Institution: The University of Huddersfield

Unit of Assessment: 15 General Engineering

a. Overview

Engineering is based within the School of Computing and Engineering and along with the Department of Informatics forms the School of Computing and Engineering, one of seven Schools of the University of Huddersfield. Since RAE2008, the Unit has expanded significantly with 37 staff being submitted compared with 10 in 2008. This growth reflects the success of our research strategy, which includes the creation of new research centres and facilities. For example, the UoA now hosts one of the EPSRC Centres for Innovative Manufacturing in Advanced Metrology. All staff being submitted to this UoA belong to one of four research centres, namely:

- The Centre for Precision Technologies (CPT) which hosts the ESPSRC Centre for Innovative Manufacturing in Advanced Metrology. Research in precision engineering and metrology forms the basis of this industrially focussed research centre. The CPT is headed by Professor Liam Blunt and 18 staff in total from this centre have been submitted.
- The Centre for Efficiency and Performance Engineering. Diagnostic engineering, machine performance, preventative maintenance and energy efficiency constitute this group's research. The centre is led by Professor Andrew Ball and 10 staff have been submitted.
- The Institute of Railway Research (IRR) carries out research into the interaction between railway vehicles and track. This understanding of the wheel-rail interface has resulted in the development of a number of tools and techniques which are being used to predict deterioration of railway wheels and rails to control and optimise the vehicle-track interface. This institute is led by Professor Simon Iwnicki and 5 staff in total have been submitted.
- The Systems Engineering Group. The principal research activities within the group currently include the development of measurement techniques/sensors and mathematical models relevant to 'difficult' multiphase flows and optical communications. The group is headed by Professor Gary Lucas and 4 staff from this centre have been submitted.

b. Research strategy

The University Research Strategy 2011-2020 responds to grand challenges in research, and to growing selectivity in research funding, by supporting distinctive concentrations of excellence in user-inspired basic and applied research. Research strategy is coordinated by the University Research Committee (URC) reporting to the Senate. The Co-chairs are Andrew Ball, PVC for Research & Enterprise and Professor of Diagnostic Engineering and Liz Towns-Andrews, Director of Research and Enterprise (R&E) and 3M Professor of Innovation. URC includes representation from the R&E Directorate and from all Schools and has responsibility for coordinating strategic investment, operational planning, external peer review, and benchmarking against national/international exemplars. URC reviews progress against target annually for each subject area and the institution as a whole through a planning and accountability conference.

Consistent with the University Strategy, Engineering aims to be world leading in its four key specialism areas, focusing on the needs of industry and delivering applied research of international quality and impact. The vision for the UoA aligns strongly with the UK Government's Industrial Strategy set out in September 2012, which advocates the development of strategic partnerships with industry in key sectors. The vision supports emerging innovative technologies and knowledge transfer between academia and industry. The UoA has strategic partnerships already established with organisations such as the National Physical Laboratory, the Rail Safety and Standards Board (RSSB), Borg Warner and 3M. Our activities align strongly with priority sectors in the Industrial strategy such as Advanced Manufacturing, Automotive, Aerospace, Energy and Healthcare and we seek to build on new and existing collaborations. The UoA has two industry-sponsored professorial appointments (Taylor Hobson and Precision Technology Group CHIMTII) and two additional support staff dedicated to industrial liaison, industry research brokering/management and development of Knowledge Transfer Partnerships (KTP). KTPs have provided a sustainable backbone to the research activity and over the REF period seven KTPs have been established. In addition, four key patent applications have been filed.

The future strategy for the UoA recognises the emerging challenges for the discipline. In particular, real time and in-situ measurements, imaging and visualisation and remote sensing – all of which ultimately lead to the grand challenge associated with 'Big Data' management. A business report in the *MIT Technology Review* in January 2013 clearly identifies 'big data' and the industrial internet as emerging technology for the next generation of businesses in the advanced

manufacturing sector. This has been recognised and endorsed by the UK Government, following the announcement in January 2013 of £600M of investment in 'eight great technologies'.

