our strategy as a unit. First, we have restructured our research themes, building on existing strengths and establishing a new breadth of expertise in Systems Modelling. Second, we have moved the unit, albeit from a strong base, into one in which effective collaboration with other disciplines and research users is core to our research. Finally, we have significantly increased the scale of our activities across all three themes: 28% increase in staff submitted from 14.8 to 19 FTE, along with an annual income that has trebled.

REF 2014 vision and its intended execution. Our vision for 2014 and beyond builds upon the successful execution of our strategy since 2008 and is grounded in our core concerns.

To continue to identify and develop the intellectual skills that underpin our evolving research programmes and to seek to develop and appoint appropriate staff. Our strengths lie in our identified themes – ARK, NLG, and SM – each having an essentially interdisciplinary and industry-focussed approach. In SM, we combine ideas from biology, economics, engineering, mathematics, philosophy, security, and the theory of computing science, to take a whole-systems point of view. We plan to further develop this theme as a vehicle for bringing a unique perspective on modelling complex socio-technical, natural, and synthetic systems. NLG has unique strengths in the analysis and use of natural language to render complex data sets, such as in oil exploration and healthcare, in order to support human decision-making and affect behaviour. We will develop this theme with its by building expertise in other modalities of complex data presentation and user interaction. In ARK, we will develop work in argumentation, reasoning under uncertainty, and in logical [Norman1] and game theoretic [Sycara2] formal methods, which reinforce NLG and SM collaboration.

To build our research around deep interactions with partners from industry, government, the third

sector, and the public. Throughout the REF period we have established a significant network of collaborators across all of these sectors, and throughout the research process from early development through to delivery of impact. To enhance these engagements, we will increase the number of internships and high-level secondments of students and staff to industrial and other research partners, as well as hosting visitors from them. Good examples of existing practice include research student and staff internships at IBM, and the Arria NLG Research Centre established in 2013 (arria.com/research-centre-A420.php).

To work with partners to enhance staff and research student development both in terms of its relevance to partners and for the future careers of researchers. Our collaborative research culture supports staff development to allow them to interact with a wide range of emerging scientific challenges. This provides us with the ability to respond to emerging opportunities, such as interactions with social, biological and environmental sciences, and with humanities. We will extend existing researcher training to include interdisciplinary research strategies and challenges as an integral part of the development of research staff and students. This has proved highly effective within *dot.rural*, which will serve as a model to be extended to all research students/staff.

To maintain and continue to grow sustainably our research funding base. In the RAE 2008 period annual research income for the unit *doubled*, and it has *trebled* since 2008. We have achieved this through effective implementation of our strategy and the quality of the academic staff in the unit. Particularly important to this success has been increased interdisciplinary, international and industry collaboration, and we aim to further diversify the funders and partners we work with.

c. People

Staffing strategy and staff development. We have invested in new staff across our three themes to deliver on our research strategy. Our approach to staff recruitment is focussed on high-quality early-career researchers with interests that complement and extend those of existing staff. When the opportunity exists to develop a new area, however, complementing this with more experienced research leaders is important. Our approach to the development of the unit is to recognise and reward staff performance through promotion. The implementation of this staffing strategy is enabled by our ability to both grow talented researchers and to attract excellent researchers from other institutions: Kollingbaum (Aberdeen Ph.D., 2005) was a PDRA both in Aberdeen and CMU (with Sycara), Oren (Aberdeen Ph.D., 2007) returned after being employed as a PDRA at KCL, and Pang (Aberdeen Ph.D., 2009) was employed as a PDRA at Aberdeen (with Coghill) prior to joining academic staff. Pym and Collinson joined the Department from industry (HP), with Pym holding a part-time position at Bath, Lin joined the unit from a PDRA position at Open, Siddharthan at Cambridge, and Wyner at Liverpool. The successes of academic staff have been recognised by the promotion, since 2008, of Coghill, Edwards, Norman, Reiter and van Deemter to Chairs, Pan to Reader, and Masthoff, Oren, Siddharthan, Sripada and Vasconcelos to Senior Lecturer.

