Institution: Sheffield Hallam University

Unit of Assessment: 13 Electrical and Electronic Engineering, Metallurgy and Materials

a. Overview

Sheffield Hallam University's (SHU's), materials, metallurgy and electrical and electronic engineering research operates through the Materials and Engineering Research Institute (MERI). MERI was established in 1990 as an industry focussed, multi-disciplinary research institute. Having established an international reputation with a 5 rating in the 2001 RAE, MERI expanded in 2004 to incorporate a broader range of engineering disciplines and extend its research environment and equipment base. Its operation focuses on delivery of high quality research, research degrees, knowledge transfer (KT) and consultancy. MERI has ~50 research and consultancy staff, ranging from PDRAs to research Professors, 50+ research students, 5 technical staff and 7 professional services staff. Additionally, research active academics from teaching departments undertake their research and research student supervision, through MERI. The list of 32 category A staff submitted here is, then, an amalgam of MERI researchers and academics from teaching departments.

Administratively, MERI is divided into four Research Centres and a Consultancy Centre, each of which comprises a number of research groups. These Centres (and their groups) are:

- The Centre for Automation and Robotics Research (Mobile Machines and Vision Lab, Control and Electronic Engineering)
- The Polymers, Nanocomposites and Modelling Research Centre (Polymers and Nanocomposites, Materials and Fluid Flow Modelling)
- The Structural Materials and Integrity Research Centre (Sol-Gel and Corrosion Technology, Ceramics and Glasses, Infrastructure Management)
- The Thin Films Research Centre (PVD, HIPIMS, Electronic Materials and Sensors)
- Consultancy Centre (Materials Analysis)

b. Research strategy

SHU's corporate research strategy is to prioritise areas of international standing and activities that have a positive impact on economic and social transformation. MERI aligns with these principles by focussing on academic excellence and industrial relevance. It achieves financial sustainability by utilising a broad portfolio of funding streams, and embeds impact by proactively engaging with non-academic partners to give them access to expertise and state-of-the-art equipment.

(i) RAE2008 Research Strategy. In MERI's UoA29 RAE2008 submission, future strategic targets were to: **make new blood appointments**; **increase Post Graduate Research (PGR) student numbers to 40 FTE;** and **grow income by 10% pa.** Furthermore, a commitment was made to **diversify research activity towards five specific topic areas**. To avoid duplication with later sections, progress against these targets is described only in brief here.

New Blood Appointments Three strands have contributed new Category A staff: one appointment at Professorial level (Alderson); five staff developed through/appointed on research/consultancy contracts within MERI (Ansari, Faraji, Purandare, Spencer, Starinieri); and five research-active academic appointments (Bingham, Breikin, Feteira, Kordatos, Sterianou). This third strand has resulted from academic appointments to teaching departments being aligned with MERI's research strengths.

PGR Student Expansion PGR student numbers have *exceeded target*: they have been >50 FTE since 2011. This has been achieved by setting Institute-, and Centre-, recruitment targets, enhancing training for supervisors and students, and upgrading marketing materials. Further, year-on-year strategic investment in joint funded MERI-Industry bursaries has attracted high calibre candidates, whilst raising MERI's profile with funders and applicants. This has led to a sustained increase in competitive funding awards and recruitment levels. Directly invoiced student fee income from industry and international sponsors rose from £165k in 2007/8 to £262k in 2012/13.

Income Research Grants and Contracts (RG&C) income data are reported in **REF4b**. The £2.1m pa average is a significant increase over the £1.2m pa average reported in RAE2008 and *meets the target set*. In addition to this £2.1m pa from RG&C, MERI's other main income streams averaged over 2008-13 are £460k pa from research students, £680k pa from consultancy, KT and licensing and £590k pa from QR. This portfolio of four consistently strong funding streams totalling ~£3.8m pa is a realisation of both the REF2008 income target and MERI's broader sustainability strategy. It represents a 6.5-fold leveraging of QR income.

Diversification The fourth strategic aim identified in RAE2008 was to foster inter-disciplinarity by focussing MERI's research on five topic areas: **Automation and Robotics**; **Materials Systems**; **Performance and Reliability**; **Sustainability and Green Technologies**; and **Healthcare and Bioscience**. This was central to changes implemented in 2009, through which MERI's Research Centres were aligned into the structures presented in **section a**. This led to Automation and Robotics being upgraded to Research Centre status and the rebalancing of materials research activities across the other Centres. Research Centre structures have remained stable since 2009, enabling consistent operation of business and work planning cycles, whilst at the same time promoting a healthy balance of long-, medium-, and short-term research activities.

Automation and Robotics research has developed considerably in the REF period. Research areas include swarm robotics (Alboul 4, Penders 1&2), human-robot interaction (Penders 4), computer vision and automation. Funding success (awards of £2.6m from four EU grants, £456k from EPSRC EP/I028757/1 and £119k from TSB 29600-208318) has enhanced both the quality and the volume of activities. The standing achieved is exemplified by Penders being commissioned by the UK Government as lead author of a 2013 *Foresight Futures* paper on Robotics and becoming Deputy Director of the robotics hub SCentRo http://www.scentro.ac.uk/ .