The 2020 vision for the UoA is to be research intensive and world leading in all areas, and to be a recognised centre of excellence for industrial engagement in our specialism areas. The concept of 'Big Data' management will become a cross-cutting theme which will integrate all aspects of our research. In order to achieve this goal and increase the critical mass of research activity we will continue to build on existing practices adopted since RAE2008. Initiatives will include:

- Consolidation and further investment of time, resource and capital equipment in the four primary research areas described in this submission;
- Identification of fundamental gaps in research capability which are necessary to deliver an integrated programme of research to fulfil the vision. Where necessary, recruitment of fully formed and successful research teams;
- Recruitment of staff will focus on those individuals who demonstrate potential to become research leaders in their field. Existing staff will be mentored by research leaders in the UoA and research aligned with identified centres and institutes linked to the strategic vision;
- Formation of strategic partnerships with other research intensive academic institutions, key industrial partners and research institutions both nationally and internationally;
- Provision of clear and mobile career paths for progression for our best researchers to enable them to assume group leadership roles and ensure succession planning and research continuity into the mid to long term.

To help guide and advise the UoA, an international panel of experts has been established: Prof Isobel Pollock (IMechE President), Prof Albert Weckenman (Nuremberg Erlangen University Germany), Mr Evert Henkes (3M), Dr Sam Beale (formerly Rolls Royce). The Panel meets twice annually to review research strategy, to benchmark our progress against other institutions, and to provide strategic advice on our research activities.

Since 2008, the UoA vision and strategy has been fundamental in transforming the research output and environment. A clear example of this being the successful award of ~£8M to establish an EPSRC Centre for Innovative Manufacturing - one of only 12 allocated in that funding round. In addition, the UoA has been successful in winning RGF3 funding (£7.6M) in partnership with Borg Warner to establish a research institute in turbocharger engineering and has been selected for RGF4 funding to create a Rail Innovation Centre worth ~£20M, with confirmed commitment of £2.5M from RSSB. The UoA has been no less successful internationally co-ordinating a €7.25M FP7 project NanoMend.

The staff profile across the UoA has changed significantly since 2008 reflecting the focus of the research centres and output levels for research increasing dramatically. Comparative data below demonstrate UoA growth and in the majority of areas we have grown by a factor of ~3.

	2008	**2013**
Number of Research Fellows	9	28
Number of FTE submitted	10	34.8
PhD students (FTE)	42.5	116
Number of research active staff	15	50
RGC research funding (£k)	993	2,320

Expansion over the period is in-line with our strategy to establish a critical mass of research activity in key centres with alignment to industrial challenges and end user needs. Execution of the UoA strategy has led to increased capital and resource investment in the four key research areas through University, School and external funding. State-of-the-art equipment and research infrastructure, has attracted researchers to Engineering at the University of Huddersfield – hence the growth in staff and PGR numbers – and has facilitated strategic partnerships with organisations such as NPL, RSSB and Borg Warner.

In line with the delivery plan, new groups, such as the Institute for Rail Research, have been brought in to the UoA since 2008 and others are planned, particularly where they will address key gaps in future strategy, e.g. areas such as robotics and mechatronics. To demonstrate commitment to the strategy, all staff recruitments since 2008 have been research active appointments able to contribute to research excellence. New individual recruits and those returning to research, are seeded into existing research centres to provide a supportive and productive environment. The School has made significant investment in terms of a new Professors Scheme

(3.3FTE) and a PGR Research Scholarships initiative, as well as recruiting seven research fellows to support the research output. Short term funding gaps for specific staff has been provided by the school and facilitated much needed continuity and succession planning.

