Institution: University of South Wales

Unit of Assessment: B11

a. Overview

Research in the Computer Science and Informatics Unit of Assessment spans the computing and electrical engineering departments within the Faculty of Computing, Engineering and Science and contains some interdisciplinary work. All staff returned for the Unit are from the old University of Glamorgan (merged with Newport to form the University of South Wales in 2013).

Research is clustered around four research groups:

- ***Geographical Information Systems* (GIS)** led by Professor Higgs with Langford, Ware
- ***Mobile Communications*** led by Professor Al-Begain with Professor Otung, Al-Daher, Kuwadekar
- ***Intelligent Systems*** (this subsumes three distinct research units: AI, Medical, and Hypermedia) led by Professor Tudhope with Carroll, Cunliffe, Muller, Roula
- ***Security Information Systems*** led by Professor Blyth with Xynos.

Additional staff and RAs not selected for this REF also participate in the research groups.

b. Research strategy

For RAE2008, the Unit returned 22.45 FTE. Five staff returned in RAE2008 have since retired and another two have taken posts elsewhere. Two staff are returned in the Mathematics submission this time. Sutherland has been 80% seconded for an extended period as part of a (Security) collaboration with Noroff University College, Norway. The current submission of 13.5 FTE reflects the University's strategy to focus on major areas of research strength. The aim is to be internationally significant within our distinctive research areas.

In 2008-2013 we wish to call attention to the following advances in our research culture:

- Increased research funding and widening of funding sources
- Significant user engagement across a wide spectrum of impact types
- Major advances in research infrastructure and specialist facilities

The general strategy outlined in RAE2008 included increasing research student numbers, widening sources of funding, promoting interdisciplinary research, developing infrastructure. In 2008, we aimed to build on distinctive strengths, while exploiting topical application and teaching opportunities in areas, such as mobile computing and information security. In large part, this strategy has been pursued successfully over the REF period and it remains current.

Research is structured via Research groups (units), each with a Leader who acts as a conduit for information from the centre and provides mentoring generally. Each group maintains its own research web portal, which serves to disseminate activities and successes. Since 2008 (see Collaborations), the established research groups in GIS and Hypermedia (Intelligent Systems) have continued to develop their international profile with significant AHRC funding for Hypermedia and major influence for GIS via the ESRC/HEFCW WISERD initiative. The research groups new to RAE2008, Security and Mobile Communications, have become internationally recognised centres of excellence, with specialist laboratory facilities and sustained research income, also supported by the strategic decision to develop undergraduate and postgraduate provision in these areas. Specialist Security, Mobile and GIS MSc courses have assisted PhD recruitment.

One key element of the University's future research strategy is the establishment in 2013 of five (inward facing) Research Institutes (RIs), including Computing and the Digital Economy (co-Directors Professors Tudhope & Fyfe), which contains all staff returned in the Unit. RIs have been established in areas where the University has significant research strength and a strategic decision has been made to support that area. Additional protected time for research is built into the University workload model for RI members. The focusing of University resources on RIs is seen as a sustainable research strategy. Administrative support is provided by the University Research Office and mentoring is available by experienced researchers. RIs are selective with criteria based on REF potential, with RI membership subject to review. Progress is assessed via the RI annual

process of setting and monitoring research objectives.

Over the medium term our research strategy is for controlled growth, growing capacity through appointments and externally funded projects. We will build on distinctive strengths where investment will be focused. The Unit will continue to encourage and support the cultivation of long term collaborations with key users, embedding research outcomes in user contexts according to the different strategies followed by the research groups. Each research group has tended to emphasise a particular combination of user sectors and funding instruments (see Impact). As described below, the specialist Security and Mobile infrastructure and collaborations and the major GIS and Intelligent Systems projects (WISERD, ARIADNE/SENESCHAL) offer immediate foci to build upon. We will continue to bring on early career researchers (see People). Via the Computing and the Digital Economy RI, future research strategy includes individual impact plans together with impact workshops run by experienced researchers. The RI will also encourage integrative projects between the research groups and interdisciplinary projects in digital economy and creative industries, particularly applied to emerging research areas, such as mobile security, brain computer interfaces (the focus of a recent High Performance Computing Wales grant award), big data, internet of things, smart cities and location aware services. A recent example (October 2013) is a research consortium (with Surrey and Aberystwyth Universities) supporting partnerships in the Welsh creative industry sector funded by an AHRC/NESTA scheme, which combines Mobile Communications and Intelligent Systems.