The unit uses strategic funds to help new members of staff bootstrap their research teams. Collinson and Pym, for example, have received joint support from the EPSRC DTG and *dot.rural* to fund two Ph.D. studentships, and Kollingbaum, Oren and Siddharthan have each benefitted from University support for Ph.D. studentships. We actively support ECRs by seeking ways to engage them in existing research programmes. Kollingbaum, Oren and Siddharthan, for example, are associate investigators (with fEC commitment) on *dot.rural Hub* projects, all of which involve other disciplines including Transport Studies, Economics and Ecology. Lin, Pang and Wyner all have the opportunity to receive funds from *dot.rural* to help establish new, interdisciplinary research links (to date, funds have been awarded to Pang, and proposals from Lin and Wyner are under review). This helps new academic staff to develop experience playing a leading role in a funded project, and to form effective collaboration with other disciplines. This approach is highly effective: Oren, for example, collaborates with experts in transport in *dot.rural*, leads a task within the *International Technology Alliance in Network and Information Sciences (ITA)* (usukita.org) with colleagues from UCLA and IBM, and is an investigator (with Vasconcelos, van Deemter and Masthoff) on the *Scruitable Autonomous Systems (SAsSy)* project (EP/J012084/1) that crosses the ARK and NLG themes. Success is also quickly recognised: Oren was promoted to Senior Lecturer in 2013.

We operate a discretionary model to reward successes in acquiring research funding, promote entrepreneurship, and to support the development of new initiatives. The indirect cost contribution received by the unit is shared between a strategic fund and investigators' discretionary accounts. The unit maintains a fund for staff and research students to attend conferences that cannot be

supported through grants or discretionary funds, and to seed new collaborative initiatives with other disciplines/institutions. ECRs receive an initial discretionary allowance for each year of probation.

The unit operates within the Researcher Development Framework, ensuring that policies and procedures reflect the principles of the Concordat. Aberdeen was one of the first UK universities to be awarded the Human Resources Excellence award for its researcher development programme. All new academic staff have reduced teaching and administration loads to help accelerate their research, and a senior colleague is appointed as mentor for ECRs with progress being reviewed annually. The Researcher Development Unit (RDU, abdn.ac.uk/develop) offers a range of opportunities, including many workshops and courses with an emphasis on support for ECRs. The induction programme is attended by all new researchers, and is followed-up by longer term support at both university level (through CPD) and through local provision. Units across Scotland also collaborate through the Scottish Computer Science and Informatics Alliance (SICSA) in providing discipline-specific staff development opportunities such as new lecturer induction. We operate an annual staff development scheme for all academic and research staff, addressing both progress and future plans, and their wider career and professional development.

Researcher-led initiatives are encouraged and supported by research themes and our collaborative research culture. This has led to significant successes for researchers. Pignotti (PDRA & Aberdeen Ph.D. 2010), for example, has acquired over £100k in external funding from the Edinburgh eScience Institute (Leader of a theme on Provenance and Linked Open Data), and the *Digital Economy IT as a Utility Network+* with *dot.rural* partnership funding (research on trust and the Internet of Things). Şensoy (PDRA) significantly contributed to the development of two new strands of research within the *ITA* project following its renewal in 2011 after the first 5 years by spending 3 months at IBM (US) and CMU helping to develop research proposals. The outcome of this initiative represented over £300k of research income for the unit. Now Assistant Professor at Özyeğin University, Istanbul, and Honorary Lecturer, Şensoy has received an award from NATO to continue his engagement with the unit in research aligned to the *ITA* programme.

