Institution: University of the West of England, Bristol

Unit of Assessment: 15 General Engineering

a. Overview

Staff in the Unit are situated in the **Department of Engineering Design & Mathematics**, and conduct theoretically informed, applied research that is collaborative and inter-disciplinary. The Unit principally comprises three research teams that have complementary expertise and facilities: 1) the **Centre for Machine Vision** (CMV) which addresses practical surface and object analysis using optical methods; 2) the **Institute of Bio-sensing Technology** (IBST) which addresses sensors and instrumentation in biological contexts; and 3) the more recently formed **Engineering Modelling and Simulation Group** (EMSG) which addresses control systems, data analysis, mathematical modelling and simulation of complex systems.

There has been **significant growth** in research and Unit staffing in the six years since 2008 when a single group (Engineering and Medical Technology - EMT) incorporating the emerging activity of IBST and CMV, was submitted to RAE 2008. The IBST and CMV are now strong in their own right – superseding and replacing the existence of EMT - while EMSG has grown rapidly with the recruitment of new staff.

b. Research strategy

UWE's vision is to have an outstanding reputation for its **user-led** research applicable to real world problems and to conduct world-class research in **identified areas of strength**. Responding to this, the Unit's own vision is to deliver high-quality **interdisciplinary** research that meets the needs of industry and society – especially, but not exclusively, in relation to applications addressing **health and detection/diagnosis**. This is achieved by maintaining a vibrant research culture that encourages extensive **cooperation** within the Unit and with other UWE researchers whilst ensuring that researchers are **outward looking**, collaborative nationally and internationally, and **responsive to opportunities**, particularly in terms of **engagement with industry**.

The Unit's RAE 2008 strategy sought to increase **industrial collaboration** across important business sectors and thereby advance research of applied relevance. This has been achieved with some notable successes and a more than **doubling of average annual income compared to the RAE 2008 submission**. For example, IBST has generated **new opportunities** not just for itself but also for CMV, EMSG and other researchers across UWE. The number of **business partners** has increased from 50 in 2008 to 210 in 2013, providing fruitful collaborations that have led to funded research and development projects valued in excess of £9M across UWE since IBST's launch in 2008.

Major technological advances in the Unit have arisen from the strategy, with significant contributions to engineering science at a **fundamental** level carried out, importantly, in an **applied context**. Advances since 2008 include:

- **Moving 3D face data capture**. **Smith M** from CMV has advanced photometric stereo techniques for medical application. He has pioneered a low-cost technology to allow high-resolution moving data to be captured from the human face. This has led on to developing photometric stereo analysis (in collaboration with Bristol University) aimed at revealing signature traits in depressed patients. Diversification into intelligent security has also resulted in partnership with surveillance technology company Aralia Systems Ltd and supporting TSB funding.
- **An ultra-high-resolution skin-imaging device**. This technology, developed by **Smith L** in the CMV, was the first to correlate topological and surface pattern data from pigmented lesions in vivo. Data modelling has been used to identify a correlation between disruption in surface skin line patterns and the presence of malignant melanoma. This assistive technology for cancer detection has been deployed within the North Bristol NHS Trust, and utilised by the National Cancer Research Institute.

- **A novel high-sensitivity low-noise electrochemical measurement system for metal ions in complex biological matrices**. People with metal-on-metal joint replacements risk leakage of metal ions into their bloodstreams and tissue. Research led by **Kiely** from IBST has developed rapid measurement techniques able to provide regular in-clinic patient assessment and early detection of leakage. Johnson & Johnson have supported this via a TSB grant with direct follow-on industrial funding.
- **An electro-acupuncture instrument system, with skin impedance detection**. **Zhu** from the EMSG team has headed this multidisciplinary research which has led to a new concept of "acupuncture engineering", using electrical, mechanical, and computing engineering, and bio-physics methodologies. Acupuncture research is immature and needs more rigorous evidence-based engineering approaches.