c. People, including:

i. Staffing strategy and staff development

The University has been awarded the HR Excellence in Research Award by the European Commission for our work to implement the Concordat to Support the Career Development of Researchers. This award demonstrates the University's commitment to meeting the needs of researchers and improving opportunities for them in terms of development and future careers. The University Research Office runs both the Vitae Careers in Research Online Survey (CROS) and the Principle Investigators and Research Leaders Survey (PIRLs). In 2013 over 90% of CROS respondents confirmed that they had been given adequate access to training and development opportunities. Following its performance in RAE2008, the University is a member of the St David's Day Group of Welsh Universities. One of the aims of the collaboration is to provide development opportunities for research staff through initiatives such as the Welsh Crucible (Roula has participated from the Unit). The University Research Investment Scheme (RIS) is allocated by the DVC (Research and Student Experience) with the aims of stimulating research activity and pilot projects. It operates on similar principles to the UK Research Councils with directed calls intended for pump priming. Al-Daher, Otung, Roula and Tudhope have been awarded funding.

Research related staff development since 2008 has resulted in promotions to Reader (Cunliffe, Roula) and Professor (Otung, Sutherland). The (continuing) strategy of developing promising young researchers is evident in the 4.5 FTE staff returned as Early Career Researchers (ECR), a third of the submission (Al-Daher, Carroll, Kuwadekar, Muller, Xynos). Research unit leaders and senior researchers mentor ECR, including advice on grant proposals, funding bodies and target journals and collaborative opportunities. External research projects have been used to buy out time and help develop research portfolios. ECR have been involved as Co-Investigators in collaborative grant applications and given opportunities for PhD supervision.

During the assessment period, the Unit has profited from a 12 month visit by Renato Souza (now Visiting Research Fellow) to Hypermedia, funded by the Brazilian Government CAPES scheme, a 1 month visit by Alexander Dudin (Belarus) and a 2 month visit by David Villa (Spain) to Mobile Communications. Kurt Ammer MD Vienna and Graham Machin (NPL Teddington) are Visiting Professors in medical imaging, Brian Turton (EADS/Cassidian) a Visiting Professor in Security, Keith May (English Heritage) Visiting Research Fellow in Hypermedia.

ii. Research students

57 PhDs have been awarded in the 5 year assessment period. This represents a significant increase over the RAE2008 total of 37 PhDs in 6.5 years, with double the average number of PhD awards per year.

Both the Faculty and University have invested in PhD studentships to reinforce successful or developing areas of research. This includes the recent University Centenary PhD Studentships awarded via a competitive bidding process (Roula, Muller, Tudhope successful from the Unit). All research students have a Director of Studies and at least one other supervisor. New students are required to attend a Research Methodology course. Each full-time student within the Unit is provided with a computer, desk and storage space. Research Student Voice Reps are members of relevant Research Committees. There is an annual University research student conference and there have been several Faculty research student conferences.

The Research Programmes Sub Committee (RPSC), on behalf of the Research Committee and Quality Assurance Committee, has responsibilities for the quality and standards of research degrees. This includes annual monitoring of research degree students, examination arrangements and examiners' reports, ethical issues and dissemination of good practice in the delivery of research degrees. Faculties operate in accordance with the University's approved quality assurance procedures, as agreed by Academic Board and published in the University's research handbooks. All faculties undertake the quality assurance of research degrees through a Faculty Research Programmes Committee (reporting to RPSC), which considers the approval of research degree applications, notes registrations for research degrees and transfers students from MPhil to PhD. The Faculty Ethics Champion advises the committee on ethical issues.

The Research Office is responsible for servicing research-related committees and has led various strategic research initiatives. These include the development of a new 60-credit research module leading to a Postgraduate Certificate in Research. In 2011, the new Postgraduate Centre was launched with the aims of helping to foster a sense of community and encourage multidisciplinarity by providing a space outside of the Faculty structure. It also provides a calendar of events that have been aligned to the four domains of the Researcher Development Framework.