The University is fully committed to equality for all staff and students. We received bronze membership of the Athena SWAN Charter in 2011, and achieved Investors in People (IiP) status across the institution. Our Equality and Diversity Policy is applied to all aspects of employment within the unit, including recruitment, promotion, development opportunities and disciplinary procedures. All staff have access to Equality and Diversity training providing fundamental education in the legislative framework and its practical implementation. This training is mandatory for all staff with supervisory and recruitment responsibilities.

Research students. All research students work with a supervisory team (in many cases, across disciplines) with one lead supervisor. Their progress is monitored formally at 6-monthly intervals by procedures developed with the specific requirements of the unit in mind within an institutional framework. Progress is assessed through first- and second-year reports on training and outreach activities and research progress, and a viva with two internal assessors. Research students give annual poster (for first year students) and oral (second year) presentations as part of postgraduate workshops held twice a year. Written feedback is given to students and their supervisors from both presentations and viva. The first-year report is in the form of a thesis proposal, the acceptance of which is a prerequisite for a student to progress. Pan (Research Training Coordinator) manages this process with support from the Research Office and Graduate School.

The Department runs advanced taught MSc programmes closely related to our research strengths, which provide an excellent means to identify future Ph.D. students. We also collaborate with European partners in joint supervision of Master's-level projects. Within the REF period, Daniele Masato (Ph.D. 2012) and Alice Toniolo (Ph.D. 2013) both did projects with academic staff at Aberdeen (degrees awarded by European partner institutions) prior to commencing research degrees. More recently, Luca Gasparini commenced his Ph.D. research (funded by Selex ES) after conducting his Masters project (Aberdeen-Padua joint supervision). In addition to these internal and collaborative routes, we make use of the usual channels (findaphd, jobs.ac.uk, etc.), social media (twitter, facebook), and professional networks to facilitate research student recruitment.

Research students are expected to attend seminars in both Computing Science and the dot.rural Hub. They organise informal journal clubs and special interest groups (such as argumentation that spans ARK and NLG). Together, these provide means of broadening their knowledge and their appreciation of how to organise and present research. We have a strong culture of student

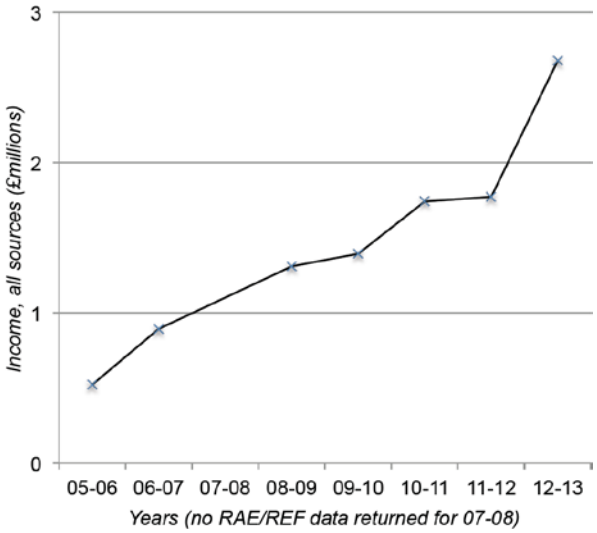
engagement in the research community, and in outreach. Students (along with academic and research staff) regularly contribute to outreach events including those organised through National Science and Engineering Week and the British Science Festival, supported by the Public Engagement with Research Unit (abdn.ac.uk/engage). Alice Toniolo (ARK PGR) was programme chair for the SICSA conference for Ph.D. students (2012), and our students regularly attend and serve on programme committees for doctoral consortia at major international conferences (ISWC/AAMAS/AAAI). Academic staff also contribute to training initiatives within research communities (e.g., Pan was doctoral consortium chair at the Int. Semantic Web Conf., 2010, and Extended Semantic Web Conf., 2011), and the unit regularly engages with international partners in research student exchanges. Students have made extended visits (3 months or longer) to IBM (US), US Army Research Lab, and the Spanish SME iSOCO (isoco.com), for example, and there are other opportunities with the Arria NLG Research Centre and Selex ES. These help to establish a vibrant and dynamic atmosphere within the unit, support students' engagement in impact, and to develop their profiles for future careers.