The Unit's forward strategy builds upon its achievements over the period and takes its lead from UWE's **Research with Impact priority** in its 2020 Strategy - "aiming for world-class performance, in selected areas of research that meets the needs of a sustainable economy and society".

Thus the Unit aims to:

- further **strengthen interaction with industry** and form partnerships with end-users, recognising that knowledge exchange motivates research, leading to new collaborative projects and the commercialisation of research;
- **consolidate** the Unit's expanded **staff base** and ensure that the synergies between the talents of more recently appointed staff, alongside more established staff, are recognised, supported and developed thereby enabling new collaborations and avenues of scientific advance to evolve; and
- more strongly **integrate research with teaching** to inspire and inform students as STEM subject popularity increases leading on to new intakes at PhD level and, over time, extending the Unit's network of external connections and prospects for collaboration.

The technical focus of the Unit's research up to 2020 will be driven by intellectual challenges and real-world problems in key areas related to the 3 research teams:

- **Centre for Machine Vision** (**Smith M**, **Smith L**, **Atkinson, Sun**) - innovation in 3D and 4D (moving 3D) imaging technologies and advanced modelling for application in medical diagnostics, metrology and person biometrics;
- **Institute of Bio-sensing Technology** (**Kiely**, **Cox**, **Monekosso**) - development of new techniques for bio-sensing and signal analysis which permit sensitive and rapid measurement using robust, inexpensive and easy-to-use technology, for point-of-care/test applications; and
- **Engineering Modelling and Simulation Group** (**Yao**, **Clark**, **Zhu**, **Sendova-Franks**, **Narayan**, **Cardoso, Adetoro**) - complex engineering system modelling and simulation, including fluid flow, heat transfer, energy and environment, combustion modelling, material process modelling, together with structure analysis, flight simulation, complex system modelling and engineering operational research.

The **EMSG** (formally recognised within the Unit from 2012) in particular with its combination of established and more recently appointed staff will be achieving some convergence between the technical areas it currently covers as synergies and internal collaborations are identified. All three groups have strong **cross-linkages** within the Unit and with other staff across the University; for example, **IBST** is a formal collaboration with the Faculty of Health and Applied Sciences with whom the EMSG team also carries out interdisciplinary research. The Unit works closely with other staff in UoA 11 – for example **CMV** is now co-located and directly associated with the Bristol Robotics Laboratory whose teams are also diversifying into areas of medical application.

c. People, including:

i. Staffing strategy and staff development

The Unit's **three research teams** are in the Department of Engineering Design and Mathematics whose staffing strategy aligns with the UWE 2020 Strategy by emphasizing **Research with Impact**, quality outputs, and the integration of research with teaching. To this end, **new appointments** have been made in the 3 research teams of academics with a strong research profile, often with industry experience, and with networks of external contacts to foster future collaboration. The marked increase in the size of this Unit's submission compared to RAE2008 reflects an investment strategy of **recruitment** of staff where the benefits of new teaching capacity can be combined with new talent and ambition in research.

A **new professorial position** has been created to provide leadership for the EMSG team (**Yao**), supported by the appointee's background as a design engineer at Shanghai Aircraft Research and Design Institute and **Clark**'s industrial experience and mathematical optimisation expertise. The EMSG has been enhanced by its new staff appointments (including **three early career appointments**), strengthening the following areas: finite element modelling capability and industrial expertise (**Cardoso** joined EMSG from the University of Aveiro); unmanned aerial system and biosensor modelling and design (**Narayan** from Queensland University of Technology); numerical analysis of aerodynamics, aerospace structures, fluid-structure interaction and aerospace manufacturing (**Adetoro** from Queen Mary University of London).

In addition, **two new lectureships** have been created resulting in staff retention and career development for CMV staff and ensuring continuation of CMV capability - e.g. specialism in instrumentation and modelling for biometrics (**Atkinson**). In 2012, a new Associate Professor position (**Monekosso**) was also created to forge a strategic collaboration between IBST and **Bath Institute of Medical Engineering** (BIME). BIME is an Assisted Living charity closely aligned with Bath Royal United Hospital with access to health professionals and end-users.