The number of national and international collaborations associated with industrial, EU and EPSRC projects has risen sharply such that all research areas have key partnerships with UK and international partners. Further details of the existing centres and institute are provided below:

The Centre for Precision Technologies

Commitment by the University to invest in high profile quality research groups, such as the CPT, has been rewarded by the announcement of £8M EPSRC and industry funding to establish a Centre for Innovative Manufacturing in Advanced Metrology (PI Prof X Jiang). Prestigious centre partners include Rolls Royce, Renishaw, Taylor Hobson and the National Physical Laboratory. The University provided significant funding to support the proposal (~£1M) including resource for staffing costs and the construction of new optics and computer tomography laboratories plus new office/meeting room facilities. The CPT has expanded to 40+ staff and students and is recognised as a leader in its field. The CPT has hosted nine visiting international senior academic researchers, demonstrating the depth of expertise within areal surface metrology, machine tool error compensation and nano-metrology. The CPT has unique facilities which have provided the working environment and focus for research sponsored by numerous external funders:

- EPSRC (4 projects, including the EPSRC Centre and EPSRC Manufacturing Fellowship)
- ERC Advanced Investigator Grant (Prof X Jiang)
- EU (7 projects, including NANOMEND a €7.25M project coordinated by Prof L. Blunt)
- TSB (2 projects) One project in Collaboration with Rolls Royce (as a sub contractor)

CPT research publications are numerous and include high profile journals such as the *Philosophical Transactions of the Royal Society*. Members of the group have given more than 30 invited plenary lectures, keynote addresses at international conferences and the CPT hosted the 12th CIRP Conference on Computer Aided Tolerancing at Huddersfield. Research areas include micro/nanoscale metrology, ultra precision machining and machine tool error compensation.

Engagement with industry and end users is foremost within the CPT and this is demonstrated through the track record of innovation and achievements of the Centre e.g. first demonstrations for many applications in precision engineering. Significant industrial funding for proprietary research has been secured from companies including Taylor Hobson, DePuy Johnson & Johnson, Renishaw, and Rolls Royce. Commercialisation of research outputs is a key deliverable and has led to the development of two leading edge commercial software products which are marketed and sold under licence and are the basis of two of the impact case studies:

- SURFSTAND - new generation surface metrology software sold under licence by Taylor Hobson a world leading metrology company and marketed as Talymap
- VCS - machine tool volumetric error compensation software, under licence to Dapatech Sarl.

In addition, the CPT has led the development of 23 International Standard (ISO) projects in metrology and machine tools. The work of the CPT is highly interdisciplinary and project partnerships bring together disciplines such as printed electronics (NANOMenD), bio-technology (TSB Orthox) and Archaeometrology (Royal Armouries). Industrial projects with companies such as Rolls Royce and Renishaw are testament to their regard for the research (Myers, Ball, Longstaff, Fletcher Bills). Training materials based on our research are now becoming keystone offerings of our collaborators e.g. CMTrain has been adopted by Rolls Royce, HP (USA) Renishaw (UK).

In the future, the CPT will focus research activity in the area of High Added Value Innovative Manufacturing techniques and methodologies aligning strongly with the challenges associated with the Digital Economy agenda. More specifically, the EU FP7 MINAM Roadmap 2012, “Nano-manufacturing” (2008) and the Nanofutures Roadmap2012, highlight a range of micro/nano-manufacturing technologies which are forecast for exploitation in industrial applications in the short to medium term. Design specification, quality and traceable measurement will be critical for innovative product development if this goal is to be achieved. These reports have influenced the strategy and direction of the CPT, concentrating research efforts on i) embedded process measurement for machine tools and roll-to-roll manufacturing ii) development of novel in-process optical measurement systems iii) metrology for biotechnology applications and iv) application of

leading edge measurement systems for application in aerospace manufacturing.

The Centre for Efficiency and Performance Engineering

Prof. Andrew Ball joined the University as Pro-Vice Chancellor for Research and Enterprise, and Professor of Diagnostic Engineering in 2007. Prof. Ball was previously at the University of Manchester, where he established the largest independent maintenance engineering research group (25-strong). On moving to Huddersfield he brought with him a Senior RF, a KTP Associate, 3 PGR students and in excess of £750k of research equipment.

The strategy behind the Centre is based upon a strong industry focus addressing Grand Challenges in Energy (conservation) and the Digital Economy (smart sensors, data handling and remote sensing). Prof Ball's research is predominantly applied, with most of his income coming from industrial sources; including Rolls-Royce Power Engineering, Rolls-Royce Civil Aviation, Teradyne, Power Systems Services, Smart Components, MAN B&W, Compact Instruments and the Chinese Institute of Acoustics. Since arriving at Huddersfield, Prof Ball has established a new research group; Diagnostic Engineering, and work is presently underway to install 300m^2 of specialist laboratory equipment. Within the REF period, Prof Ball has generated in excess of £1M of research grant/contract income, has graduated 26 PhD and EngD students, and has been the primary or co-author of more than 20 quality journal publications.

