**Institution: University of the West of Scotland**

**Unit of Assessment: UoA11**

**a. Overview**

At the last RAE, 5 staff were submitted under UoA23 and UoA37. On this basis, the unit 11 group set the target of doubling the number of staff to be submitted in the next assessment and this target has been exceeded (14 are being submitted under UoA11). The unit also decided that there should be at least one completion for the number of people being submitted and this has also been achieved (there have been 17 doctoral completions up to July 2013 and there have been a further 2 since then). The unit also set the target of having each research active member supervise at least 2 PhD students and this too has been achieved (in addition to the 19 completions, 77 PhD students are currently being supervised). To achieve these targets, the University has made significant investment in research and within UoA11: 10 new members of staff have been recruited (3 professors with international reputations and 7 lecturers), complemented with new laboratories, including a new visual communication lab, two new networks lab, a new Ambisonics lab and a new games lab. During the period 2011/12 the University embarked on a process of research restructuring to support groups of scale, and 18 new Institutes or Groups were formed. The University confirmed new investment of some £1m per annum into these Institutes over the next 4 years and these are the focus for all research activity across the University. In UoA11, the University established the Institute of Creative Technologies and Applied Computing (ICTAC) (http://www.uws.ac.uk/ictac) consisting of 3 research centres: ICT in Education (ICTE), Interactive Creative Technologies (ICT) and Audio-Visual Communications and Networks (AVCN) and a research group in Database and Knowledge Management (DBKN), with underpinning R&D and Knowledge Exchange (KE) carried out through the Scottish Centre for Enabling Technologies (SCET).

At the last RAE, external income generation was £216,965. For this assessment exercise, external income generation has increased significantly to £2,409,000 through a number of national and international projects (the actual project values are in excess £10m). A number of important collaborations have been established in this period both nationally and internationally and these will be further developed over the next years.

Underpinning the activities in Knowledge Exchange is SCET (Scottish Centre of Emerging Technologies), which focuses on facilitating co-operation with industry. Initially supported by the Scottish Government and Scottish Enterprise with over £1m in grant funding, SCET is now self-sustaining and brings in R&D projects for research staff in the Institute. Since 2008, SCET has carried out over 175 projects with companies, which have helped to create almost 500 jobs and safeguarded a further 940 jobs, and has increased company R&D by over £4.6m and company turnover by over £80m.The investment by the University and the focus on research has produced a vibrant and robust research environment where the emphasis is on operating in an international context.

**b. Research strategy**

UWS is committed to supporting a vibrant research and knowledge exchange environment across all of its subject disciplines, underpinning the main student experience, providing a stimulating environment in which staff can work and develop, contributing to the development of each discipline, and supporting our communities and regional economies through the exchange of leading edge knowledge into industry, commerce, government and the professions. UWS aspires to deliver world class research outputs across its research portfolio.

Since RAE 2008, the University has invested heavily in research and embarked on a £3.8m academic development programme to recruit 70 new academic staff, including 14 professors, 4 senior lecturers and 46 lecturers to date. The majority of the new lecturing staff are early career researchers, although not all will be returned in REF 2014. The University continues to invest in the future, and the focus of these new staff will be academic and R&D within their discipline.

All new staff appointed have been prioritised (if appropriate) to receive internal funds to supervise a PGR student as part of a package of support to orientate them to the University. Each also receives tailored induction and support from the Innovation and Research Office (http://www.uws.ac.uk/iro) to facilitate engagement into Research Institute life and supported research and KE engagement.

At the same time the University continues to invest over £1m per annum in building its Research Student population to 500 students by the year 2015. Currently one third of the population of 416 students is funded externally and two thirds are funded from internal sources. The University also commits some £0.5m significant capital investment annually into research infrastructure across the University.

The strategy for ICTAC is to develop research and KE activities in the areas of computer games, web/mobile technologies, visual communications and networks. The targeted 3 professorships and 7 lectureships appointments in these areas matches this strategy.