The University collaborates with other Universities in the region to deliver Vitae's *Effective Researcher* course and other Vitae training e.g. *The Part-Time Researcher*. The Research Office conducts an internal Annual Monitoring Survey and runs the Higher Education Academy's Postgraduate Research Experience Survey (PRES) every two years. Results of these surveys are reported at both Faculty and University level and feed into Faculty Annual Monitoring Reports and action plans. For PRES 2013, in Computer Science and Informatics, 95% of research students who responded to the survey felt their research skills had developed during their programme of study (9% above the sector average). Two ECR submitted to the REF gained PhDs within the Unit.

d. Income, infrastructure and facilities

i. Income

Between 2008 and 2013, the Unit attracted £3,064,496 of external funding. The total income for RAE2008 was £1,904,739. Thus the average research income per annum more than doubled over the respective periods (£613k for REF vs £293k for RAE2008). Since there are various changes in methodology between REF and RAE the comparison can only be illustrative (as with the PhD comparison). In our view, it nonetheless reflects a significant increase in funding. We are pleased to note a strong increase in both Research Council (more than doubled) and EC funding, combined with a widening of funding sources. Further strengthening of external funding forms one of the key goals of the new Research Institute. Further details are supplied below under Collaboration.

Additionally, £648k has been raised from consultancy (£543k for Security work detailed under Collaboration). There have been three KTPs between 2008 and 2013 (GIS and Security) and three spinout companies have been operating. The *Glamex Security* flagship product, Live Guard (a mobile consumer device and service), is an outcome of Mobile Communications research reported within this submission. *GeoVS* (via retired GIS Professor Gold and PhD graduate) secured a £250,000 equity investment in 2010 to continue developing its interactive 3D visualisation and simulation software platform used in marine and geo-modelling applications. It was recently (Oct 2013) bought by Software Radio Technology, the Bath-based specialist in maritime domain technology (the transaction valued GeoVS at about £955k). *Photometrix*

develops applications for a portable device for skin topology based on a novel stereo-photogrammetric algorithm and inverse cross-polarised lighting technique. Versions have been licensed to QuantifiCare A/S (France) and Perry Baromedical Inc. (USA).

ii. Infrastructure and facilities

2008-2013 has seen major investment in research infrastructure and specialist facilities in Security and Mobile Communications funded by commercial, government and University sources (see Collaboration). The **Security** group has three specialist laboratories. The **Secure Computing Research Laboratory** is one of the very few government approved high security computer forensics laboratories in a UK University. It took over two years to build at a cost in excess of £200k, comprising a physically secure environment built to HMG standards and approved to Impact Level 5. It has highly controlled access. This builds upon Faculty and University support (augmenting external funding) for specialist facilities. While the exact nature of the laboratory equipment is protectively marked, facilities include forensic analysis systems, data recovery tools and the capacity to simulate and analyse large volumes of network traffic. The facility also actively conducts live research in the areas of computer forensics and data recovery from electro-mechanical and NAND storage devices. The lab is equipped with a clean environment and rework station to support this work. The secure nature and limited, controlled access of the laboratory, in addition to ensuring continuity of evidence, allows the laboratory to undertake sensitive research for the UK Government.

The **Computer Forensics Research Laboratory** is equipped with a range of forensic software tools. In addition to the in depth forensic analysis of individual computer systems, the laboratory has the capability to analyse large volumes of network data. Commercial activities have included handling cases for commercial organizations, Trading Standards, local Computer Crime Units, National Crime Agency (NCA) and National Police Units. Casework has been related to a wide variety of different cases, including intellectual property theft, fraud, hacking, child protection, assault, robbery, theft and murder. A number of investigations have resulted in members of the Information Security group providing expert witness reports and giving expert testimony in court.

The laboratory is developing best practice in the areas of the recovery of data from computer hard drives. Work focuses in particular on the recovery of data from drives that may be classed as 'failing'. These are drives that demonstrate reduced performance due to some degradation or failure in electrical or mechanical components. Research in this area has developed a number of best practice procedures for drive diagnosis including analysis of damaged drives. This has been disseminated to UK Police and Government via specialist training courses. The **Network Security Research Laboratory** supports PhD work in the area of network security and analysis of malicious software and cloud environments, with access to both systems and data for various research programs.