The Institute for Railway Research

In July 2012 Professor Simon Iwnicki joined the University to establish the Institute of Railway Research (IRR). Professor Iwnicki was joined by his research team of 10 Postdoctoral researchers and two PhD students. This group was formerly the Rail Technology Unit and is recognised internationally for its work on computer modelling of railway vehicle track interaction. The IRR is housed in 200m^2 of self-contained offices and laboratories.

The IRR has outlined its strategy in a five year plan which includes the following key values: ***Research Excellence*** – carrying out research into focused and strategically important railway challenges of the future. ***Industrial Impact*** – supporting the railway industry through the development of innovative tools and solutions to tackle current and emerging engineering requirements. ***Education*** – facilitating the education of current and future railway engineers at all stages of their careers. ***Visibility*** – the work of the IRR will be highly visible to stakeholders in the railway industry, in academia and to the wider public. The IRR will have a clear identity within and outside the University both nationally and internationally.

This strategy for IRR ensures contribution to the current and long-term government and industry lead objectives and challenges, identified for example in the EU White Paper 'A strategy for revitalising the Community's railways' and in the UK, the 'Rail Technical Strategy' and the McNulty 'Rail Value for Money' review. This includes the 4Cs as identified by the Technical Strategy Leadership Group: ***reduced carbon, lower costs, improved communication*** and ***improved customer satisfaction***. The themes will focus on new and future rail operations, including high speed rail and urban mobility.

The research themes identified also support future research opportunities expected under UK and European funding initiatives, such as EPSRC, EU Horizon 2020 and DBIS's Regional Growth Fund. In addition, new collaborations and strategic partnerships will drive the 'blue skies' research opportunities for the Institute, supporting academic goals in terms of PhD completions, publications and impact. The IRR has formed a strategic partnership with the Rail Safety and Standards Board (RSSB) and secured Regional Growth Fund investment to establish a Rail Innovation Centre.

Systems Engineering Group

The Systems Engineering Group is a growing group involved in a diverse range of research combining different engineering disciplines, predominantly electrical and mechanical. The current strategy covers research concerning (i) the imaging of flows for both medical and oilfield applications; (ii) micro wind power generation and the supply of power to networked housing; and (iii) optical inter-satellite communications links. The strategy for the group has mainly focussed around the Grand Challenges of Energy with aspects of Lifelong Health and Wellbeing. The group has strong links with a number of industrial organisations including Schlumberger, Petroleum Development Oman and TUV NEL. Flow measurement and flow imaging research, as applied to the mixed flow of crude oil and debris in production pipelines, has achieved notable funding successes since 2008 including: £252k for 'A Numerical Model for Inclined Oil-Water Flows

(EPSRC) in collaboration with Nottingham and Leeds Universities, £257k for 'Next Generation Visualisation and Metering Technology for Multiphase Flows(EPSRC) in collaboration with Cambridge and Leeds Universities and £133k for 'Multiphase Velocity Profile Measurement using an Induced Electromagnetic Sensor Array' (EPSRC).

In 2010, a successful bid was made to Yorkshire Forward for £80k to develop a commercial prototype for an imaging electromagnetic flow meter to measure flow velocity profiles in single phase and multiphase pipe flows. As a result, patents have been applied for in the EU and USA and the University has recently (2013) licensed the rights to manufacture the device, as part of an oilfield multiphase flow meter, to a UK company backed by Venture Capital. Work on electromagnetic flow measurement is currently being extended to medical applications including the non-invasive monitoring of flow rates in blood vessels, as a means of detecting atherosclerosis in diabetic patients. The Research Group has 20 PhD students and provides lecturing and project support to the MSc course 'Engineering Control Systems and Instrumentation' attracting ~20 overseas students each year.