The University provides an extensive training programme through the RDU for students in both research and transferable core employment skills, directly aligned with the national Vitae Research Development Framework (RDF). Continuous training throughout the Ph.D. is supported by Personal Development Plans, and, through this mechanism, students and their supervisors identify further training in specialist areas and monitor progress. The unit offers courses that augment the University provision, including research methods in computing science and training to support interdisciplinary research, and collaborate with other units in Scotland via SICSA to provide a wide range of opportunities. Research students regularly attend specialist summer schools, and training/events hosted by RCUK Digital Economy Centres for Doctoral Training.

This student-centred environment supports our graduates in establishing successful careers in a wide range of sectors of the economy. Of those reported in the REF4a, 50% commenced careers in large corporations (e.g. Microsoft Research, Qualcomm Research, AstraZeneca), SMEs (e.g. Data2Text, salienceanalytics.ca), and the public sector (e.g. Dept. Work & Pensions, NHS). The remaining 50% have pursued academic careers both in the UK and internationally.

d. Income, infrastructure and facilities

Our strategy has been to broaden the intellectual base of the unit, develop our depth and breadth of collaboration with other disciplines, and increase the scale of our activities and the diversity of our engagement with users. This has contributed to a significant increase in research income throughout the REF period. At the end of the RAE 2008 period our annual income was just under £0.9M, which had more than doubled since 2000/01. Over the last 5 years our annual income has *trebled* to just under £2.7M: over £140K per FTE.



Within these figures, RCUK/TSB income continues to be the largest proportion: approx. 70%. This does, however, represent an important shift from RAE 2008; income from sources other than RCUK/TSB has doubled in real terms from RAE to REF. This shift demonstrates greater diversity in engagement with users and collaborators, including with other disciplines. In particular, there has been a significant increase in income from the European Union from under 2% in RAE 2008 to over 13%; a tenfold increase in real terms. The *MOST: Marrying Ontologies and Software Technologies* project (Pan, 2008-2011), for example, funded collaboration with SAP, BOC Information Systems and others, which has contributed to significant non-academic impact [REF3, case study 3]. Of the remaining income, 15% is either direct industry funding or funding for collaborative research with industry and government partners. A significant proportion of this (10%) is through the 10-year *International Technology Alliance in Network and Information Sciences* (usukita.org), in which continued funding is determined through international peer review and biennial competitive bidding against evolving research challenges from UK and US governments.

Although representing a reduced share in total income, annual income from RCUK/TSB has more

than doubled since the high point in RAE 2008, representing continued growth from these sources. Our strategy of collaboration has supported this, as shown by the diversity of research councils and cross-council programmes we engage with. These include BBSRC (in collaboration with Applied Mathematics and Biological Sciences), ESRC (in collaboration with Human Geography, Finance and Economics), and, of course, the RCUK Digital Economy Theme led by EPSRC.

In response to our leadership in interdisciplinary research, the University has invested £550k (infrastructure and Ph.D. studentships) in establishing a dedicated centre that accommodates major external investments including *dot.rural*, the £1.2M (2006-2012) *PolicyGrid* project (ESRC RES-149-25-1027/1075) and the £1.7M (2012-2014) UK-India project *TRUMP: A Trusted Mobile Platform for the Self-Management of Chronic Illness in Rural Areas* (EP/J00068X/1). This provides shared accommodation for researchers to collaborative in interdisciplinary teams. The administrative support team (5 FTE support staff: Hub manager, administrator, secretary, training and outreach officer and computing officer) work to support project management, finance, training and other functions, many specific to the inter-disciplinary nature of the research activities hosted by the centre. They coordinate with Research and Finance support staff in Computing Science (two members of staff) in supporting both research student administration/monitoring and project finance, providing joined-up administrative support for research across the unit. The University's Research Finance and Research and Innovation services support the unit in a range of ways including business development, project finance planning, financial reporting, and legal services.

