**Institution: Glyndŵr University**

**Unit of assessment: 11**
**Computer Science and Informatics**

**a. Overview:**

The University Research Centre supporting staff and students in UoA 11 (Creative and Applied Research for the Digital Society, CARDS www.cards-uk.org) includes staff and students from a number of academic departments in the University Institute for Arts, Science and Technology and provides an environment for research-active individuals to conduct research, supervise students, undertake doctoral studies, publish and present new material, seek funding, sponsorship and serve as referees, editors and members of expert committees and professional bodies. This submission relates to activity within CARDS in the areas of computer networking and telecommunications (Professors Grout, Excell, McEwan, Dr Liu), algorithms/optimisation (Drs Liu, Cordeiro de Amorim) and human-computer interaction (Professor Earnshaw and Drs Picking, She).

**b. Research strategy:**

In RAE 2008, Glyndŵr University submitted in Computer Science and Informatics for the first time. Although a small submission in terms of FTEs (3.2), the results were very encouraging for us: 5% 4*, 35* 3*, 50% 2*, 10% 1*, and 0% U/C. In RAE 2008 we stated 'The main strategy over the next five years will be to continue to expand the academic staff teams supporting the two key research themes and to further develop the international collaborations which have already been well established.' These objectives have been and continue to be achieved through supporting early career researchers, making key new appointments, and cultivating strong international collaboration. In 2008, 33% of staff associated with this UoA were qualified to PhD level (5 from 15). Now, this figure has climbed to over 50% (10 from 18). 3 further members of academic staff have submitted their theses. These developments have led to the original two research themes growing to three in this submission: computer networking/telecommunications, algorithms/optimisation and human-computer interaction (new). During the assessment period 8 visiting scholars have been appointed from countries such as Germany, Italy, Australia, China and Spain. These appointments are facilitating collaboration with international partners, and have resulted in joint publications, research bids, and industrial liaison/consultancy. Existing international collaborations have also been strengthened. The University's Internet Technologies and Applications (ITA) biennial conference is now in its 5th cycle, bringing delegates from more than 40 countries including New Zealand, USA, Brazil, Germany, Spain, Russia (www.ita13.org). Many delegates continue to collaborate with Glyndŵr University researchers in this submission, for example in telecommunications research at the International Workshop on Energy Efficient and Reconfigurable Transceivers (EERT), which has been held at ITA on 3 occasions (www.ita13.org/index.php/eert/), and in human-computer interaction (assisted living/telehealth) at the International Workshop on Technologies for Health and Wellness (THAW) http://ita13.org/index.php/technologies-for-health-and-wellness/. Erasmus staff and student mobility with Hochschule Darmstadt has led to substantive research collaboration investigating novel timing mechanisms to enhance the efficiency of particle accelerator operations, in collaboration with the GSI Helmholtz Centre for Heavy Ion Research, Germany. Erasmus funding has also been used as a vehicle to explore research collaborations with Universitat de les Iles Balears and Aalborg Universitet. EU-FP6 supported a collaboration with Universidad de Zaragoza, Siemens BSH and other industrial partners in the EasyLine+ project (www.easlylineplus.com) in which University staff researched and developed innovative interfaces for controlling intelligent white goods to support independent living (http://www.easylineplus.com/index.html).

In addition to funded collaborations, staff included in the submission have a wide range of non-funded collaborative relationships leading to joint publications, including partnerships with Ghent University, National Research University Higher School of Economics (Moscow), Chernihiv State Technological University (Ukraine), and the University of Bradford. Picking, Grout and Excell have participated in the Prince of Wales Innovation Scholarships scheme (POWIS), through supervision of high-quality research students in collaboration with Welsh companies and with Massachusetts Institute of Technology (MIT). This has resulted in jointly published work with MIT academics in the Geospatial Data Center that has led to the published proposal of secure social networking

environments for military families. Knowledge Transfer Partnerships (KTPs), the Welsh Government's Academic Expertise for Business programme (A4B) and POWIS have all been successful in this submission area, highlighting our continuing strategy to engage with applied research and industrial need. These examples demonstrate our employment of the University's research strategy: *"… to promote research more strongly externally and to engage more with Welsh businesses in knowledge transfer through collaborative applied research".* In the period since RAE 2008, the researchers in this submission have published over 150 papers in peer-reviewed journals and in conference proceedings (http://www.glyndwr.ac.uk/CARDS/Papers/). Since RAE 2008, 7 PhD students have successfully completed their doctorates. There are now 15 research students currently under supervision of the 8 researchers in this submission. Our strategy is to support talented undergraduate and postgraduate taught students to consider progressing to research degrees and in the assessment period, 8 Glyndŵr graduates have been recruited via this route, in particular from our BSc and MSc in Computer Networking, both of which were strategically designed to provide a route into research which is supported by the UoA's collective expertise in networking, telecommunications and optimisation.