Immediate plans for the UoA include the establishment of a new automotive research group in turbocharger technologies. This activity is in conjunction with one of our strategic partners, Borg Warner (Bradford), who are funding the £7.6M Centre through Regional Growth Fund and inward investment from its American parent. In addition, with RSSB, we plan to build on the success of the IRR to establish a £20M Rail Innovation Centre. 23 staff will be recruited to the new centre to deliver research and exploitation programmes focusing on the needs of the rail sector.

c. People, including:

i. Staffing strategy and staff development

Staffing Strategy: Over the REF period, the staffing strategy has had two primary aims namely; supporting and further developing the UoA's most successful existing research areas and in parallel the aggressive recruitment of fully-fledged research teams in key complementary research areas. The staffing strategy has been aimed at establishing well-founded research capability based on quality and critical mass and has been achieved through a recruitment and retention process which has allowed for greater depth of capability through staff development and expansion through recruitment. The staff appointment process has been designed to encompass overseas applicants as well as UK and European appointments and nearly all interview lists for positions since 2008 have included overseas applicants. Three key approaches to staff recruitment have been adopted:

Appointment of full time academic staff – an essential criterion of new staff appointments is that individuals must be research active. During interview, the strategy for the UoA is outlined to ascertain alignment of personal research interests to that of the UoA. New academics are assigned a mentor and become part of one of the research centres if appropriate. An induction programme for researchers has been introduced across the University and tailored to the specific requirements of a School or discipline. All new staff receive an induction programme and discuss research objectives with their mentor and/or line-manager – usually their research group leader. Levels of support for new staff vary and depend on the level of appointment. For all staff, a research plan is agreed and reviewed as part of the appraisal process. Ongoing promotion within the institution, to reader and professor, is through an annual scheme based on merit and external peer review - A Myers and R Mishra were promoted to Professor during the REF period.

Appointment of senior academic staff and their research teams – the University has proactively recruited senior academic staff and their teams from outside the Institution. High profile research leaders with strong research records and a critical mass of researchers within their teams has been a priority. This recruitment approach has been supported centrally by the University with funding provided for two years to establish the researcher and their teams. Following the initial two-year period, responsibility passes to the School and to the research teams themselves. Implementation of this strategy has led to the recruitment of Prof S Iwnicki in 2012 and Prof P Scott from industry (Taylor Hobson) in 2010. Prof Scott is now fully integrated into the research activities of the CPT. Prof Andrew Leung an overseas appointment (City University Hong Kong) was recruited in 2012 (Automotive and Diagnostic Engineering). More recently, in 2013, Prof J, Allport has been recruited from industry (Cummins) to lead the new Turbocharger Institute.

Appointment of fixed term senior research fellows - recruitment of fixed term senior research fellows to support strategically important research programmes in the research centres has been an important initiative. In 2012, seven SRF appointments were made and significant funding made available to support all of the REF submitted research fellows beyond 2014. We aim to appoint staff with strong potential to become research leaders of the future. This is essential for succession planning and the UoA is actively securing the long term futures of key research fellows by appointing them as lecturing staff. Since 2008, three early career appointments have been made. (Dr L. Fleming, Dr Paul Bills and Dr H. Martin). In addition in 2013, Drs A. Longstaff and F. Gu have been promoted to Reader and Principal Research Fellow respectively.

The University has made provision for physical expansion of Engineering and in numerous instances – such as the IRR and the Turbocharger Institute – the equipment and facilities offered were a key deciding factor in the successful recruitment of senior academics. We are confident that continued expansion and future strategy can be delivered using these approaches.

Staff Development: The University was granted the HR Excellence in Research Award by the European Commission in September 2011 in recognition of the alignment of our processes and plans with the principles of the Concordat to Support the Career Development of Researchers and with the European Charter for Researchers and Code of Conduct for their Recruitment. Progress in achieving exemplary standards through our action plan is overseen by our Concordat Steering Group, which reports directly to the University's Senior Management Team.