Within the unit we require infrastructure that supports a broad range of research activities. Each research student, associate and member of staff has at least one PC running an OS of their choice, and there are laboratories of varying sizes offering flexible accommodation for different kinds of research teams. Three members of staff provide support dedicated to computing research infrastructure. They provide support for experimental equipment (sensor network rigs, web services infrastructure, simulation, etc.) in a flexible way that responds rapidly to research needs. We have used institutional investment to create a sensor-robot laboratory that includes Raspberry Pis, sensors, Arduino microcontrollers, and robots, as well as a 3D printer for spare parts. Research requiring high-performance computing (primarily within the SM theme, but also ARK) is supported through a compute cluster within a recently refurbished computing research server room. These facilities support all our research activities, including those with other disciplines, and represent a further institutional investment of £560K during the REF period (excluding staff costs).

A strong and growing portfolio of commercialisation and consultancy activity has been developed and supported within the unit, providing further evidence for the increased level of engagement with users. The development of these activities is further evidence for the success of the strategy taken by the unit since 2008, prior to which there was little of this kind of activity. Norman (with selex-es.com), Pym (with hp.com) and Vasconcelos (with technabling.co.uk and novavision.com) have been employed as consultants over substantial periods. In the case of Selex ES, for example, the company have made further commitments to two 42-month PhD studentships. Through HP, Pym has continued to provide scientific guidance for the Security Analytics service and now provides on-going support for the TSB's follow-up reporting for *Trust Economics* and *Cloud Stewardship Economics*, both of which inform new collaborative research projects with HP, *Trust Domains* (TS/I002502/1) and *ALPUIS* (EP/K033042/1). Through Technabling, Vasconcelos has provided major input to the Portable Sign Language Translator (pstl.org). Two companies have been established by members of academic staff during the REF period, and both continue to be profitable: Technabling (est. 2008) and Data2Text (est. 2009) [REF3, case study 1].

e. Collaboration or contribution to the discipline or research base

Interdisciplinary Research. Driven by the interests of academic staff within Computing Science we have developed and sustained a strong culture of interdisciplinary research with a broad range of disciplines. The *dot.rural Hub* is just one, albeit major example of this, but it is this culture that led to our success in securing this external investment. Edwards and Mellish have collaborated with colleagues in human geography throughout the REF period (PolicyGrid, 2006-2012). Coghill and Pang collaborate with colleagues in mathematics and biology through the BBSRC-funded *CRISP: Combinatorial Responses In Stress Pathways* project (£2.9M, 2008-2012), and Coghill collaborates with colleagues in music funded by the Digging into Data initiative (*ELVIS: Electronic Locator of Vertical Interval Successions*), the first large data-driven research project on musical style. Reiter and Sripada have long-standing collaborative research with experts in medicine and

psychology through the EPSRC-funded *BabyTalk* project (EP/D049520/1), conducting research into the analysis of data streams from neonatal intensive care systems and presenting summaries both graphically and in natural language. Further research used natural language summaries, but this time tailored for families (EP/H042938/1), again in collaboration with medical researchers. Edwards and Norman have strong research links with experts in mental health and diabetes, design and anthropology (EP/J00068X/1). Both Sidharthan, through the ESRC-funded project *Studying the appropriateness of different formulations of a discourse relation in context* (RES-000-22-3272), and van Deemter, through the EPSRC-funded network *RefNet: An interdisciplinary network focussing on reference* (EP/J01950X/1), collaborate with experts in psychology. The latter having a remit to foster further collaboration between computer scientists and psycholinguists with an emphasis on close engagement with industry and the public sector. Pym and Collinson have strong research collaborations with economics and finance, leading research into new understanding of the economics of security decision-making in organisations (TS/I002502/1, EP/K033042/1, seconomicsproject.eu). Furthermore, Pym collaborates with experts in mathematics, economics, management and law through the Digital Economy project *Creativity Greenhouse: SeRTES* (EP/J021601/1).