**Future strategic aims and goals:**

Our intention is to continue to support the broader community of academic staff associated with the subject areas covered by this UoA in gaining research degrees, so that by 2016 80% of departmental staff will be qualified to doctoral level. This will increase the extent to which staff are able to engage in collaborative research with colleagues in other institutions, in the UK and internationally, produce high quality research outputs, and increasing the capacity to supervise research students. The development of staff in their research careers has a clear pathway, which at this stage involves them being immediately registered for supervisor training and mentorship. They are also expected to join with currently established collaborations that form the basis for seeking external funding for substantive collaborative research projects. Our strategy is to continue to grow the number of full-time research students, through a combination of bidding for external support for studentships and reinvesting overheads and profits obtained from consultancy and knowledge transfer in research student bursaries or studentships. Three such appointments were made in the assessment period at a value of £30K per student. As part of our strategy to be internationally more influential, we actively recruit research students from all over the world. Currently, we have students from Nigeria, China, Saudi Arabia, Germany, Libya and Bangladesh amongst others, as well as UK students. Our focus in terms of project-based research income is to seek opportunities for applied and close-to-market research. We attract funding through Research Council grants, European Union Framework projects (and other EU schemes), KTPs, industrial and social funding, commercial and academic collaborations and existing professional and industrial links. One member of staff received an EPSRC early-career researcher grant at a value of £76,370. A visiting researcher was supported by the Leverhulme Trust. Fee waivers have been enabled through the Prince of Wales Innovation Scholarships scheme (POWIS) programme. The above successes have resulted in 18 funded research posts in the assessment period.

As our capacity and reputation has grown, our opportunities for research collaboration increase. We are now approached more as experts within our respective domains and are invited increasingly to join as partners in cooperative joint grant bids. Our strategy is to continue to grow this research capacity at a similar rate through further grant funding, re-investment and national/international recruitment. The University is committed to undertaking research which contributes not only to economic development, but also to social and cultural development. To that end, we take a proactive role in the promotion and dissemination of our research activity to the wider public, taking a central role in local, national and international events, such as the Wrexham Science Festival, international conference attendance and organization. Dissemination is also evident through interaction with media organizations, such as regular press releases and BBC TV, radio and newspaper interviews. We have a vibrant fortnightly seminar programme, which is promoted both within the University and further afield. In academic year 2012-2013 there were 17 such events http://www.glyndwr.ac.uk/C.A.R.D.S./Seminars/. These were delivered by academics from the Research Centre, by research students and there were also three CARDS seminars delivered by external experts (Prof. James Foley, Georgia Institute of Technology, USA; Prof. Alan Dix, Birmingham University; Dr Jon Peddie, Jon Peddie Ass. USA). Our external seminars are also

promoted through press releases. This initiative is particularly useful for researcher development, giving them the confidence to present their research findings, and to prepare them for wider dissemination at conferences etc. Feedback on research progress is also provided by domain experts at these events. Our strategy is to continue this approach and to strengthen the structure of the seminar series, for example in future all research students are to be formally reviewed in a seminar presentation at least once per year, and at important development points (e.g. transfer from MPhil to PhD). Another example of researcher development is from Prof. Earnshaw. His primary role is to act as a research leader. He runs a regular 'Researcher Development' workshop, which is open to all researchers throughout the University, he offers one-to-one support, and he ensures that research funding and collaboration opportunities are targeted to relevant colleagues. This is an example of where more experienced researchers mentor and support their less experienced peers, and is evidence of our strategy towards staff development in research activity.