In support of the objective to strengthen partnerships with industry, **Cox** was appointed at Senior Research Fellow level in IBST to develop collaborative research projects with industry. He brings industrial experience and contacts from his previous position as Technical Leader at QinetiQ.

Career development and support

Early career researchers are recognised as key to ensuring a sustainable research environment in the Unit and are given significant **protected time for research** in their workload beyond that attributable to externally funded projects. Further support includes:

- **mentoring** from the Unit's team leaders and **one-to-one** guidance from the Unit's Associate Head of Department for Research as well as from the Faculty Associate Dean (Research);
- UWE's £1.5m investment over the period in an **early career researchers' grants scheme** in which recipients receive up to £20k per project and access to bespoke development sessions from UWE's Research, Business and Innovation team – awards enable staff to undertake preliminary research, generate quality outputs, forge external collaborations, and **develop proposals for external funding** - the Unit's eligible ECRs in recent years (**Atkinson**, **Narayan**) have been successful in this competitive scheme; and
- enrolment in UWE's **Academic Development Programme** (accredited by the Higher Education Academy) - designed to build an understanding of the structures and mechanisms within which academics operate as researchers, administrators, managers and teachers.

All staff receive an annual **Performance Development Review** which reflects on their personal research and scholarship activities and achievements and establishes plans for future activity and outcomes. Time requirements for research are considered at the level of individual staff to help ensure they have the capacity to progress dissemination of their work and pursue initiatives for new projects and external funding. During the period the Unit has benefited from a major **EPSRC-funded Bridging the Gaps** project called 'HEAT' which aims to facilitate and support new interdisciplinary collaborations across UWE to tackle research challenges in **Health, Environment And Technology**. Young researchers in the Unit have engaged effectively with HEAT securing

funding to support their own research development. For example, a post-doctoral researcher mentored by **Clark** received funding to develop innovative research into the rescheduling of nurse shifts – a key resource management challenge in the NHS.

More broadly, UWE is implementing the **Concordat to Support the Career Development of Researchers** (2008) and operates a University-wide **Researchers' Forum** with training and information events designed to ensure research staff are clear about, and supported in, their career development within UWE.

Equality and diversity

The Unit respects the diversity of staff and students and is proactive about ensuring people are **treated fairly** regardless of age, disability, race, nationality, ethnicity, gender, religion or sexual orientation. UWE is the third highest ranked UK University in the **Stonewall Workplace Equality Index** Top 100 (2013).

The University is a member of the **Athena SWAN Charter** that addresses gender inequalities and seeks to advance women's careers in science, technology, engineering, maths and medicine (STEMM) in higher education. It received its first Athena SWAN Award in September 2013. The Unit has started to actively implement the Charter through, for example, recruitment and promotion. In addition, the **Women Researchers Mentoring Scheme** aims to promote and facilitate professional development for women researchers working at UWE and help them reach senior research roles. The proportion of women in this submission (15%) to REF UoA15 is in line with the overall proportion of women in the Department, and benchmarks favourably with similar departments in the UK.

ii. Research Students

The Unit has a robust approach to the training and **support** of its **postgraduate research** students:

- A UWE **Code of Practice** for Postgraduate Research Study is applied (closely aligned to the QAA Code of Practice).
- During the reporting period, a UWE-wide **Graduate School** has been formed, drawing in the previous Faculty-based Schools with enhanced consistency of approach, training support to students and greater opportunity for **student interaction across disciplines**.
- The **Faculty Research Degree Committee** (RDC) relevant to the Unit (and linked to the Graduate School) monitors and supports the **performance and development** of each research student from application and interview, through initial enrolment, registration and research plan, the progression exam after 10 months, annual monitoring, thesis outline and draft, to the quality of the examining team and the use of **independent chairs** at vivas to ensure fairness and quality.
- The Unit's **Associate Head of Department for Research and Scholarship** offers localised support and advice to research students, and takes action when issues are flagged through the RDC's **monitoring** process and other less formal channels.
- Each research student has the opportunity and requirement to fulfil at least 60 credits' worth of postgraduate **taught courses** in order to benefit from a broad base of relevant training and skills development alongside the specialist expertise required to undertake their doctorate.
- Students facing financial pressures towards the end of their doctoral studies can have access to UWE's **completion bursary scheme**. The Faculty has, during the period, also made awards available to students who successfully pursue high **quality published outputs** with their supervisors – thereby both incentivising and supporting the importance of **dissemination skills** development as part of the doctoral experience.

The National Postgraduate Research Experience Survey (2013) showed **overall student satisfaction** with our Faculty's Research Degree Programmes is 91.9%, compared with 82% nationally. The success of the Unit's research students is evidenced by the award of a number of **prizes** including the following examples. Raphael Wedowski received the best paper award at the

2010 International Conference on High Performance Computing and Simulation for his paper '*High speed, multi-scale tracing of curvilinear features with automated scale selection and enhanced orientation computation*'. Yu Zhou was the winner of the Skin Forum Award 2009 at the 10th Annual Meeting of Skin Forum ('*A new image acquisition system building 3D model of skin*').

d. Income, infrastructure and facilities

Research funding portfolio

The Unit's annual **research funding** has **more than doubled** compared to the 2008 RAE with funding secured from **EPSRC** (8 grants, £2.6m value to UWE), **MRC** (1 grant, £96k value to UWE), **EU** (4 grants, £424k value to UWE), **MoD** (2 grants, £59k value to UWE), **NIHR** (3 grants, £750k value to UWE) and **TSB** as well as industry. There have been particular successes with TSB funding, especially on collaborative projects with industry such as **Knowledge Transfer Partnerships** (20 grants, £2m value to UWE), with a special emphasis on translational funding, as evidenced by several TSB Collaborative R+D grants. This aligns well with the Unit's vision to carry out **research with impact** to meet the needs of industry and society. The following specific research grants (showing value to UWE) help illustrate the nature of the Unit's research portfolio:

- Shape and outline amplification using 2.5D and 3D imaging, Ministry of Defence, **Smith L** (£30k).
- Rapid Diagnostics for Endemic Animal Diseases, Technology Strategy Board, **Kiely** (£490k).
- Industrial extensions to production planning and scheduling, EC FP7, **Clark** (£180k).
- Using 3D facial asymmetry in better diagnosis and treatment of plagiocephaly, MRC, **Smith L** (£96k).
- First Grant Scheme - Skin Reflectance and Face Shape Estimation, EPSRC, **Atkinson** (£102k).
- Medical Electronics, Bath Institute of Medical Engineering (charity), **Cox, Kiely** (£218k).

Infrastructure and facilities

Specialist facilities support key areas of the Unit's experimental research. Key **improvements of the facilities** since 2008 include the following:

- A **new machine vision laboratory** facility was completed in 2011 for the CMV (as part of a £1.6M investment in the Bristol Robotics Laboratory). This laboratory is equipped with a full spectrum of precision optical facilities and soft computation tools, together worth around £1M. These include high-end geometric and optical calibration targets for flexibly implementing a range of photometric stereo experiments, and high-performance graphic processor units for boosting intensive computation and visualisation applications.
- In 2009, an investment of £1.2M refurbished the facilities within the suite of IBST laboratories (used both by staff included in this Unit and by staff the Faculty of Health and Applied Sciences). In 2012, IBST was awarded a £1.8M European grant to create a **Business Technology Centre for Alternative Testing and In-Vitro monitoring**. The Centre comprises 2 well-equipped laboratories: (1) a *cell culture facility* containing incubators, flow-cabinets and other associated equipment for growing and supporting cell cultures; and (2) an *instrumentation laboratory* that will be furnished with test equipment to allow the development and integration of monitoring technology. This development is also supported by the European Centre for Cell Cultures, Strategic Health Authority, Humane Society International, and Gouch and Housego.
- In line with Faculty priorities, £1.1M was invested between 2010 and 2012 in **refurbishment of laboratories and specialist wind-tunnel testing equipment** for the EMSG team.