The above is not an exhaustive list. In fact, 75% of academic staff are actively involved (with fEC time commitment) in funded research that also funds the time of academics from other disciplines. In addition, the three ECRs who have most recently joined us (Lin, Pang and Wyner) have either received funding from dot.rural for interdisciplinary research, or have proposals under review.

Industry, Government and the Third Sector. Within each research theme there are long-term and substantive collaborations with industrial, government and third sector partners. Through dot.rural alone, we collaborate with over 60 non-academic external organisations including 32 government/public sector bodies, 17 industry partners, 8 nongovernmental organisations and 11 community-based organisations. Examples include: FirstGroup, providing practical input to projects applying research to support passenger transport activities (access to vehicles, staff and discounted travel) and advisory input regarding the UK public transport sector; NHS, providing support for project activities (patient surveys, access to clinical staff, nurses, paramedics, first responders); Scottish Enterprise, providing access to a network of over 200 rural SMEs for technology trials; Hebridean Connections, a community-based organisation, providing access to large datasets and staff expertise to support research into the use of NLG and Semantic Web technologies for community-centered cultural heritage curation; and RSPB, the largest environmental charity in Europe, facilitating access to the public for 'citizen science' engagements with technology in collaboration with ecologists. In other research funded by the RCUK DE Theme, Reiter collaborated with experts in assistive technology, plus two special needs schools, to enable children with Cerebal Palsy to generate and tell stories about their school day to parents and carers (EP/F066880/1, EP/H022376/1).

International Collaboration. A good example of our strong international links was highlighted in a joint US-UK press release during Prime Minister Cameron's US visit in March 2012: "Since 2006, an International Technology Alliance of industrial and academic organizations from the U.S. and UK, led by U.S. Army Research Laboratory and UK Defense Science and Technology Laboratory, have been jointly conducting collaborative research to enhance information-sharing and distributed, secure, and flexible decision-making to improve networked coalition operations" tinyurl.com/7quvnm7. This programme supports research collaborations with US government (ARL), industry (IBM, Boeing, Honeywell) and academic (CMU, CUNY, Penn State, UCLA, Maryland) partners. The Arria NLG Research Centre, established in May 2012, enables research exchange through project work and training among the unit, Data2Text (a spin-out company from the unit led by Reiter and Sripada) and Arria NLG (a company with a global presence). Pym is leading the development of the National Grid Cyber-Security Research Centre, establishing a research agenda and a range of academic collaborations, and engaging with UK and US government departments and agencies, such as CPNI, TSB, DECC, DoE, and NIST.

These are just a representative sample, but they illustrate the breadth and level of engagement we have with research users. Throughout the REF period, we have sought to develop core partnerships spanning a number of activities. With colleagues in IBM (UK, US, India and China), for example, we collaborate through the *ITA* project (joint research, internships), *dot.rural* (Steering Committee chair), a Marie Curie Industry-Academia Partnership and Pathways network (staff

exchanges, internships), and the *TRUMP* project (advisory). This approach establishes longer-term relationships centred on core, shared research challenges, enabling the more rapid exploitation of new opportunities. Other examples include a strategic partnership with IIIT Bangalore, established to support student/staff exchanges and pilot projects. Our engagements with users in collaboration with experts from other disciplines have also influenced the approach we take to research. Effective understanding between complementary disciplines and early engagement with end users helps to maximise the relevance of research to challenging real-world problems. This is an important part of our research strategy across all themes, and it ensures that users have real buy-in to the research: a key enabler to impact. Research away days provide a means for all academic staff to share and reflect on experiences, and influence future strategy; a recent example being an EPSRC-funded *Creativity at Home* event led by Edwards where we explored future interdisciplinary research strategy with a number of colleagues invited from other disciplines.