**Progress since RAE2008**

At the last RAE, the School of Computing submitted under two UoAs: UoA23 - Computer Science and Informatics and UoA37 - Library and Information Management. Under UoA23, 2 staff were submitted and judged as 30% (3*), 45% (2*), 20 (1*) and 5% (unclassified). The research at that time was in Artificial Intelligence with 10 PhD completions and a small amount of external income generation (£23,469). Under UoA37, 3 staff were submitted and judged as 20% (3*), 40% (2*), 25 (1*) and 15% (unclassified). The research was through the ICT in Education Research Group (see below). There were no PhD completions under this UoA although the research group did have a reasonable amount of external income generation (£216,965) from UK and EU government bodies. The research in the ICTE group investigated the use of advanced technologies within education and training and organisations. Since then, significant progress has been made in developing the research environment through increases in staff participation in Research/KE, income generated and in the number of students supervised/completed.

*Centre for ICT in Education (ICTE)*

ICTE is a multidisciplinary research centre consisting of staff from computing, psychology, social sciences, education and mathematics. The Centre has wide ranging research interests spanning the use of advanced technologies in all sectors of education and training. Since 2008, when the focus was on identifying the potential for advanced technologies in education and training, the Centre has focussed on the application of games technology and, more generally, Web2.0 technologies for learning. The group have considerable experience in the design, construction and evaluation (both technical and educational) of advanced online learning environments. Notably, the group helped construct the FP7 Network of Excellence in Serious Games (http://www.galanoe.eu/) and lead the EU Network on Web2.0, Ed2.0Work, (http://www.ed20work.eu). The Centre has also led a further 7 EU-funded projects and partnered in another 6 EU-funded projects since the last RAE. The Centre led by Professor Connolly has 10 research and KE active academic staff, 2 Research Fellows, 1 research assistant (+1 vacancy), 26 PhD students and has had 5 PhD completions in the period. The value of projects that ICTE has coordinated/partnered is in excess of £8.5m since RAE 2008.

*Centre for Interactive Creative Technologies*

The Centre for Interactive Creative Technologies covers several disciplines, principally those of 1) Interactive Systems development and 2) Ambisonics, Spatial Sound and Sensors and Acoustics. The first group covers design, development and evaluation of innovative and sophisticated cross-platform web and mobile systems, novel mobile transaction protocols, 3D visualisation, embedded systems, QoS and the social and cultural issues associated with web/mobile systems. The second group examines the application of Ambisonics and spatial sound for reproduction. The research focus also provides a mechanism to engage with both large and small organisations at national and international level in joint research across a broad range of mutually beneficial research areas. The most recent links involve a joint collaboration between the BBC (Scotland) and the Institute of Hearing Research (Glasgow Royal Infirmary). The Centre, led by Professor Connolly, is multidisciplinary with 8 research and KE active academic staff covering computing, engineering and science, 1 research assistant and 17 MPhil/PhD students.

*Audio-Visual Communications and Networks (AVCN)*

The AVCN Centre, led by Professor Christos Grecos, contains 3 professors and 1 lecturer and has established considerable national and international expertise in the areas of visual communications and networks. These areas have been significantly strengthened by the recruitment of 5 research active lecturers. In addition, a professor in Intelligent systems will start in December 2013 to complement the existing expertise of the centre. A key part of the AVCN research strategy is to

become an active contributor to the prestigious Video Quality Expert group (VQEG) http://www.its.bldrdoc.gov/vqeg/vqeg-home.aspx. AVCN already co-leads the working group in Ultra High Definition Television (UHDT) in VQEG through a newly appointed member of staff**.** Such standardisation activities provide not only high visibility to the Institute but also to the University worldwide. Another part of the AVCN research strategy is to leverage its capabilities in the areas of expertise through the use of the Archie-West High Performance Computing (HPC) infrastructure as described later. AVCN has 9 research and KE active academic staff, 1 post doctoral research assistant and 17 PhD researchers.

*Database and Knowledge Management Group*

The main research in this group relates to the information content of data (information bearing capability, inclusion relationships) and its relationship with ontology, semantics, and social networks. Practical applications of this work have led to the development of an experimental SQL-based database management system (Pyrrho), some of whose unusual features have been taken up by international community (e.g. DBTech VET). This work has also been applied to semantic interoperability between Web services and databases, schema transformation, database theories and systems integration. On the knowledge management side, the group studies support mechanisms for knowledge management processes such as business intelligence and virtual communities of excellence. The group, led by Professor Crowe, currently has 5 research and KE active academic staff, 1 research assistant and 17 research students.