Materials Systems research has continued to be a core activity. Projects range from fundamental, such as modelling of multicomponent fluid flows (Halliday 2&3) and investigation of metal matrix composites (Hasan 1-4), to applied, such as tribological studies of hard coatings (Luo 1-4, Purandare 1-4, Hovsepian US patent 8,173,248 B2). The profile of activities undertaken has evolved to reflect funding successes and staffing changes. For example, the Corrosion Technology Group has focused more on sol-gels as Wang's developments have secured significant contract income, while work on Ceramics and Glasses has grown substantially with the appointments of Bingham, Feteira and Sterianou.

Performance and Reliability has developed as a research theme within a number of research groups, and has generated innovations with both potential and actual impact. These include: HIPIMS coatings systems to enhance component durability (Hovsepian 1,3&4, Ehiasarian *Innovatial* FP6 project, **REF3b(1)**) which underpin licence-income-winning contracts for cutting-tools, turbine blades and automotive parts; biotic sol-gels for anti-fouling of ship hulls (Greenfield 4); lightweight, low cost, environmentally friendly ceramic materials suitable for body armour and kiln furniture (**REF3b(3)**); anti-corrosion coatings for aluminium (Wang 2) being trialled by aerospace suppliers; auxetic structures capable of endowing composite materials with novel elastic and morphological properties (Alderson 1,2); and cathodic protection systems being used to extend the lifetimes of metal-framed buildings (Mangat 1&2, **REF3b(2)**).

Sustainability and Green Technologies activity has developed with a substantial focus on photovoltaic materials leading to three experimental (Dharmadasa 1-3, Wang 3&4, Ehiasarian EPSRC EP/J011398/1 £330k), and two theoretical (Pereira 4, Cleaver 3), programmes. Additionally two major EU FP6/7 projects (*FlexPakRenew* and *NewGenPak*) have been undertaken with industrial and academic partners to develop sustainable packaging materials (Breen 1, Clegg 4); an international collaboration has devised novel phenol sensors (Hassan 2&3); collaborative vitrification studies have been used to inform immobilisation of sewage sludge ash (Forder 2); and both research (Breikin 1) and KT projects (**REF3a**) have been undertaken to enhance the energy efficiency of industrial processes.

Healthcare and Bioscience research has progressed through a series of interdisciplinary collaborations. These include: modelling of bone tissue engineering (Spencer 4, BBSRC BB/F013744/1 £299k); ellipsometric studies enabling detection of Alzheimer's disease precursors (Nabok 2); the EU FP7 project *NPMimetic* investigating a gel-based approach to vertebral disk repair; work investigating the use of nanoparticles within cancer treatment (Bricklebank 2&3); and research student projects on controlled drug release (Sammon 1, Patent PCT\GB2012\052046). Three further projects have entered clinical trial: novel coatings for hip prostheses (with *Biomet*); a contactless breathing monitoring system; and an acoustic method for bone density assessment (with Sheffield Children's Hospital).

(ii) Research Strategy: 2014 – 2019

Income MERI will maintain financial sustainability by continuing with its portfolio of funding streams: RG&C; research students; and consultancy, KT and licensing. Income will increase by 6% pa across all sources with RG&C exceeding 50% of a £5m pa average total income.

Refurbishment In 2014 and 2015, respectively, MERI will move into newly purpose-built

laboratory and staff/student accommodation. This enlarged and enhanced working environment, funded by £5.5m of SHU Capital Investment, will underpin future strategies in relation to infrastructure / equipment and staff / research students.

Staff As set out in **section c(i)**, SHU has an exceptional record in identifying and nurturing Early Career Researchers (ECRs) and has used this strength to attract increasingly high-quality appointees. MERI will continue to concentrate new-blood appointments at the ECR level and invest in structures and CPD opportunities that develop and reward high-achieving researchers; 20% of the REF2020 submission will be ECRs.

PGR MERI will expand student numbers to over 60 FTE and focus these on areas of highest research quality. Training and skills will be further enhanced and completion rates maintained above RCUK target levels. A diverse portfolio of competitive funding sources will be maintained through, for instance, a continuation of the joint MERI-Industry student bursary scheme.