Esteem. During the REF period 6 members of staff were members of the EPSRC Peer Review College (Coghill, Edwards, Mellish, Norman, Pan & Pym), and one the ESRC College (Edwards). Pym is a member of UKCRC. We also support the community through, for example, Edwards taking on the role of Director of the RCUK *Digital Personhood* IDEAS Factory (2012-2013), serving on the strategic evaluation panel for the EPSRC IDEAS Factory Programme, contributing to the EPSRC Shaping Capability exercise by service on a number of pilot panels, and serving on the US/UK/Canada/Netherlands *Digging into Data Challenge* Panel, The Hague, 2013.

There is extensive evidence of international recognition of our strengths through involvement in the foremost international fora. Within ARK, members of the unit are Senior Programme Committee (SPC) members of the Int. J. Conf. on Artificial Intelligence (IJCAI) (Norman, 2013), Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS) (Norman, 2009 Area Chair, Theory & 2010; Vasconcelos, 2009-2010 & 2012), the International Semantic Web Conference (Pan, 2013), the Extended Semantic Web Conference (ESWC) (Edwards, 2012). Pan is Program Chair of Joint Int. Semantic Technology Conference (JIST2011), Editor of Int. J. on Semantic Web and Information Systems (2012-), Editorial Board Member of J. of Web Semantics (2010-), and gave a keynote at 2nd Web Science Conference (2013). Sycara has been an editorial board member of the J. of AAMAS throughout the period and numerous other journals including Group Decision and Negotiation, Fundamenta Informaticae, and Web Intelligence and Agent Technologies. Within NLG, Reiter was Area Chair (NLP Applications) at ACL (2013), van Deemter is a member of the Editorial Review Board of the J. of Artificial Intelligence Research (2012-) and has served as Associate Editor for the journal Topics in Cognitive Science (2009-2013), and Siddharthan is editorial board member of the J. of Computational Linguistics (2010-). Within SM, Coghill was PC Chair of the UK Computational Intelligence Conference (2012), and Pym was PC Co-Chair of the Eighth Workshop on the Economics of Information Security (2009), is Corner Editor (Semantics) of the J. of Logic and Computation and editorial board member of the Int. J. of Service Science, Management, Engineering and Technology.

Mellish was made ECCAI Fellow (2010) and Coghill Fellow of the IET (2009). Members of the unit were invited to give keynote talks at international events including van Deemter (12th European Workshop on Natural Language Generation, 2009), Pan (International Conference on Web Intelligence, Mining and Semantics, 2012; International Conference on Web Information Systems and Technologies, 2012), Sycara (International Conference on Cooperative Information Systems, 2008; International Conference on Intelligent Agent Technology, 2009), and Vasconcelos (3rd Workshop on Autonomous Software Systems, 2012).

Members of the unit are also prominent in events more focussed towards industry and policy-makers, and in standardisation efforts. With respect to industry and standards, Pan was Advisory Committee Representative, World Wide Web Consortium (W3C, 2006-2012), member of the W3C OWL 2 Working Group (2007-2009) [REF3, case study 3], member of W3C RIF Working Group (2006-2010), is Primary Member Representative of Object Management Group (OMG, 2006-), and member of OMG Ontology Definition Meta-model Task Force (2010-). With respect to industry and policy, Pym was invited speaker at the Microsoft Cyber-security & Digital Crimes Forum, Brussels, May 2011, co-speakers including leaders of OECD, European Commission, NATO, ENISA, and the UK Cabinet Office (http://tinyurl.com/c3tx5jm). Pym contributed to the ENISA (European Network and Information Security Agency) report “Economics of Security: Facing the Challenges”, http://dx.doi.org/10.2824/23063, and is on the academic advisory board for CESG.