*Scottish Centre for Emerging Technologies (SCET)*

SCET underpins the Institute's activities in Knowledge Exchange and focuses on facilitating co-operation with industry. Initially supported by Scottish Government and Scottish Enterprise with over £1million in grant funding, SCET is now self-sustaining and establishes R&D projects for research staff in the Institute. Since 2008, SCET has carried out over 175 projects with companies, which have helped to create almost 500 jobs and safeguarded a further 940 jobs, and has increased company R&D by over £4.6m and company turnover by over £80m.

**c. People, including:**

**i. Staffing strategy and staff development**

The Research Institute operates a focused research strategy, concentrating its efforts on a selected number of areas of strength, though allowing for growth and responsiveness. In the last few years, external income has allowed the ICTE research centre to grow and this has been supported with investment from the University through new staff and studentships. Significant University investment has seen the establishment of the AVCN research centre in staff and studentships. The Interactive Creative Technologies research centre and the Database and Knowledge Management Group have had a more embryonic growth internally, supported by the University through the provision of one lectureship and several studentships.

**Career development support**

The University recognises the critical importance of recruiting and retaining high quality staff in order to meet its strategic objectives and achieve its goals. The appointment of staff is essentially an investment decision with long term implications for the future of the University and its continued growth and success. The University values and recognises the benefits of a diverse and multicultural community and is committed to equality of opportunity for all staff. Flexible and part-time working is supported. The University has an annual cycle of promotion to the posts of Senior Lecturer, Reader and Professor for staff able to demonstrate the required level of contribution and achievement in the areas of learning and teaching, research and KE, as well as the wider mission of the University.

The University operates a system of activity planning for all staff annually, allocating time and resources to research and KE, teaching and administration. Staff who are research and KE active are allocated a higher research and KE proportion to assist them in development of their research and KE capabilities. Research is supported financially through funds made available through the School of Computing and the ICTAC Research Institute and allocated through the research groups described above. These funds support equipment, RAs, conference attendance, doctoral research students working with staff, and there is seedcorn money to assist in the development of research proposals that may then be submitted for external funding. Some staff have benefited from

financial support to buy teaching relief to help them complete research projects and papers.

**Implementation of the Concordat to Support the Career Development of Researchers**
All researchers, whether staff or students, benefit from the University's commitment to the Concordat for Researcher Education. Early career research staff (ECRs) are nurtured through the Research Institute, and can access a range of support measures:

- Enrolment onto the PGCert in Research Supervision to develop supervisory capacity
- Mentoring to support academic publishing or grant application
- Peer review of all grant applications
- Access to the research training programme including credit bearing modules in Research Methods and a wide range of short courses
- Access to conference attendance funds and research development funds via the Research Institute
- Dedicated Early Career Research Development and Knowledge Exchange Development programmes with on-going after-care and peer support for staff development
- Tailored grant assistance including support to identify funders and dedicated support through First Grant Schemes.

As discussed below, the Institute strongly supports the University policies for equality and diversity. Since RAE 2008, several international staff have been recruited from Algeria, China (3 academics and 1 RA), Greece, Iran, Malaysia, Nepal, Pakistan (2 academics) and Spain (2 academics). The Institute has also had a number of visiting scholars from overseas (eg. University of Lagos, Nigeria; University of Texas in Dallas; Universidad Nacional de San Martín in Argentina; Sukhothai Thammathirat University, Thailand; Cracow University of Economics, Poland; University of Gaza; University of Wroclaw; Belarusian-Russian University; Beijing Union University, China; Donghua University, China) and in addition a number of staff have acted as visiting professors overseas (eg. Bangkok University, Thailand; Cape Peninsula University, Cape Town; University Henry Poincare, France; University of Tun Hussein Onn, Malaysia; Belarusian State University; Brest State Technical University; Donghua University, Shanghai, China; Beijing Union University, China).

**Equality and Diversity**
We are proud of our tradition of committing ourselves to the widening of access to HE from all sectors of the community and of our record in attracting students from under represented socio-economic backgrounds. The University wishes to build on its existing reputation as an inclusive institution and ensure that it extends its commitment to all, regardless of age, disability, gender identity, pregnancy and maternity, marital status, race, religion or belief, sex or sexual orientation, across all areas of student, staff, campus and community activity. The University works to promote understanding and integration between groups of different backgrounds and beliefs and will not tolerate any exclusion, harassment or victimisation of students or staff. This means tackling discrimination and prejudice where they are found to exist in the University and tackling the systems, behaviour and attitudes that cause or sustain them.