Diversification Following a successful bid for a £6.9m HEFCE Catalyst Fund award, in 2014 SHU will launch the National Centre of Excellence for Food Engineering. This Centre, which has also secured £3.3m of industrial support, will become fully operational in 2017 and will deliver industry-informed collaborative R&D as well as workforce development activities. The list of topic areas that MERI has developed since RAE2008 will be expanded to include **Food Engineering** to maximise opportunities arising through this Centre, particularly collaborations with its industrial partners.

c. People

(i) Staffing strategy and staff development

MERI's staffing strategy focuses on achieving academically leading and impactful research in a financially sustainable environment. This is realised through strong research groups achieving excellence in their cognate disciplines, but with researchers also encouraged and enabled to engage in interdisciplinary projects. MERI has a simple management structure with a Director sitting above the Centre heads, each of whom line-manages staff in their constituent research groups. Mainstream QR funds are distributed to Research Centres via a formula based on performance against the HEFCE REF weightings for Outputs, Impact and Environment. By devolving QR income to this level of granularity, individuals and research areas are identified for support on the basis of research quality and record of / potential for, income generation. Underpinning developments leading to patents by Wang on sol-gels and Ehiasarian on HIPIMS were both enabled through such support, and led to subsequent research funding (including EP/I028471/1 £131k, Rutherford Appleton Lab £40k) and industrial collaborations/licence agreements, with, for example, *Biomet*, *Crown Packaging*, *Mahle*, and *Socomore*. Individual work-plans are set annually covering research, supervision, KT, consultancy, teaching and admin / management. For several established MERI researchers (Breen, Clegg, Ehiasarian, Hovsepian, Jones, Luo, Penders, Purandare, Sammon, Wang), teaching is consistently below 20% of work plan. The flexibility this provides makes MERI agile to business opportunities and responsive to a range of funding calls (**REF3a(b)**). Research active academic staff are assigned to a research group and Centre and receive work-planned allocations for PGR supervision and, where appropriate, research secondment. For example, ECRs Bingham, Feteira and Spencer have all received teaching remission to promote their independent research.

Whilst MERI is characterised by stability in relation to staffing, a small number of senior staff have departed over the REF period through retirement (Professor Chris Care) or to take up positions elsewhere (Prof Bob Akid to become BP / Royal Academy of Engineering Research Chair at Manchester; Prof Jan Evans-Freeman to become PVC Engineering at Canterbury, New Zealand). Succession planning in respect of these senior roles has largely been achieved through internal promotions recognising and rewarding research achievement. Research Chairs have been awarded to Cleaver, Ehiasarian, Nabok and Penders in the REF period. Consistent with this policy of internal promotion, whilst one new external Professorial appointment has been made (Alderson), eight new-blood appointments have been at ECR level (Ansari, Bingham, Faraji, Feteria, Kordatos, Spencer, Starinieri, Sterianou). Six of these nine new appointees were based outside the UK at some point in their career before joining SHU.

Research career trajectories in UK HEIs are commonly characterised by an unstructured series of "fixed-term contract" positions. However, with its mixed economy of research, supervision, KT and consultancy, MERI has realised a more progressive pattern for its developing researchers. Through the use of open-ended contracts, a culture of capturing and distributing consultancy and KT work, and an expectation that researchers should contribute beyond the confines of their main

projects, MERI has nurtured several staff through this potentially difficult transitional career phase. This consistent implementation of supportive staff development policies over many years is reflected in the histories of Category A staff submitted here: five MERI PhD graduates (Clegg, Ehiasarian, Sammon, Spencer, Wang) now hold permanent posts, with Sammon promoted to Principal Research Fellow and Ehiasarian to Professor in the REF period; four staff (Bricklebank, Cleaver, Halliday, Jones) who joined SHU as ECRs have been promoted to Principal Lecturer, Professor, Reader and Principal Research Fellow, respectively, in the REF period.

Additionally, through research collaborations and KT interventions with industry, and strong engagement with IP issues, MERI has developed the entrepreneurialism of its staff. This is reflected through, for instance, the award of an Industrial Fellowship of the Royal Society 2013-15 to Jones in relation to his *XeraCarb* spin-out (**REF3b(3)**). More broadly, MERI's mixed-economy operation has developed individual researchers by supportively exposing them to real-world projects, team-based working, and regular report writing. Development through movement between roles is also encouraged across SHU and is supported by the institutional approach to vacancy management. Greenfield, for example, moved to a Senior Lecturer post in 2011, having previously been a Senior Research Fellow.

Evidence of SHU's wider record of supporting research career development comes from the VITAE 'Straight Talking' project conducted by Loughborough University (2012). This found SHU researchers' levels of satisfaction with / optimism for, their career to be 79%, significantly higher than the average (56%) across the eight participating HEIs. The project related this finding to SHU having "a far greater proportion of its researchers on open-ended contracts than the other universities"," job security", and "variety of work over time." Similarly in the 2013 VITAE 'Careers in Research Online Survey' (CROS), SHU was found to have an exceptionally high proportion of researchers on permanent contracts: more than two thirds, compared to the post-92 average of one third and an all-HEI average of 20%. This same survey showed SHU researchers to be considerably more experienced than those at other HEIs with regard to: collaborating with external organisations; cross-disciplinary work; managing budgets; project management; grant writing; knowledge exchange; public engagement; teaching; and conference presentations.