Mobile Communications has several specialist laboratories. The £6.4 million **CEMAS Centre** (funded by ERDF through the Welsh Assembly Government, the University and with support from Orange) is equipped with an Industry grade testing facility which is supported by Telecom industry key players. The facility emulates the next-generation mobile operator network and consists of the latest IMS and LTE technologies, carrier grade equipment, conforming to the latest 3GPP specification and generally reflects the current state of the art in the area of mobile telecommunications. The **Sensor and Ad hoc Network Lab** has a full set of programmable sensor boards and sensing devices and a large range of smart phones. The **Wireless and Satellite Communications Lab** comprises research and development tools and computing devices for research and development of Gigabit indoor communications system at 40-70GHz. It has a satellite receiver system that collect regular data from a military satellite, as well as a fully equipped weather station. The setup allows the analysis of signal quality variation in case of severe weather conditions, as well as the development and testing of new and more efficient algorithms for improving the drop-out probability of broadcast signals in severe weather conditions. The **Microwave Propagation Lab and Anechoic Chamber** comprises a high quality chamber for testing systems with no interference up to 70GHz. The lab also comprises a fully equipped vehicle for outdoor signal measurement. Research in this lab has focused on

measuring the effect of vegetation on mobile signal propagation in dense areas. A long term collaboration project with Sub10, a market leader in the field of high-speed wireless communication links, has been established. It is planned that four high-speed (up to 1 Gbps) wireless trial links on campus compromising different setups and environments will provide long term radio data to be correlated with weather information.

The University is a hub within the High Performance Computing Wales, a £40 million five-year project in collaboration with Fujitsu Research to give Wales a supercomputing capacity and network with the support of £24 million from the Welsh Government, including from the EU Convergence programmes and £10m from the UK Department for Business, Innovation and Skills. A first innovation grant has been awarded to the Unit (Roula) on Brain Computer Interfaces building on a University RIS funded pilot study (see Collaboration - Intelligent Systems).

e. Collaboration and contribution to the discipline or research base

Geographic Information Systems (GIS)

The ESRC/HEFCW funded Wales Institute of Social and Economic Research, Data and Methods (WISERD – Higgs is Co-Director) has been a key focus for collaboration. It was established to promote cross-institutional and multi-disciplinary research in the social sciences across the UK and internationally. Since 2008, WISERD has operated as a networked research institute with Universities of Aberystwyth, Bangor, Cardiff, South Wales and Swansea. Initial funding of (up to) £1.462 million was allocated by ESRC and £3.42 million by HEFCW. Based on multi-disciplinary teams, WISERD has attracted research funding of some £4.15 million. A major initiative within GIS has been the development of the WISERD Geo-Portal which provides enhanced metadata for a comprehensive range of quantitative and qualitative data sources relating to Wales (but with the potential for wider application). It is complementary to other sources, such as the UK Data Archive, the Economic and Social Data Service, EDINA and the Welsh Government. Collaborative relationships have been important and will form part of further development of the Geo-Portal, for which ESRC Follow-On funding has recently been obtained. WISERD's contribution to the development of the social science infrastructure in Wales has been as important to its impact as its research projects; it has attracted some £1.75 million in additional grant funding to support infrastructural activities. WISERD has also made an important contribution to the development of the Welsh Government's National Data Strategy, especially with respect to the linking of administrative data. Capacity building has been a central part of WISERD's activities, with an emphasis on quantitative research methods and the utilisation of secondary data sources; the GIS group has contributed to this programme by running successful GIS workshops and training events using open source software tools. A key element has been the development of a robust system of knowledge exchange and transfer involving close collaboration with the Welsh Government and its associated bodies. In March 2012, the St. David's Day Group of universities undertook to provide financial and infrastructural support for WISERD. On these bases, WISERD has now entered a new three-year period of activity that will build upon its achievements to date. In addition, in September 2013 a bid was submitted to the ESRC Large Centres initiative (WISERD/Civil Society) for a further five years funding in order to continue this inter-disciplinary research programme.

The GIS group has also conducted an AHRC (£33k) study of connectivity of minority communities with Universities of Cardiff and Swansea and minority advocacy groups such as Disability Wales and RNIB Cymru. Ordnance Survey have funded a 3 year PhD studentship from February 2013 in the area of Spatial Data Usability. Since 2008 they have also supported research on automatic map generalization and Linked Data work. Other GIS industrial collaborations include the development of web and mobile applications for West Coast Network Services (£200k KTP); a Web-based client for Kestrel and telematics work for Admiral Insurance.