We also collaborate in inter-disciplinary research and several projects have involved co-research with other UoA areas (specifically 4, 13 and 36). For example, a NESTA-funded project that is developing 'apps' for use by autistic audiences at arts events to help them both prepare for and engage with new stimuli and experiences, is involving collaboration between this UoA and UoA 36. Applied research and knowledge transfer activity are integral to the work of staff in the unit of assessment. The majority of research income stems from research undertaken in collaboration with companies, and academic consultancy has generated income of £37k in the assessment period. Our close links with industry and demonstrable expertise in applied research will enable us to grow in this area of income generation. Our strategy is to support staff in this area and to give them the opportunities to engage with real-world, cutting edge projects that in turn will enable them to apply and transfer new knowledge in their research work.

**c. People - Staffing Strategy and Staff Development:**

The University's Equal Opportunities Policy applies to staff and to students. The University has a recruitment policy that requires newly appointed staff to possess a doctoral degree and to be able to demonstrate appropriate research experience/expertise. Their particular area of expertise is taken into consideration when making new staff appointments and in Computing this is exemplified by the appointment of Drs Liu and Cordeiro de Amorim on the basis of their expertise and potential in their research theme of algorithms and optimisation. All research active staff are members of one of the five University Research Centres which provide a vehicle for the enhancement of research capacity and capability. The University's Graduate School has overall responsibility for supporting and developing staff and research supervisors. A programme of generic skills training and personal development events based largely on the Vitae's Researcher Development Framework is provided for the research community. The University's policies and processes are consistent with the principles of the Concordat to support the career development of researchers. The Careers in Research Online Survey and the Principal Investigators and Research Leaders Survey are run when available. Analysis of responses informs the University's further development of its policies and practices and enables benchmarking.

In addition to the University-wide strategies, systems and initiatives, researchers in this submission have undertaken a number of developments to encourage and support the culture of research. For example, the development of our wide-ranging fortnightly seminar programme, where researchers disseminate their work, and seek advice from more experienced researchers has proved very successful, and is popular with research students and early-career researchers (ECRs) http://www.glyndwr.ac.uk/C.A.R.D.S./Seminars/. Less experienced researchers are mentored by more experienced colleagues, informally and through appointing ECRs as members of PGR supervisory teams. The culture within the UoA fosters close working relationships in a vibrant yet intimate environment. Experienced researchers share office and working space with ECRs and postgraduate research students for example, facilitating access and support whenever required. ECRs also take active roles in the co-ordination and organization of research events, such as the biennial ITA conference. Spin-off activities from the conference include research and development collaboration, joint PhD supervision with Universities in other countries, agreements to teach postgraduate courses to international students both in the UK and overseas, and invitations to

deliver keynote addresses at other, related conferences. These agreements have been fulfilled in the Ukraine, Russia, Spain and USA amongst others. The ITA conference is highly visible throughout the whole University, and as a consequence it has acted as a catalyst for other subject areas to increase their research profiles and activity.

**Research Students:** Support for PGR students in terms of induction, training, facilities, monitoring and supervisor support is provided at University level. All research students are allocated to a specific University Research Centre as part of the admissions process, to ensure that they are welcomed into an appropriate research environment. All research students are required to take part in the University's research and transferable skills training programme. This has been mapped against the Vitae Researcher Development Framework and supports students throughout their programme of study. Feedback from students contributing to enhancement work is gained directly, through the student – staff consultative committee, through student representation on University committees, and through analysis of responses to the Postgraduate Research Experience Survey. In response to research student feedback, more campus space has been reserved for their exclusive use. For example, there is now a dedicated PG common room, in addition to the work/office environments throughout the campus specifically for research students. In addition to the University-wide strategies, systems and initiatives, researchers in this submission have undertaken a number of developments to encourage and support the culture of relevant research (the seminar series, ITA conference, researcher development workshops are all examples of these presented in this submission). Additionally, we are part of an international consortium that organizes and participates in a biennial research-student development conference (http://www.cscan.org/default.asp?page=sein). Our research students take part in this event by submitting and delivering papers, attending the organized researcher CPD sessions, and in forming collaborations and links with peers at partner Universities. SEIN 2011, which took place in Furtwangen Germany, welcomed a delegation of 5 Glyndŵr researchers, and their papers collectively formed over 50% of the proceedings.