The Athena SWAN Charter (launched in 2005) promotes the representation of women in science, engineering and technology and recognises commitment to advancing women's careers in science, technology, engineering, maths and medicine (STEMM). UWS has committed to achieving Athena SWAN accreditation by the end of 2014.

The University has a policy to carry out an EIA on policies and actions to assess systematically the likely (or actual) effects on people with respect to disability, gender, racial equality and wider equality areas. This includes looking for opportunities to promote equality that may have previously been missed or could be better used, as well as negative or adverse impacts that can be removed or mitigated, where possible.

**ii. Research students**
The research strategy following 2008 was to have at least one PhD completion per submitted staff member by 2014. At the end of July 2013, staff in UoA11 have supervised 23 doctoral students to completion, of which 17 have been at UWS and 6 by the newly appointed professors at their previous institutions prior to joining UWS. Since then, there have been a further 2 doctoral completions.

Another part of the strategy was to encourage each research active member of staff to have at

least two PhD students. The University has significantly expanded the numbers of research students through a system of University studentships. Staff are encouraged to develop proposals for PhD topics that are then ranked in terms of their "fit" with the University's main research themes and UoA entries, and are subsequently advertised. The University studentships include the payment of fees and the provision of an annual stipend, supplemented by income from part-time teaching. In some instances, stipends have been supplemented by external income. The number of doctoral students has risen over the REF period and, within UoA11, staff currently supervise 77 doctoral students.

**Training and support mechanisms**

In 2012/13 a cross-University Graduate School was established to increase engagement with and between students, to improve opportunities to engage in credit bearing educational development, and to drive forward an agenda of engagement with other Graduate Schools across Scotland and beyond.

PGR students undergo research training, are supported by an experienced supervisory team, and are normally provided with their own desk, computer etc. There is a Research Students' Society, providing mutual support. Students complete a Transfer Event (with an independent assessor) to move from MPhil to PhD registration, and there are annual Research Conferences, at which students present their work either through an oral presentation or a poster display. Within UoA11, research students also lead seminar presentations within the School. All students have access to a guaranteed fund of at least £1,000 to support development, including conference attendance, regardless of their funder arrangements, and many will have additional funds in addition to this minimum. PGR students also have access to Scottish Informatics and Computer Science Alliance (SICSA) events and 35 students attended the SICSA PhD conference in the last 3 years.

**Progress monitoring**

UWS has an approved system for monitoring research student progression. The system aims to ensure that any potential problems/specific needs the student might have are highlighted at an early stage. It encourages students to reflect on their progress and to meet their targets, thus supporting successful completion. Reports must be submitted for all students (all reports are completed by the student and Director of Studies) at the 12 week, 6 month and 12 month points and annually thereafter. Students are appointed an assessor at the commencement of their studies. The assessor has oversight of the student's progress and discusses this with them at an annual panel meeting. All students have an annual panel meeting attended by the supervisory team as well as the assessor. Following the meeting, the assessor submits a report to the Graduate School Board confirming the student should progress to the next year of their studies. In the case of students who have exceeded the usual period of study, confirmation is sought instead about the likelihood of thesis submission within the next academic year.

**d. Income, infrastructure and facilities**

The research activities of the AVCN centre have been supported by the new visual communication research lab equipped with state-of-the-art acquisition, processing and visualisation platforms, cameras for remote monitoring, advanced FPGAs and GPU platforms, as well as 3D Full HD visualisation monitors. The research activities are also supported by two state of the art networking labs equipped with HEVC and SVC video streamers for multi-homed mobile networks, mobile cloud computing, WiMAX/WiFi/Wireless/Mesh and sensor networking platforms, as well as body area networking infrastructure for e-health applications. AVCN has also access to Archie-West, the regional Tier-2 High Performance Computing (HPC) centre for the West of Scotland, established in 2012 through the EPSRC e-infrastructure funding call.