Excellent University-wide computing provision is complemented by engineering-specific hardware and software, including **high performance computer clusters** and major engineering computing packages. The IT provision is supported at University level with specialist engineering technicians to support engineering-specific software.

e. Collaboration or contribution to the discipline or research base

Industrial collaboration and contribution

The Unit collaborates in a number of ways with key mechanisms being:

- **Major research project partnerships**, e.g. DePuy Ltd, STMicroelectronics, Sarum Biosciences;
- **Public understanding projects** carried out with industrial partners, for example the Bloodhound Supersonic Car project with STP (motor oil), Cosworth (high-performance engineering) and Goodridge (performance fluid transfer systems); and
- **Knowledge Transfer Partnerships**, e.g. Jacarta, Ecotricity, Auger Torque Europe, CFH Total Document Management, Haley Securities, Fans and Blowers Ltd, Bart Ingredients and Seed Developments Ltd.

The Unit is a major partner in the **Bloodhound Supersonic Car** (SSC) project that aims to design, build and run a car to break the World Land Speed Record. Pursuit of this aim is in turn used to explore how to use a highly challenging engineering project to engage, enhance and enrich STEM-based University activities. Its prime objective is to provide academic access to live project-level information including design, test and run data as the project progresses. The **EPSRC** has awarded UWE £1.4m to support Bloodhound SSC activities in engineering design, development and production.

Research **users** have informed the Unit's research strategy and activities both formally and informally. For example, the **Industrial Advisory Board** of the IBST includes representatives from large companies (GE Healthcare, Axis Shield), SMEs (Atlas Genetics, Uniscan) and other bodies (Electronics Sensors Photonics KTN, UK Trade & Industry, both Bristol NHS Trusts). The Board has provided advice and support ranging from topical multidisciplinary research themes/applications and identification of priorities for funding, to opinions on new initiatives offered through the Institute. For example, advice concerning the water-monitoring sector led to new industrial collaborative projects being instigated with SMEs PML Applications Ltd. and Chelsea Technologies Ltd.

Collaboration between CMV (**Smith M** and **Smith L**) and a Consultant Plastic Surgeon has led to new opportunities in imaging for assessment of surgery. Collaboration with **North Bristol NHS Trust** and the Children's Hospital led to innovations in respiratory assessment (and an associated NIHR project 'NORM'). Collaboration with **University Hospitals Bristol Trust** led to application of 3D imaging for monitoring facial anomalies and a resulting NIHR project.

Members of the Unit have been critical in informing strategy outside academia and hold a wide variety of **advisory positions**. For example:

- **Smith L** is a member of **Bristol Child and Adolescent Health** and **Social Care Research Strategy Development Group** and a member of Academic Steering Committee, Laboratory for Integrated Metrology Applications.
- **Smith M** is a member of **Human Identity Management & Biometrics Sector Consultation Group**.
- **Kiely** has informed TSB strategy, via the **Electronics Sensors Photonics KTN**, relating to low power technology.

Academic collaboration and contribution

External academic collaborations are significant to the vitality of the Unit's research environment. Such collaborations are **institutional** in nature but also draw significantly upon relationships and exchanges at the level of **individual** staff.