Intelligent Systems

Hypermedia research unit funded projects (Tudhope) overlapping the REF period include 3 AHRC, 4 JISC (in collaboration with Universities of Bath and Manchester) and a transatlantic Digging into Data project with Universities of Manchester and Drexel on automatic generation of subject metadata. The successive AHRC funded STAR, STELLAR and SENESCHAL projects (over £350k to USW) on semantic web services and Linked Data in archaeology are in collaboration with

strategic partners at English Heritage and Archaeology Data Service. SENESCHAL also includes the Royal Commissions on Historic Monuments Scotland and Wales, together with Wessex Archaeology Inc. Related pilot studies have been conducted for National Museum Wales and University of Oxford. The 4 year ARIADNE FP7 Infrastructures project (€205K to USW starting Feb 2013) for archaeology involves 24 partners, including most existing European national services. It aims to integrate existing archaeological research data infrastructures so that researchers can use the various distributed datasets. USW's role as Leader of the Linked Data WP builds on the AHRC funded research. Cunliffe has conducted pioneering work in use of the Welsh language online, informing the Welsh Language Board's IT strategy and studies of minority language use online. Key collaborations in minority language include Aberystwyth University. Roula (PI) has collaborated with Clearspeed Technology and Swansea University on EPSRC funded research (£97k) on magnetic induction tomography image reconstruction. This led to further collaboration with Phillips on medical applications. He has recently been successful with a High Performance Computing Wales Research Innovation grant proposal on Brain Computer Interfaces for Stroke Rehabilitation using High Performance Computing with Neuradaptix Ltd. A small exploratory grant with Sound Technology Ltd is investigating emotion detection using EEG.

The journal New Review of Hypermedia and Multimedia, Taylor & Francis (founded in 1989 as Hypermedia), has been located in the Hypermedia research unit from 1997 (editors Tudhope and in this assessment period Cunliffe). In 2010 the journal was accepted for the ISI Science Citation Index Expanded™. Tudhope has been involved in standards work, as a member of the ISO (and NISO) working group on the new thesaurus standard (ISO 25964) and was a member of the Europeana Digital Library Thematic Network, as part of a task group advising on semantic interoperability issues and metadata. He has (co)organised a workshop on Networked Knowledge Organization Systems/Services at each ECDL (now TPDL, Theory and Practice of Digital Libraries) conference since 2008. Emeritus Professor Ring was awarded (2009) the Medal of the Royal College of Physicians, Surgeons, Gynaecologists through the Royal Photographic Society for services to medical imaging. In 2011, he was awarded the Fenton Medal of The Royal Photographic Society and invited to Brazil as Honorary President of an international Congress on Standards in Medical Thermography. He is a thermal imaging national specialist to the British Standards Institute and a member of the task force on Fever Screening standards for the International Standards organisation. Muller has co-organised the Logics, Agents, and Mobility workshop since 2008 and from 2011 has been Treasurer of the Society for the Study of Artificial Intelligence and Simulation of Behaviour. Cunliffe was invited to join the Welsh Government's "Welsh Language, Technology and Digital Media" advisory group (2012) and commissioned by the Welsh Language Board to write an independent report entitled "The implications of web2.0 for bilingualism on websites – towards best practice" (2009).

Mobile Communications

The £6.4 million Centre of Excellence in Mobile Applications and Services (CEMAS led by Al-Begain) has been a major focus for collaboration. CEMAS is funded by ERDF through the Welsh Assembly Government (£3.47 million grant total plus match funding by the University) to help smaller businesses in the Convergence areas of Wales take advantage of emerging mobile technologies. It offers a test bed for SMEs to design, develop, test and protect the creation of new mobile phone services and applications across all sectors. The group has collaborated with Orange and Telefonica for specialist next-generation test bed network services and conducted consultancy projects with major industrial partners, such as General Dynamics UK. Academic collaborations include Dudin (Belarus), Villa (Spain), Alameh (Australia), Obayya (Egypt), Zreikat (Jordan), Dmour (Saudi Arabia). Research projects on video to mobile techniques resulted in a patented security system licensed to a UoG spin-out company (Glamex Security Ltd). An FP7 Project (€243K to USW) with 17 partners from 11 EU Countries including 10 social housing organisations is investigating the potential of smart metering and wireless technology for reducing energy and water wastage. Future plans over the next five years include establishing a Centre for research, design, development and business support in Wales, based on the success of CEMAS via a major follow on ERDF proposal.