**Research funding portfolio, including future plans**

Prof. Connolly has been principal investigator with over £4m worth of income generation and over £10m with other projects included. Since RAE2008, he has run 10 European-funded projects, 10 SCORE/KTP projects and has secured £1m+ from the Scottish Government/Scottish Enterprise for the Scottish Centre for Enabling Technologies and other research projects (eg. Wellcome Trust, Scottish Social Services Council, Celestica).

ICTAC continues to seek national and international funding and is developing a strategy for Horizon2020. The institute is a member of two Innovation Centres (ICs) - the Digital Health Institute (DHI) and the newly announced "Data Lab" on big data – enabling it to identify additional funding

opportunities. All envisaged projects will be enablers for new collaborations with industry, public sector and universities in the areas of expertise. Such projects will also provide necessary extensions to our infrastructure base for practicing "research at large". They will further offer training and help develop the local and wider ecosystems so that all stakeholders can benefit from the latest wave of technologies. The innovation opportunities will create societal and economic benefits in Scotland and, more generally, worldwide.

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

ICTAC has established a significant number of other collaborations (200+) through its portfolio of funded national and international projects. The institute is also a member of SICSA, a collaboration of Scottish Universities whose goal is to develop and extend Scotland's position as a world leader in Informatics and Computer Science research and education. SICSA achieves this by working cooperatively rather than competitively, by providing mutual support and sharing facilities, by working closely with industry and government, and by appointing and retaining world-class staff and research students in Scottish Universities. SICSA works closely with companies of all sizes to transfer advanced research to industry and informs researchers of current industrial problems. As noted above, SICSA funding will continue for at least the next few years through the IC "Data Lab". ICTAC has also recently signed a partnership with the Scottish Social Services Council (SSSC) to undertake collaborative R&D in supporting the professional social service workforce in Scotland around connected health. In addition, ICTAC is also represented in the Scottish Imaging Network: A Platform for Scientific Excellence (SINAPSE). Collaboration has been established with the Institute of Hearing Research (joint PhD) and the BBC (Scotland). With both organisations, a current project assessing the possibility of different broadcast audio streams to help the hearing impaired has been started. This is supported by an RA through the Research Institute.

ICTAC enjoys strong links with 3 Fachhochschules in Germany (HDM Stuttgart, HAW-Hamburg and Reutlingen) and engages with a range of collaborative activities resulting in joint PhD supervisions, joint publications and inter- and cross-disciplinary engagement. AVCN collaborates with Ghent University in Belgium in distributed video coding and through the Video Quality Experts Group (described above). In addition, Dr Sergio Goma (senior manager in the Multimedia Division in Qualcomm, San Diego) helps shape AVCN work in 3D imaging (algorithms and hardware) and in video coding standards (streaming for the H264 and the High Efficiency Video Coding standard). AVCN has joint publications with Dr Goma and Qualcomm were a co-investigator in Dr Q. Wang's EPSRC project in video streaming where they provided funding in kind, as well as technical expertise. In addition, AVCN is collaborating with Beijing Union University (BUU) to investigate novel mechanisms to meet the quality of service (QoS) and user experience (QoE) requirements of delivering time-sensitive/constrained applications over computer clouds. AVCN has also established solid collaboration with the University of Texas in Dallas through Prof. Nasser Kehtarnavaz (FSPIE, FIEEE and Honorary Professor at UWS), who contributes regularly to the centre's research strategy. Prof. Amira is associated with a project from NPRP-QATAR (US$970K) with two IEEE Fellows internationally recognised in their fields: Prof. Sawan (École Polytechnique de Montréal) and Prof. Bermak (Hong Kong University of Science and Technology). Prof. Amira and his team are investigating new pattern recognition algorithms for gas data analysis and processing.

**Support for and exemplars of interdisciplinary research**

It is recognised in UoA11 that some breakthroughs in science take place at the boundaries of disciplines. While mono-disciplinary studies will continue to play an important role, the solution to many of today's complex problems must be addressed using a multi-disciplinary approach. This is particularly true in the ICTE research group that takes a multi-disciplinary approach to investigating the boundaries between advanced interactive and collaborative technologies (such as games and Web2.0) and education, training and organisational learning. The group consists of researchers from computing, psychology, social sciences, education and mathematics. The group also collaborates with a vast number of researchers internationally from multiple disciplines. One example is the FP7 Network of Excellence in Serious Games (Gala) with 31 partner organisations that takes an interdisciplinary approach to integrating and harmonising the research in serious games across Europe. A second example would be the EU Network in the use of Web2.0 in education, training and the workplace, Ed2.0Work, with 11 partner institutions and 14 associate

members.