The CROS 2013 (Careers in Research On-line Survey) demonstrated some lack of awareness of national initiatives to support researchers such as Athena Swan, the Concordat and the Researcher Development Framework (RDF). However, the UoA has taken advantage of the initiatives developed institutionally through the Concordat Steering Group action plan and a central Researcher Development Fund. For example; substantial funds for students (£250,000 p.a.) and staff (£300,000 p.a.) have been established to sustain a series of specific schemes that support individual researchers to manage their own development in accordance with the RDF principles. The most popular of these schemes support conference presentation, international networking and collaborations by groups of researchers on initiatives to improve the intellectual climate. The training allowances for acquisition of modern languages and of public engagement skills, supported by the Fund, are also well utilised. Additional funding has been provided to allow researchers to attend training in writing impact statements and to enhance the impact of their research by engaging new user communities. Formal training programmes covering all of the abilities and areas of expertise identified by the RDF are available throughout the academic year to all researchers, from postgraduates to members of the professoriate. These programmes are delivered by internal and external trainers utilising dedicated facilities in our new **£2.6 million Researcher Hub** – a dedicated building with outstanding office and computing facilities for resident and visiting academics. Since 2008, the UoA has hosted 30 international visiting researchers for one month or longer and to facilitate collaborative research programmes, we aim to situate them in the vicinity of the host research group In addition, a JISC funded research information management system ("RIMS") supports research managers with information, analysis and performance management tools. The UoA also has dedicated support staff working alongside central teams to monitor and assist in bid development and grant management.

The staff development programme is continuously updated and ~40 short courses are offered to help develop the skills of academic research staff, research supervisors and PGR students. Courses cover research supervision, research project planning, publishing research etc. Open weekly seminar programmes are offered by the UoA research groups as part of staff and PGR development. Career development for young staff and especially postdoctoral fellows is provided in line with the Concordat. For example, Haydn Martin has recently been appointed to the newly formed EPSRC Early Career Forum in Manufacturing Research. The School has an Equality and Diversity Policy which encompasses research. Examples of policy adoption include:

- Appointment of Dr. L. Fleming as an Engineering representative in the University Athena Swan panel. Dr Fleming is helping coordinate the submission for the institutional Bronze Award. Once the University Award is established we will submit for a departmental Bronze Award;
- Prof J. Jiang's leadership of the EPSRC Centre and our close links with Prof. Isobel Pollock (IMech E) are evidence of our policy operating at senior levels;

- Establishment of a School Ethics Committee ensures no discrimination issues or ethical concerns in the research activity.

Over the period, Prof Jiang attained the accolade of a Fellowship of the Royal Academy of Engineering, and also became a Fellow of the CIRP (College International pour la Recherche en Productique). Prof Paul Scott also received and EPSRC Advanced Fellowship award.

ii. Research student support

Recruitment and progression The UoA has 116 full and part time research students and scores extremely highly for overall experience on the Postgraduate Research Experience Survey (PRES). Since 2008, the number of overseas research students has increased and we have progressively refined admissions and progression criteria to ensure only students capable of completing satisfactorily are accepted and approved beyond the first year. Part-time research students often have jobs related to their research in companies both at home and abroad and are normally expected to spend four to six weeks on site per annum.

Cultural Environment: Each year, research is celebrated and disseminated to all University students, the wider academic community, and business via the annual Research Festival. This is a University-wide event over several days within which the Unit's members give seminars, demonstrations and tours of facilities to promote research. A one day annual Researchers' Conference for research students, their supervisors and sponsors is organised within the School. Students have the opportunity to submit and have reviewed a scholarly paper, to present their work in a conference atmosphere, and the opportunity to showcase their work. Each year there is a Postgraduate Researchers' Day, where students from across the University meet, hear talks from distinguished researchers, and discuss research issues. A weekly seminar series is held by the CPT comprising seminars aimed at internal dissemination and debate of research areas. In 2011, the UoA PGR and academic staff engaged in the delivery and organisation of the EU funded Researchers Night event held at Huddersfield.