SHU works to create an environment that respects the diversity of all stakeholders and enables them to achieve their full potential and to contribute fully to University life. SHU has a gender, race and disability equality scheme which ensures compliance with all relevant legislation. Examples include: a commitment to good practice in employing people with a disability ("Positive about disability"); a Right to Request Flexible working Policy for parents and carers; and institutional (July 2010) and departmental (Engineering and Maths, May 2013) Bronze awards for the Athena SWAN Charter 'Women in Science, Engineering and Technology' recognising SHU's commitment to eliminating gender bias and developing an inclusive culture.

Formally, responsibility for career development is shared between MERI and each researcher and is systematically reviewed within annual appraisal. Professional development is promoted by identification of the training and development needs required to achieve individual objectives and career aspirations, including research-led applications for HEA Fellowship. Staffing policies also provide one-to-one support such as mentoring of ECRs by more senior colleagues in respect of proposal writing, research supervision and development of industrial collaborations. Ansari, Spencer and Starinieri have benefited from this in the REF period.

SHU is committed to the principles of the Researcher Concordat - a valued research and KT workforce is seen as central to maintaining a successful research culture. SHU was awarded the Research Excellence in HR award in 2013 and an action plan is being implemented (http://www.shu.ac.uk/research/researcher-concordat.html) under the oversight of SHU's Research and Innovation committee structure. Key investments in the REF period include: the appointment of a dedicated Researcher Development Advisor; training materials addressing research integrity; and participation in international collaborative projects to develop professional skills for Research Leaders and Research Supervisors. An Academic CPD web portal, gives all researchers access to these resources and also to the VITAE Researcher Development Framework (RDF) Planner.

(ii) Research students

In the 2008-13 period, MERI achieved 58 PhD completions, i.e. ~12 pa, compared with ~8 pa reported in RAE2008. Full time completers have an average time to submission of ~3.7 years. As outlined in **section b(i)**, sustained growth has been achieved in recruitment of competitively funded students. Funders include EPSRC, BBSRC, EU, The Commonwealth, industrial sponsors

(including *Beckers*, *Sandvik*, *Smith and Nephew*, *TDK* and *Unilever*) and international governments/universities (including China, Egypt, Indonesia, Iraq, Libya, Malaysia, Nigeria and Vietnam). As evidenced below, strong student satisfaction has been maintained through both this growth phase and a coincident move to a cohort-based training provision. PGRs contribute well to MERI's research activity: 29 of the 110 submitted outputs have student co-authors.

SHU operates a 'hub and spokes' model for the administration and management of PGR degrees. Within this framework, MERI implements institutional regulations and codes of practice under the auspices of the University Research Degrees sub Committee. PGR operations in MERI are led by a Head of Programme Area (HoPA), responsible for recruitment and progression decisions, supported by a dedicated Research Student Administrator assisted by other members of the MERI professional services team. The professional services team lead maintains an overview of PGR student operations and co-ordinates the allocation and maintenance of facilities such as desks and computers. Admissions are implemented via a pre-offer proforma developed to ensure adherence with all internal and external (i.e. QAA, UKBA, F&CO ATAS) requirements. All applicants are interviewed by their prospective supervisor(s) and an independent experienced academic. Supervision is team-based so ECRs can readily contribute/develop their skills. Each team receives a 6% work-plan allocation and is required to meet SHU criteria relating to supervisory experience, research quality, engagement with update sessions, and supervisory loading (6 FTE max). Supervisor training includes an institutional Research Supervisor Development Programme and research degree examiner workshops. In addition, MERI runs supervisor update sessions to flag procedural changes, promote exchange of good practice, and disseminate feedback from PGR surveys.

Student progress is formally recorded at four stages: Approval, Confirmation, Submission and Completion. Statistical information on these is used to monitor Programme Area performance. The Approval, at month 3 for FT, and 6 for PT, students is assessed by two independent rapporteurs in respect of project themes, methodologies, supervision, training and development needs, research ethics and technical resource requirements. The Confirmation of PhD, at month 12 for FT, and 24 for PT, students is a rigorous, independent assessment of the candidate's ability to succeed at doctoral level. It is based on a ~6000 word report, an oral assessment (usually a viva) and a verification that all research ethics protocols are in place. Final examination arrangements, put in place ~3 months before submission, are reviewed at University level. Criteria to ensure examiners' experience and independence are in line with QAA guidance.

Induction takes place annually at University level and twice a year within MERI. This is supplemented by an electronic resource through a comprehensive and well-maintained Virtual Learning Environment which gives all PGR students access to formal Regulations, the Code of Practice for Research Students and Supervisors, and current versions of progression forms. MERI runs termly PGR staff-student meetings and all students are free to raise issues confidentially with the HoPA. An institution-wide Annual Monitoring and Feedback Exercise of all PGR programmes operates via an on-line questionnaire for students and supervisors. Resultant information and performance indicator statistics feed into the SHU Quality and Standards Profile. SHU also took part in the 2013 HEA Postgraduate Research Experience Survey (PRES). Comparator data from this were excellent, 95% of MERI respondents expressing overall satisfaction with their research degree experience (c.f. 90% for SHU as a whole and 82% for all 122 HEIs taking part). SHU and MERI achieved well above sector-average in all seven of the main scales in PRES, including a 97% score for MERI in respect of Research Skills Development.