The FP7 Gala NoE has a Joint Programme of Work (JPA) with the 31 partners and external associate members and a wide range of stakeholders to harmonise the research across Europe in serious games. The JPA involves collaborative research activities to address some of the grand challenges in the field. Engagement with industry and stakeholders informs the research undertaken and is a key component of the sustainability strategy to support business exploitation and technology transfer.

After demonstrating an indoor location technology to members of staff at Morriston Hospital in Swansea, Dr John Dingley and Dr David Williams approached Prof. Wang to discuss the possibility of using wireless technology to help monitor and cure joint problems. This inspired Prof. Wang's team to apply a precise localisation technique by inertial sensors and body area networking technology to coordinate the acquisition and presentation of the data. A prototype wireless goniometer was then developed to be used by the doctors in hospitals.

**Wider Contributions**

Many staff have external roles outside the University, sitting on programme committees and advisory boards, chairing sessions and giving invited talks. Some exemplars are:

- **Prof. Connolly** is Conference Director for the European Conference in Games-based Learning (ECGBL), which has been running for 7 years now. He is also Director of ICTAC and the Scottish Centre for Enabling Technologies (SCET) with an advisory board comprising major organisations such as Scottish Government, Scottish Enterprise, BBC, STV, Channel 4. Member of CPHC. He is an expert evaluator for Dutch and Portuguese research councils and for FP6/FP7.
- **Prof. Grecos**, SM SPIE, SM IEEE, has been in the EPSRC College for 10 years and invited to ICT panels (July 2011). Vice Chairman of IEEE UKRI GOLD and steering group member for ARCHIE-WEST (HPC centre).Expert evaluator of research grants (Greek ministry of education, Belgian Research Councils). Session chair twice for the SPIE Electronic Imaging conference. Technical committees in IEEE Real Time Systems and Multimedia Computing. Invited presentations in 1 ACM and 3 SPIE conferences. Guest editor for 2 special issues in JRTIP (Springer) and Phd examiner for Ghent University (Belgium).
- **Prof. Amira**, FIET, FHEA, SMIEE, SMACM: Tutorial at ICIP 2009, and keynote speaker at ICCV2009 (ECVW), Chair of ECVW 2011, Program Chair of ECVW2010, Program Co-Chair of ICM12, DELTA 2008. He has been an external examiner for many Universities in UK, Hong Kong, Australia and Malaysia. Guest editor for the Special Issue in the Pattern Recognition Journal, titled "Feature Generation and Machine Learning for Robust Multimodal Biometrics", March 2008. Expert reviewer for QNRF, EPSRC, and Czech Science Foundation.
- **Prof. X Wang**, a board member of BSI in ICT, Electronics and Healthcare and an external expert adviser for the National Assembly for Wales. He is an invited keynote speaker for DICE-CONNECT 2013 and Wireless Signal Processing and Networking Workshop: Emerging Wireless Technologies (2013).

Editorships include: JRTIP (Grecos, associate editor), Network Protocols and Algorithms (Prof. Wang, associate editor), Journal of IT in Education (JITE) (Connolly, editor), Recent Patents on Telecommunications (Qi Wang, regional editor), VQEG eLetter (Ramzan, editor in chief), Computers & Electrical Engineering and Journal of Advances in Network and Communications (Calero, associate editor).

Awards include: VARIAN Prize by Swiss Society of Radiobiology and Medical Physics (SGSMP) for the best paper impacting Radiation Oncology, Best Paper Award in UK-MEC 2010 Conference (Amira); Best paper award in IEEE ICCE 2012 (Grecos/Qi Wang); 10th International Conference on Mobile and Ubiquitous Multimedia in 2011 (Prof. Wang); accesit award in Primary Health Care research from the Castilla y León regional government in 2011 (Casaseca).

ICTAC staff have been involved in 50+ TPC/IPC/SCs including BIOCAS, AHS, DASIP, ICM, IDT, ISSPA, WOSSPA, ECVW, ICMIS, BAGS, ICIP, ICC, EUVIP, ICME, ISSPIT, ICCVE, EUSIPCO, ACM SAC and ECGBL conferences.