Student Pastoral Support and Graduate School: Every PGR student has a supervisory team and a personal tutor to guide them through their studies. There is a University-wide schedule of progression monitoring and to progress from one year to the next PGRs must submit an end of year report and make an oral presentation to an examination panel. Attached to this progression are milestones including the official recording of the Programme of Research; Personal Development Planning and Review; Research Progression Advice and Student Feedback. With both a physical and a virtual presence, the University's Graduate School provides both intellectual and social contact between postgraduate researchers of different disciplines and from different backgrounds and countries. The Graduate School provides training courses, seminars and inter-disciplinary programmes to encourage postgraduate researchers to look beyond the boundaries of their chosen discipline, as well as promoting the sharing and broadening of knowledge across disciplines, through societies and competitions.

Internal Research Awards: To further celebrate research achievement, the School and the University have set up annual research awards, e.g. the Vice-Chancellor's Prize for an Outstanding Doctoral Thesis, and the Vice-Chancellor's Prize of Postgraduate Research Student of the Year. The Graduate School also gives an exceptional output award, to students leading research outputs with high impact. Haydn Martin received the VC's Research Student of the Year in 2010 and is now an early career researcher within the UoA.

Central Support: the Researcher Development Fund offers mechanisms to support students and early career researchers: the **Conference Presentation Fund** facilitates the presentation of papers and posters at conferences of national and international standing; the **Intellectual Climate Fund** supports student-led initiatives to enhance opportunities for learning and research practice and transferable skills alongside and within a community of researchers. The **Research Networking Fund** supports full-time and part-time postgraduate researchers visits to centres of research excellence in the United Kingdom or overseas and, in exceptional circumstances, to support travel for data collection. The **Public Engagement Fund** supports formal training in public engagement to develop communication and research skills in the context of outreach to a variety of

audiences in schools/colleges, third sector organisations and the wider public.

Virtual Environment: a range of software services are available to support researchers: *ePrints,* eprints.hud.ac.uk, is a comprehensive research repository and one-stop shop for research outputs – for example internal personal and research group websites are automatically updated with new publications placed in ePrints. We also maintain a comprehensive intranet-based information system which is the first port of call for researchers when seeking any information.

We aim to provide a world-class environment for researchers and to benchmark our success we employ a series of national and international indicators including: i) excellent UoA PRES performance ii) the International Student Barometer poll by overseas students (in which Huddersfield was voted number one in the world in 2011) iii)THES 2012 Entrepreneurial University of the Year, emphasising collaborative R&D iv) Awards and prizes – e.g., Dr H. Muhamedsalih was awarded a prestigious scholarship from the Worshipful Company of Scientific Instrument Manufacturers based on our partnership with this august body.

d. Income, infrastructure and facilities

Income: The funding portfolio for the UoA runs across seven main providers, namely:

EPSRC: the £8 million EPSRC Centre for Innovative Manufacturing in Advanced Metrology was launched by Business Secretary Dr Vince Cable in 2011 and is a highlight of the UoA in the REF period. In addition, a further 11 EPSRC grants totalling ~£6.1M have been secured.

EU: UoA researchers have been partners in 13 projects worth more than £4M and recently the CPT, as coordinating partner, has secured the NANOMenD project worth **€**7.25M

ERC: Prof. Jiang received an Advanced Investigator award (**€**1.9M) for the SURFUND project.

TSB: Since 2008, 7 successful KTP projects have been funded and valued at over £900k.

Industry: the UoA has secured numerous industrial projects, with partners including DePuy Johnson & Johnson, Rolls Royce, Network Rail, Renishaw and Schlumberger. Total funding from industry is approximately £6.M. A strategic partnership with RSSB was signed in 2013 worth £2.5M

RGF: the UoA has significant track record with regional growth funding and has been involved in three successful applications with David Brown Gears, Borg Warner Systems, and RSSB. In total, the projects are worth >£25M

Commercial Exploitation: A growing pipeline of IP is being generated and funding from the Yorkshire Forward Proof of Concept scheme has been secured to support new commercial opportunities (machine-tool compensation, aerodynamic fuel saving devices, multi-phase flow measurement and smart sensors). Licensing agreements and/or joint ventures have been established to exploit the IP with income during the period equating to ~£250k and due to increase significantly over the next period.