Otung's experimental investigation of satellite links using earth stations established at the

Trefforest campus and Chilbolton Obervatory is in collaboration with Rutherford Appleton Laboratory (supported by CCLRC funding in kind grant, £40k). The ongoing experiments include multi-frequency radiometry, meteorological measurements and monitoring of EUTELSAT HotBird 6 satellite beacon and have contributed to COST IC0802. Commercial collaborations include EADS Astrium (Portsmouth) on GNSS receivers. He is Associate Editor, Journal of Aeronautics and Aerospace Engineering (JAAE).

Al-Begain was President of the Federation of European Simulation Societies (EUROSIM) 2010-2013 and European Council for Modelling and Simulation (2006-2010). He is a Life Fellow of the German Alexander von Humboldt Foundation and winner of the 2013 Inspire Wales Award for Science and Technology. He has been General Chair of 14 international conferences since 2008. He has been the Founder and General Chair of the IEEE International Conference and Exhibition on Next Generation Mobile Applications, Services and Technologies (NGMAST) since 2007 and General Chair of the 8th EUROSIM Congress that he hosted in Cardiff in 2013. He has been Expert Witness on two major IPR court cases between major mobile technology companies, such as Nokia, HTC and Interdigital. He is an Associate Editor of the International Journal on Telecommunications (Wiley) and is on the editorial board of 3 other journals. He is a Member of the Welsh Educational Minister advisory ICT Steering Committee and Leader of the Mission Critical Communications project with General Dynamics EDGE, developing a world first 4G Mission Critical Voice over LTE.

Security Information Systems

Security have developed a service for the forensic recovery and analysis of data funded via successive MOD/DSTL and Home Office grants and consultancy work (>£500k consultancy in assessment period), in partnership variously with Cassidian, Northrop Grumman and Warwick and Oxford Universities. They are Co-Investigators with Royal Holloway in the Centre for Secure Information Technologies led by Queen's University Belfast and funded by EPSRC (more than £2 million overall). They are also members of the EPSRC funded Network in Internet and Mobile Malicious Software coordinated by Queen's University Belfast. The government approved high security computer forensics laboratory carries out training and consultancy work for police and government and is a recognised centre of excellence. Key non-academic user groups and audiences include BT and Sims Recycling, Home Office Scientific Development Branch (now Centre for Applied Science and Technology), various Police agencies including Police Service of Northern Ireland CCTV Unit - corporate and domestic data disposal techniques for both firmware and disk data; DSTL/MOD Cyber and Influence Centre for cyber security; Government Departments such as DfT, DVLA and HMRC for security incident analysis and computer forensics. Academic collaborations include Longwood University USA, Edith Cowen University Australia, University of Khalifa, United Arab Emirates. This work has ranged from data recovery and reconstruction of computer hard-drives to the reverse engineering of malicious software and the detection and mitigation of APT agents, together with assisting in incident analysis and computer forensics for various Government Departments concerning data recovery and reconstruction of damaged hard-drives. A Northrop Grumman consultancy (£200k) with Oxford University is developing a secure cloud environment for cyber defence.

Blyth was seconded to the Ministry of Defence (Jan 2010 – July 2011), as Technical Lead for Cyber/Computer Network Operations within the Cyber and Influence Centre, with responsibility for managing cyber security research within the DSTL/MOD for both Computer Network Defence and Computer Network Attack. In addition, he ran the DSTL CND demonstrator programme (total value approx £3.5M) and chaired the DSTL Cyber Information Exchange. He was Chairman of the Tiger Scheme and principal author of the Tiger Technical Standards for Penetration Testing and Computer Forensics. He has been expert witness for the NCA and various Law Enforcement Agencies (London Metropolitan Police Force, Police Service of Northern Ireland, Avon and Summerset, Cardiff and Gwent). He is a member of ACPO Forensic Forum run by the Police in collaboration with intelligence agencies used to define future forensic requirements.