When postgraduate students approach the end of their studies, we provide a high degree of support to help them reach successful completion, for example through peer review of draft submissions, and through intensive seminars on their research outputs/contribution. We also support the career pathways for graduating research students, whether they choose to move into academia or other areas of industry. For example, 5 recent PhD graduates have taken up academic roles as University lecturers (at Coventry, Herts, Staffs, Dhaka and Glyndŵr), and they have been mentored and supported by the Glyndŵr team during their career development. We see our research environment as extending beyond the tenure of Glyndŵr staff and students, as we continue research collaboration following career change and development. In 2008, this UoA collectively supervised a total of 9 PGR students (including MPhil). This has since increased annually, leading to the current level of 27. All have actively engaged in the CPD programmes as well as supervisory engagement over this time, contributing effectively to progression and completion since 2008. In this UoA period, there have been 7 PhD completions. A further 3 students have submitted their doctorates (October 2013) and another 2 are in writing up mode due to submit imminently. Over this assessment period, our research student activity has increased substantially, with more students, publications and diversity, and our strategy is to grow this much further. We are achieving this by recruiting enthusiastic early career research-active academics who are attracting high-quality research students in new areas. Two of those researchers (Cordeiro de Amorim and Liu) are in this REF submission.

**d. Income, infrastructure and facilities:**

In accordance with the University's research strategy to *"…engage more with Welsh businesses in knowledge transfer through collaborative applied research"*, the grants and contracts awarded in this assessment period reflect our strategic focus on real-world, applied projects that inasmuch as possible collaborate with the wider industry/business community.

**Grants and contracts awarded since 2008:**
*TSB / Motor Design Ltd*, 2008-10, value of £99,044 KTP: To develop a software package, fitting on

top of existing motor design software that makes complex processes and calculations easier for less-technical users. The research has successfully contributed to a significant increase in company profile, modified internal working procedures and an expanded portfolio of services available to customers. The final product has been well-received by the market with promising early sales and projections of significant sales and increased turnover.
*TSB / Thinking Group Ltd*, 2009-11, value of: £101,544 KTP: To exploit leading edge internet/multimedia technologies that provides competitive advantage in the promotion of the company's new commercial services to the widest possible audience.
*TSB / AQR Ltd*, 2009-11, value of £107,200 KTP: Develop in-house capability to design and implement rich interactive internet applications for delivery of traditional training programmes and further enhancement of on-line applications for children. The KTP provided technical expertise to further enhance and develop products and services into fully interactive web based applications accessible to clients around the world. The KTP developed online products in a format that was superior to anything on the market at that time. The implementation of the online products would increase the organisation's profit which would allow further investments, growth and in effect new staff employment.
*TSB/ Thermographic Measurements Ltd*, 2009-11, value of £107,200 KTP: Using up to date technology to research, develop & implement an integrated management information system across the company's four divisions. The partnership project was to develop an integrated Management Information System (MIS) to reduce waste, improve productivity and communication between the company's four divisions. As a result, the new MIS provides greater operational efficiencies by providing better more accurate information such as sales analysis, allowing TMC to target specific customers and increase sales through better marketing.
*TSB / Trackyou Ltd*, 2010-12, value of £107,200 KTP: Using up-to-date technology fully develop and integrate new and bespoke data terminals, with satellite navigation and routing functionality, in order to gain public sector contracts.
*ERDF / University of Wales*, 2010-12, value of £27,000 POWIS Scholarship (Geolang). The Prince of Wales Scholarship scheme was funded by the EU and Welsh Government. It was an innovative £11.4 million initiative, managed by the University's Global Academy programme, which brought together the private sector in Wales with higher education providers, including Massachusetts institute of Technology. Geolang is an SME which has supported two postgraduate researchers under the supervision of Glyndŵr (Dr Picking) in the areas of cybersecurity and human-computer interaction. A student on this scheme of Prof. Excell has since obtained a prestigious research post at Rutherford Appleton Laboratory.
*Leverhulme Trust Visiting Fellow Scheme*, 2011-12, value of £28,830: Dr Yunzhi Yan (Lixin University of Commerce, China) 'Measuring and modelling complex networks'
*EPSRC ECR Support Grant, 2011-14,* value of 76,370 Effective Delivery of Interactive Content via Large Scale Wireless Mesh Networks.
*RCP21/TSB*, 2012-13, value of £6,600 Emergent Mobile Technology as the Catalyst for Business Collaboration and Partnership in Business and Industrial Parks. A demonstrator was built that successfully achieved the objectives. Some new intellectual property was generated and the CEO of RCP21 is currently migrating this into a new start-up company.