Through **Zhu** the Unit has had strategic research relationships with **seven universities in China**: Shanghai Jiaotong University, Huazhong University of Science and Technology, Beijing Institute of Technology, Wuhan University of Science and Technology, Hebei University of Science and Technology, China University of Petroleum (Huangdong) and Guangdong University of

Technology. These partners and UWE set up a **Virtual Research Centre in Modelling, Identification and Control** through which the International Conference of Modelling, Identification and Control was successfully organised in 2008, 2011 and 2012. Over 100 research staff exchanges with China have taken place since 2008. The collaboration has generated over 30 joint journal publications and many joint conference publications since its start. Collaborative research projects have been funded by the **Natural Science Foundation of China** (2013 - 2016) and the **China Ministry of Science and Technology** (2012 - 2013).

Kiely has hosted the Laboratory Director of the **Tumor Bank & Genomics** Program and the Chief of the Division of **Lymphoma**, from Hackensack University, USA to work on biomarker discovery research and development of molecular diagnostic and prognostic assays for multiple human cancer types.

The Unit has a long-standing relationship with the Faculty of Engineering of the **University of Porto** (FEUP), Portugal and **three universities in Brazil**: the University of São Paulo, the Federal University of São Carlos, and the São Paulo State University. Within this relationship, **Clark** recently completed his role as the coordinator of a Brazilian-European **3-year 3-nation research project** into ***Industrial Extensions to Production Planning models***, jointly funded by the **Royal Academy of Engineering** and the EC **FP7** programme. The project exchanged research staff between the EU and Brazil with the aim of developing and testing industrial models and optimisation algorithms in production lot sizing, cutting, packing, and scheduling in 6 industries: animal nutrition, beverages, glass, dairy products, textiles and furniture.

The Unit has also been funded by an **EU grant** to create a **Centre for Excellence in Mechatronics** in Croatia. This involved a sustained, strong relationship with the **Polytechnic of Karlovac**, including many supporting visits between the Institutions and the dissemination of research and knowledge from the Unit's academic team to the Polytechnic of Karlovac and its surrounding industrial partners.

Yao is hosting a **Leverhulme Visiting Fellow** from Beihang University, China, for a year, working on a project *'Development of high-speed aerodynamics capability through direct numerical simulation of 3-D shock wave/turbulent boundary layer interactions*'.

Members of the Unit actively contribute to the their fields through **international research dissemination** roles:

- **Clark** is **Editor-in-Chief** of the *Operational Research Society*'s practice-oriented journal *OR Insight*, and a member of the **editorial board** of *Pesquisa Operacional*, the English-language journal of the *Brazilian Operational Research Society*. He also co-edited the *International Journal of Production Research*, **special issue** on *Lot Sizing and Scheduling* (May 2011) and the *Journal of the Operational Research Society*, **special issue** on *Heuristic Optimisation* (2011). He is the 2014 **Panel Chair** to award the annual EURO **Prize** for the Best Paper in the *European Journal of Operational Research*, the flagship journal of EURO – the *Association of European Operational Societies*.
- **Kiely** is **co-founder** and **Scientific Chair** of the *International Conference in Bio-sensing Technology* (conference proceedings are published by Elsevier). She also co-edited a **special issue** on *Bio-sensing Technology* in *Procedia Chemistr*y in 2012.
- **Yao** is member of the **editorial board** *of International Journal of Aviation Technology, Engineering and Management*, and the *Scientific World Journal (Aerospace Engineering).*
- **Zhu** is **Editor/Founder** of *Int. J. of Modelling, Identification and Control,* Editor of *Int. J. of Computer Applications in Technology*, and a member of the **editorial board** of the *Int. J. of Systems Science*. He is also the **co-founder and Chair** of the *International Conference of Modelling, Identification and Control* (conference proceedings published by IEEE).
- **Smith L** is a member of the **editorial board** of *Machines: Machinery and Automation*.
- **Smith M** and **Smith L** organized and **co-chaired** the *International Conference & Exhibition on Biometric Technology*, India, 3-4 Sept 2010 (conference proceedings published by Elsevier). They also co-edited a **special issue** on *3D imaging* in *Computers in Industr*y, vol 64, no. 9, in 2013.