MERI has enhanced researcher training provision significantly in the REF period, initially supported by Roberts Fund pump-priming and subsequently sustained by hypothecating a percentage of all fee income towards training. PGR training comprises two elements: technical and broader skills. In line with QAA best practice, MERI promotes individualised training plans for its PGR students. At the Approval stage, technical skills and health and safety training appropriate to the individual research topic are identified. Additionally, each student, in consultation with their supervisors, undertakes a development needs analysis mapped on to the domains of the VITAE RDF. PGRs also have access to teacher training in higher education and, through the RDF Planner and Academic CPD Portal, a series of courses covering topics such as employability skills and IP. MERI has also established a LinkedIn Group for current and former PGR students, through which students can directly interrogate the career pathways of their predecessors. To promote a cohort identity, all of MERI's first year PGR students undertake a common programme of Research

Methods training (research ethics, presentation skills, information retrieval, database development and research paper analysis). Training sessions on data usage and introducing various analytical techniques and instruments are also provided. In May each year, MERI runs a Research Symposium in which all second year PGR's give an oral presentation and all first years present a poster to the whole Institute in a conference-like environment.

d. Income, infrastructure and facilities

(i) Income

In the 2008-13 period, MERI achieved average total external income of £19.4m. As detailed in **REF4b** and **4c**, £10.8m of this (i.e. ~56%) came from Research Grants and Contracts (RG&C), the remainder deriving from three roughly equal contributions: research students; consultancy / KT / licensing; and QR. This diversity of funding streams is central to MERI's financial sustainability. The largest contribution to RG&C was European funding: total income from 18 major EU grants won/delivered in the REF period amounted to £5.3m. Support from Research Councils totalled £2.6m with other government agencies contributing an additional £1.4m. Support for RG&C and student fees also included £945k from international sponsors and £1.1m from industry. MERI's RG&C income performance can also be assessed against the target areas identified in RAE2008 (**section b(i)**). From this perspective, over £2m of RG&C income is associated with each of: Robotics and Automation; and Material Systems and over £1m with each of: Performance and Reliability, Sustainability and Green Technologies; and Healthcare and Bioscience.

Institute-, and Centre-, income targets are set annually and reviewed monthly. Additionally, ongoing income generating activity is monitored through bi-monthly listing and review of bids that are either submitted or in development. Proactive engagement with funding opportunities includes proposals submitted to research councils in responsive mode (e.g. EPSRC grant EP/J011398/1, BBSRC grant BB/F013744/1) and bids against thematic calls (particularly for EU funding and, with commercial partners, to TSB). MERI's strength in securing EU grants demonstrates a long term commitment within all Research Centres, to building multi-partner collaborations. This is enabled by MERI's staffing policy (**section c(i)**) whereby the low teaching loads of key researchers provide the flexibility needed to contribute substantively to proposal development and discussion / negotiation with programme managers. The Institute's significant engagement in consultancy (~150 interactions pa) and licence-earning activities also helps create a culture responsive to enquiries from a range of funders. This entails a very broad range of research engagements with Industry, as set out in **REF3a(b)**. It also ensures strong performance against other demand-driven income opportunities such as applications from funded International PGR students.

(ii) Infrastructure

MERI has a dedicated combined laboratory space and administrative hub. As highlighted in **section b(ii)**, SHU is investing £5.5m on the relocation and complete refurbishment of MERI's laboratories and offices between 2013 and 2015. This will result in enlarged footprints for both laboratory space and staff / PGR student accommodation. It will provide MERI with a purpose built research environment, fully supplied with services and designed to accommodate an evolving equipment base. This significant institutional investment demonstrates SHU's long-term commitment to research in MERI. Further, plans being developed for Capital Investment to house SHU's new National Centre of Excellence for Food Engineering include research facilities.

MERI's staff profile includes five dedicated technical staff. As well as maintaining the equipment base, they ensure good experimental practice through, for instance, providing one-to-one training on analytical equipment, running facility booking systems and reviewing risk analysis and COSHH forms. Coordination between academic and technical staff is achieved through a Lab Management Group and senior technician representation on MERI management committees. Institute-wide fractional academic roles have also been established for research student management, KT Champion, health and safety coordinator and seminar organiser. A programme of weekly seminars is organised each term, mainly of invited external speakers.