Research income has been £622,000 over the assessment period, from FP6, TSB, Leverhulme Trust, ERDF, and KTP projects. The majority of external funding is through collaborative research. Academic consultancy has generated income of £37k in the assessment period.

**Infrastructure and facilities:**
The largest investment related to this submission is the £5.4 million development of the University's Creative Industries Building, opened in 2011. The centre provides a focal point for creative industries activity, promoting greater interdisciplinary collaboration and research. The centre provides a hub for the development of a creative industries culture and also provides a stimulus to the development of private and spin-out businesses associated with the creative industries. There are many high-specification tools and technologies which are exploited for research purposes throughout the University. These include the computer networking research lab, a fully-functioning usability observation laboratory, recording studios, high-specification 3D printers and scanners, specialist laser cutting equipment, gesture interaction research equipment and an

immersive augmented reality 'dome'. Current research is using this equipment in wide-ranging domains such as eHealth, education and creative industries. The University hosts the science discovery centre Techniquest Glyndŵr (TQG, http://www.tqg.org.uk/) on its main Wrexham campus. This provides opportunities for staff to contribute to public engagement activity, and its presence has stimulated new interdisciplinary research. As an example, staff in Computing are working with colleagues in Creative Industries, Communications Technologies, Health Sciences and Psychology and with TQG staff, to investigate both technological and behavioural aspects of how 'domes' (usually used as planetaria) can be used to provide enhanced interactive experiences for education, creative arts, training and entertainment. This initiative has led to the presentation of these technologies at International conferences and further collaboration with the University of Aalborg, Denmark. Such interaction and interfacing with other subject areas both locally and internationally highlight our aspiration to develop further an environment which enables future projects to pull together multi-disciplinary teams of expert researchers.

Full-time research students are provided with personal office space, which is situated within the immediate environment of their supervisors and other academic staff. There is also a dedicated research study/common room within the immediate environment which can be used for hot-desking (e.g. by part-time research students), for meetings and seminars, and for social engagement. In order to expand the range of resources available, the University has a shared library system with Bangor University that enables students to borrow books from either library. In addition to University-wide resources, this UoA also has its own growing research library, comprising journals, proceedings, past dissertations, and other research periodicals. These are located within the immediate local research environment along with showcases of past research successes (research prizes, digests, photographs, media articles, awards etc.) – this presence aims to encourage and inspire our researchers in their pursuit of excellence. The University's Research Office provides support for grant and other research funding proposals, and for contract and collaboration agreement negotiation and completion.

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

**Excell** is on several national and international committees including: IEEE Society for the Social Implications of Technology, UK and Ireland chapter: member of the executive committee from August 2013, Engineering Professors' Council: member of the executive committee from April 2013, Institution of Engineering & Technology (IET): Member of Executive Team of Technical & Professional Network on Electromagnetics, 2009-, Academy of Finland and the Finnish Research Council for Natural Sciences and Engineering: member of review panel evaluating research proposals in the field of electronics and electrical engineering, 2008-10; chair in 2010. Council of Professors and Heads of Computing (CPHC): elected member of managing committee 2008-10, British Standards Institution: co-opted expert member of committee GEL/031/0-/02 on RF radiation-induced ignition and detonation, 1974-2010. Excell has continued to work in close integration with the group that he founded at Bradford University, focusing on computational methods for simulation of electromagnetic field distributions and antennas (now led at Bradford by Prof. Abd-Alhameed). This alliance has produced substantial outputs of joint papers (in double figures per year) and has graduated several jointly-supervised PhD students over the reporting period, registered at Bradford University. McEwan has recently transferred from the Bradford group to Glyndŵr and they have been joined by Liu, part of whose work focuses on advanced techniques for electromagnetic field computation and design of radio-frequency devices. Since electromagnetic field computation is inherently predominantly an SIMD problem, this work is well supported by Glyndŵr's membership of the HPC Wales high-performance computing network, including the physical presence of a node of the network at Glyndŵr.
**Earnshaw** is a member of the joint European Union/National Science Foundation Research Strategy Group. He is a proposal reviewer for the European Commission Framework 7 (FP7) Information and Communication Technologies (ICT) program and an evaluator for ICT Call 10 in "Technologies and scientific foundations in the field of creativity" in 2013. He has acted as a reviewer for the government of Canada for the Canada Excellence Research Chairs, and an evaluator for chair appointments at Nanyang Technological University, Singapore. He is a Leverhulme Trust Grant Application Reviewer 2010-present. He has been a Visiting Professor at