Administrative support is provided by MERI's seven-person professional services team, including a dedicated management accountant sub-team. SHU's Research and Innovation Office provides expertise including costing information for funding applications and legal advice for IP and research contract negotiations: REF 3a (b&d). Support for computational and IT facilities is provided by a University-wide service designed to achieve economies of scale. This service is also responsive to bespoke requirements from MERI researchers, such as systems management and upgrade implementation on the materials modelling group's Beowolf cluster.

The main SHU Learning Centre, located adjacent to MERI, integrates high quality academic library information resources in electronic and hardcopy format with excellent IT facilities, enabling students and researchers to obtain at-desk access to a wide range of journals and other materials. 24 hour opening during semester allows convenient access to print and media resources and to study facilities. A fast and effective Document Supply Service obtains items not held in the University's collections. Expert help and training in sourcing and using information resources are provided by Information Specialists. MERI staff post versions of their research outputs on SHURA (SHU Research Archive) the University's "green" open access repository – over 24,000 downloads of MERI outputs have been recorded from SHURA since 2009. SHU has a long-standing research data archive for physical records and is currently developing a comprehensive digital data archive system to comply with EPSRC requirements.

The University Research Ethics Committee (UREC) has established research ethics policies and procedures to ensure good practice and to sustain programmes of excellent and ethical research (http://www.shu.ac.uk/research/ethics/). Where research ethics issues arise, guidance and approval are usually achieved through the Faculty Research Ethics Committee (FREC) on which MERI has representation. UREC reviews and approves all procedures operating within FRECs and runs a series of annual workshops for staff and PGR students involving internal and external facilitators (e.g. Sheffield Teaching Hospitals NHS Foundation Trust). UREC policy is regularly revised to comply with EU and national legislation and standards of good practice. SHU's professional standards policy and training are also concerned with research quality, having the aim of promoting the highest standards of integrity, impartiality and respect for data.

(iii) Facilities

MERI's excellent experimental facilities comprise a range of cutting edge instruments and equipment acquired through planned Capital Investment over an extended period. As a result, the equipment base available to MERI's staff and students significantly exceeds what might be expected for a department of its size. The replacement cost of current facilities is of the order of £10m. MERI also invests significantly in the upkeep of its equipment – in addition to the in-house technical support noted above, MERI has an annual maintenance budget exceeding £100k. Equipment includes:

- Analytical Transmission Electron Microscope (Bricklebank 2, Ehiasarian 3, Hasan 3, Hovsepian 1-4, Luo 1-4, Purandare 1-4, **REF3b(1)**)
- Corrosion analysis (SVET, SKP, Environment-Assisted failure) (Greenfield 3)
- Electrochemistry Suite (Greenfield 1,3&4, Wang 1-4)
- FEI Analytical Scanning Electron Microscope (Breen 1, Greenfield 3, Hasan 1-4, Hovsepian 1-4, Jones 1,3&4, Luo 1,3&4, Purandare 1-4, Wang 1-4, **REF3b(3)**)
- FEI Empyrean Powder X-ray Diffractometer (Breen 2, Clegg 4, Hasan 3&4, Hovsepian 4, Jones 3&4, Luo 1-4, Purandare 4)
- FTIR Spectrophotometer and Imaging FTIR Microscope (Breen 1&2, Clegg 1&2, Sammon 1-4)
- Full metallography suite (Hasan 1-4, Luo 1-4, Wang 3, **REF3b(3)**)
- Hauzer 1000 PVD Coating Rig (Hovsepian 1-4, Luo 1&4, Purandare 1-4, **REF3b(1)**)
- High Performance Computing Hardware - dedicated 260-core Beowolf Cluster with Infiniband backplane upgraded 2013 (Cleaver 1,2&4, Halliday 1-4, Spencer 1-4, **REF3b(4)**)
- Instron Impact Testing Machine and Dartec-Controlled Fatigue Testing Rigs (Jones 1&2)
- Lesker UHV Sputtering Rig (Ehiasarian 2&3, **REF3b(1)**)
- Raman Microscope x 3 (Greenfield 2, Hovsepian 2, Luo 1,3&4, Purandare 2, Sammon 4)
- Spectroscpic Ellipsometer (Hassan 2&4, Nabok 1-4)
- Thermo analytical instrumentation [DSC, DMA, TGMS, TG] (Breen 1&2, Clegg 1&4, Hovsepian 1&4, Purandare 2&3, Sammon 1)
- Tribological Characterisation Equipment (Hovsepian 1-3, Jones 1-4, Luo 1&4, Purandare 2-4)
- Wavelength Dispersive X-ray Fluorescence Spectrometer (Hasan 3)
- Wissel constant acceleration Mossbauer Spectrometer (Bingham 2&3, Forder 1-4,)

Additionally, MERI researchers utilise large test rigs in the Infrastructure Management labs (Mangat 1&2, **REF3b(2)**) and enjoy access to laboratories in Chemistry / Bioscience (Bricklebank 1-4 Nabok 1,2, Greenfield 4, Wang 1). MERI also has extensive robotics and machine vision hardware (Penders 1-4. Alboul 1-4) and makes regular use of SCentRo facilities at University of Sheffield, which are to be enhanced by the 2013 award of £700k through the EPSRC Investment for Capital Equipment programme. Large facilities are used through beam time allocations

(Bingham **REF4c**) and via collaborations (Ehiasarian's work with STFC RAL and CERN).

MERI's equipment base and its usage are reviewed regularly. A long-term 'renew and replace strategy' is achieved through an annual exercise in which a rolling prioritised list is developed by MERI's Director and Research Centre Heads, and submitted to an institutional call for Capitals Investment bids. This enables experimental and infrastructure facilities to be updated in a phased manner. Institutional support through this route has enabled ~£1.6m of expenditure in the REF period. Equipment acquired by this route includes a Secondary Ion Mass Spectrometer (£200k), and Elemental Analysis for the Electron Microscope (£150k). In addition to this annual Capitals process, MERI is also encouraged to make business case bids to the University for specific, strategically important research equipment. In 2010, this approach financed the purchase of a Focused Ion Beam Scanning Electron Microscope (£600k) and in 2014 it will be used to purchase a £1.2m ultra-high-vacuum Cluster 2d Coater facility. These SHU Capitals Investments in the equipment base are all additional to the income figures set out in **section d(i).**

e. Collaboration and contribution to the discipline or research base

MERI researchers are engaged in numerous collaborations; it is only possible to cite illustrative examples here. The standout collaboration is that with the German Fraunhofer-Gesellschaft. In 2010, MERI established, with the Fraunhofer Institute for Surface Engineering (IST), the *Joint Sheffield Hallam University-Fraunhofer IST HIPIMS Research Centre*, the first such Centre in the UK (http://hipims.fraunhofer.de/en/collaboration/). This prestigious, and very productive partnership, has opened up a range of academic and industrial projects (**REF3b(1)**) and further strengthened the status of MERI's HIPIMS activities.

EU Funded Collaborations MERI won/delivered 18 major EU grants in the REF period, for example:

- the FP7 project *NewGenPak* (http://www.newgenpak.eu/ ITN 290098), Project Coordinator Breen, is a €3m, 12 partner Marie Curie Initial Training Network (ITN). Comprising an interdisciplinary team of academic and industrial groups, this ITN is advancing the state of the art in sustainable packaging solutions, whilst developing the skills of a cohort of young researchers in relation to their scientific expertise, technological knowledge and professional aptitude;
- the projects *Guardians* (IST 045269) and *Viewfinder* (IST 045541), Project Coordinator Penders, FP6 funded projects in Urban Search and Rescue Robotics. *Guardians* (budget €3.4m) focused on applying a swarm of robots to directly (in-the-field) support a human firefighter navigating a large smoke-filled indoor space (warehouse). The focus of the *Viewfinder* (budget €3.2m) project was on a remote controlled robot for data gathering, using (stereo) cameras, laser range finders and chemical sensors.

Other International Collaborations Numerous academic partnerships have been achieved through networking funding streams such as the British Council and NATO. For example, Nabok used NATO Science for Peace and Society support to collaborate with groups in Hungary, Italy and Ukraine on DNA Hybridization (Nabok 3) and Mangat hosted a British-Council-funded visitor from IIT Roorkee (India) to develop work on lightweight aggregate concrete. 44 of the 110 submitted outputs are co-authored by international collaborators.

Industrial and Public-Body Collaborations Every research group in MERI has undertaken industry-related research in the REF period. Collaborators range from multinationals (*ANSYS Fluent*, *AstraZeneca*, *Beckers*, *Biomet*, *Bristol-Myers Squibb*, *Cadbury*, *Cargill*, *Chesapeake*, *Crown Packaging*, *Fiat*, *General Electric*, *Gillette*, *Hauzer*, *Hewlett Packard*, *IMERYS*, *IonBond*, *Johnson Matthey*, *Kodak*, *Mahle*, *Mott-MacDonald*, *Nestlé*, *Pilkington*, *RMD Kwikform*, *OC Oerlikon*, *Rolls Royce*, *Sandvik*, *Scott-Bader*, *Smith and Nephew*, *Socomore*, *Straumann*, *TDK*, *Unilever*) through to mid-size firms (*AA Robotics*, *Bumaga BV, Colorobia, C-Probe*, *Firth Rixson*, *Gripple*, *Indestructible Paint*, *Infrastructure Asset Management*, *Laviosa Minerali, Netcomposites*, *Joseph Rhodes*, *Kostal, Panel Systems*, *TEKS*, *Teer Coatings*, *Tinsley Bridge Ltd*, *UTINGAL*, *Ytron*, *ZBD Displays*) and small companies (*APC Composites*, *Aqualabs*, *Critical Pharmaceuticals*, *Fluid Maintenance Solutions*, *Intaview*, *Ionotec*, *IRIS Vernici*, *Liquid Granite, Xeracarb*) Research has also been conducted with a range of public bodies such as arms of the MoD, the US Government, the NHS, the Fire Service, the Natural History Museum and the Assay Office, as well as with major facilities such as CERN, Oak Ridge (USA), NASA and the STFC laboratories. 20 of the 110 submitted outputs are co-authored by industrial collaborators.