Illinois Institute of Technology, George Washington University, and Northwestern Polytechnical University, China, and a Pro Vice-Chancellor (Strategic Systems Development) at the University of Bradford (2004-9). He has acted as external examiner for PhD theses in Belgium, Switzerland and Singapore. He is a British Computer Society (BCS) Program Accreditation Assessor and a Chartered Membership Assessor. He received the Silver Core Award from the International Federation for Information Processing (IFIP), Austria, in September 2010.

**McEwan** is a predominantly industrially-based research engineer, undertaking advanced computational simulation work for novel telecommunications hardware (antennas and amplifiers): much of this work is subject to commercial confidentiality. His industrial work has been for Millitech Corporation (Amherst, USA), Filtronic PLC and Saras Technology Ltd. He has consulted for EUTELSAT, INTELSAT and the European Space Agency.

**Grout** has collaborations via visiting seminars at University of Applied Sciences, Bielefeld, Germany, University of Oviedo, Spain, University of Plymouth, University of Reno, Nevada, USA, He was External Advisor, University of Plymouth Professorial and Readership (Academic Promotions) panel, from 2010, Leverhulme Trust Grant Application Reviewer, 2010-present**,** European Commission Framework 7 (FP7) Information and Communication Technologies (ICT) project proposal reviewer, from 2008, Institute of Engineering and Technology (IET) Registration Group Technical Assessor, from 2013, British Computer Society (BCS) Programme Accreditation Assessor, from 2012, Chair of the Council of Heads of Computing in Wales/Cyngor Penaethiaid Cyfrifiadura Cymru (CPCC); the Welsh region of the Council of Professors and Heads of Computing (CPHC), from 2012.**,** Member of the Council of Professors and Heads of Computing (CPHC)/Computing at School (CAS) [CPHC-CAS] Working Group, from 2012, Member of the Older People and Ageing Research and Development Network (OPAN Cymru) Steering Committee, since 2010, collaborating with a number of Universities, including Swansea and Cardiff, Member of the WHEB Digital Economy Working Group, from 2011, Editorial board for 11 peer-reviewed journals and European Union Independent Expert for EU Safer Internet Programme 2009-2013.

**Picking** has collaborations with Universities of Aston, Warwick, Zaragoza, UIB Mallorca, Swansea, Bangor, amongst others. He is Chair of BCS Health in Wales specialist group, conference Chair of ITA'13, is a programme committee member for 11 International conferences, is on the editorial board of 3 journals and on the review panel for a further 6 journals.

**She** has collaborations with the University of Adelaide, Australia, University of Aizu, Japan, Bangor University, UK, Fudan University and Southwest University, China. He was elevated to a Fellow of the Higher Education Academy (FHEA) UK in 2013, a Senior Member of IEEE (SMIEEE) USA in 2011 and has been on the IEEE SMC Technical Committee on Aware Computing since 2010. He has been a guest professor at Southwest University China, a guest editor of Applied Computational Intelligence and Soft Computing (Hindawi) and chair of sessions at IEEE SMC Conferences in 2010 and 2011.

**Liu** has collaborations through inter-disciplinary research with the University of Essex, Newcastle University, Katholieke Universiteit Leuven, Ghent University, University of Sevilla , and Friedrich Alexander Universität Erlangen-Nürnberg. He is a Technical consultant for Accelicon Technologies Inc, USA., is on the Editorial Board, Journal of Engineering (Hindawi).

**Cordeiro de Amorim** has research collaborations at University College London, Birkbeck, Essex University, University of Cologne, National Research University Higher School of Economics, Moscow, and University of West London, where he is a co-supervisor of a PhD student. Currently he holds a visiting research fellowship at Birkbeck, a membership in the editorial board of the international journal on advances in software, and he is a reviewer for seven journals published by Elsevier, Springer, Taylor & Francis and World Scientific.