Interdisciplinarity A dramatic increase in interdisciplinary research has been achieved within SHU

in the REF period through the EPSRC-funded *Engineering for Life* (EfL) Research Network (EP/H000275; EP/I016473/1 £934k), led by MERI, and the follow-on *IMAGINE* (£250k, SHU funded) programme. The resultant projects have facilitated engagement of researchers from across the career spectrum to build a variety of new collaborations. Seed-corn funding allocated through these programmes initiated a variety of research projects. For example, in *CROWD*, Breen, Bricklebank and Clegg collaborated with colleagues in Biomedical Research to devise systems for controlled release from open wound dressings; and in *What's in my Stuff* Jones worked with a colleague from Art and Design on a PUS project to investigate people's emotional link with 'not the latest version' high technology devices by deconstructing them, analysing their materials content and reconstructing them as artwork and jewellery (**REF3a(b)**).

Refereeing MERI has six EPSRC College members (Alderson, Bricklebank, Cleaver, Dharmadasa, Jones, Sammon) and has contributed to membership of several EPSRC and EU funding panels. MERI staff have also evaluated proposals for numerous international funding agencies (Belgium, Canada, Czech Republic, Denmark, Estonia, Germany, Hungary, Netherlands, Poland, Romania, Switzerland, USA) as well as the Commonwealth Scholarship Commission and the Royal Society University Research Fellowships Panel. All submitted staff act as referees for a wide range of national and international journals, and many have acted as external PhD examiners at Universities in the UK and Internationally.

Conferences and Professional Bodies As well as acting on organising committees of a number of meetings, MERI researchers have run the following research conferences/events:

- International Conference on HIPIMS, run by Ehiasarian in Sheffield (2008, '09, '10 and '12)
- NATO ARW, TERA-MIR, run by Pereira in Turkey (2009 and '12)
- CCP5 Annual Meeting, run by Cleaver in Sheffield (2010)
- European Conference of Organized Films, run by Nabok in Sheffield (2011)
- TAROS Industrial days, run by Penders in Sheffield (2011) and in Oxford (2013)
- RSC Biomaterials Chemistry Group Annual Meeting, run by Sammon in Sheffield (2013)
- Society of Glass Technology Annual Meeting (Basic Sci), run by Bingham in Cambridge (2013)

All staff routinely participate in national and international conferences and many have delivered invited talks at prestigious meetings. For example, in 2013 alone, Cleaver delivered invited / plenary / keynote talks at meetings in: Cambridge (Newton Institute); Maine, USA (Gordon Conf); Mexico (Mol Sim V); Oxford (ICMMES); Slovenia (ESF); and Varanasi, India (CCMB13) as well as seminars in: Boston; Glasgow; Ljubljana; Kent State; Manchester; New Delhi and Sheffield. MERI researchers are also active in many UK and International Professional Bodies and are members of the steering committees of: Academic Forum for Robotics; CCP5; Clay Minerals Society; International Association of Clay Groups, IoP Complex Fluids; IoP Ion Plasma Surface Interactions, Joint European Committee on Plasma Surface Engineering, Mineralogical Society, RSC Biomaterials, RSC MACRO and the Society of Glass Technology Groups. Additionally, Penders is Deputy Director of SCentRo, a hub devised to lead research into human-robot interactions and the impact of robotics on human society (http://www.scentro.ac.uk/)

Prizes MERI researchers have been awarded the following prizes in the REF period:

- **Peter Mark Memorial Award of the American Vacuum Society (2010)** awarded to Ehiasarian in recognition of his seminal contribution to the science and application of HIPIMS. http://www.avs.org/About/Awards-Recognition/Professional-Awards/Peter-Mark-Memorial-Award
- **The Worshipful Company of Armourers and Brasiers Venture Prize (2011)** awarded to Jones and his collaborator Dr Anthony Pick for their spin-out Xeracarb which has develop new lightweight, low cost, environmentally friendly ceramics for use as body armour and kiln furniture. http://www.armourershall.co.uk/venture-prize-winners/
- **The SVC (Society of Vacuum Coaters) Mentor Award (2012)** presented to Ehiasarian in recognition of his "technical contributions to the development and the industrialization of High Power Impulse Magnetron Sputtering (HIPIMS)".
- **Cyril Hilsum Medal of the British Liquid Crystal Society (2012)** awarded to Cleaver, in recognition of notable contributions his research has made to liquid crystal science and technology in the 10 years preceding nomination http://blcs.eng.cam.ac.uk/?page_id=65