The UoA has been very successful in securing **EU** funding and we aim to build on our track record in Horizon 2020. In particular, we plan to submit a proposal to establish an **Industrial Doctoral Training Centre** to further expand out postgraduate provision. We anticipate greater collaborative R&D with industrial partners and research programmes established through the RGF funded institutes and the EPSRC Centre will naturally lead to increased activity in this area.

Infrastructure and Facilities: Since 2008, the UoA has benefitted from significant investment in infra-structure. ~£4M. Investment has led to expansion of laboratories, specialist computing facilities and experimental equipment. 11 research laboratories are operational compared with 5 in 2008 - all equipped with state-of-the-art equipment, including:

Nanolab - high specification environmentally controlled clean room (Class 10,000 and temperature control (+/- 0.5º) laboratories include: (i) surface nano-metrology lab (tactile, scanning probe microscopes and interferometry) with novel anti-vibration technology and (ii) an ultra precision machining lab including diamond turning, nano-grinding and ultra-precision lapping. The 'Nanolab' facilities are widely acknowledged as being some of the best in Europe and are unique in the UK.

Optics Laboratory - an 80m^2 optics research laboratory with 4 separate optics benches/stations with a specially designed environment for on-line/in-line optical instrumentation research. Work carried out under the ERC (SURFUND) and EU (NANOMEND) projects utilise this facility.

Institute of Railway Research laboratory – hardware and software facilities located in newly refurbished facilities. State-of-the-art simulation software includes: Vampire, Simpack, VI-Rail and MSC Adams as well as Matlab/Simulink for advanced simulation and specialist software

development. Hardware facilities include: track and vehicle monitoring equipment: MiniProf rail and wheel, track gauge spreading jack, track measuring trolley, accelerometers, LVDT and data loggers. Fixed laboratory test rigs include 5th scale and twin disk roller rigs.
Diagnostics Lab – work extends across plant of all types and sizes: the purpose built laboratory includes instrument test beds for marine and automotive diesel engines, reciprocating and centrifugal compressors, multi-stage gearboxes, electric motor drives, centrifugal pumps, bearing systems, and flexible rotor machines (turbines, axial compressor, etc).
CT Laboratory - a 225KV Computer Tomography facility established in 2012 has extended the measurement capabilities of the UoA. Supporting work from bio implants to forensic archaeology.
HPC – the University has installed a high performance computing facility and entered into partnership with the STFC to access to the Hartree i-Dataplex facility. Primary applications include: advanced reconstruction of CT Images and high level FEA. Molecular dynamics simulations for ultra-precision machining and tribology research are planned.
FIB and TEM - SEM and TEM facilities are available and shared with researchers in Applied Sciences. A postdoctoral researcher was jointly appointed to support the facilities in 2011.
Systems Laboratory – a range of facilities including an oil-water two phase flow rig, a flow rig for solids-water and gas flows and an annular flow rig for simulating 'wet gas flows'. In addition, a range of facilities associated with wind power generation and distribution are available.

Other specialised laboratory facilities include a dedicated co-ordinate measurement **CMM laboratory**, a large **machine tool facility** and a **tribology laboratory**. Future expansion includes the establishment of an Turbocharger Research laboratory and an new Centre for Rail Research.

e. Collaboration or contribution to the discipline or research base

Exemplar Collaborations: we have numerous national and international projects with extensive collaborations. Within the UK, project partners, amongst others, include: Cambridge, Leeds, Cranfield, Bath and Manchester. The high-value TSB Catapult centres AMRC (Sheffield) and MTA (Coventry) are collaborators via our EPSRC Centre. Within Europe, partnerships include at least **7 Fraunhofer Institutes** and prestigious universities such as Paris Tech, Nuremburg Erlangen, Padova, and Chalmers. Links with NPL, NIST (USA) and PTB (Germany) have cemented relationships with National Measurement Institutions and researchers within the UoA are co-ordinators of a large EU FP7 project with **14** European academic and industrial partners. Excellent collaborations and links exist with China and India. Prof. Jiang is a **Top Talent Specialist**, awarded by the Chinese Government in 2010; a **Changjiang Professor** (awarded by the Chinese Research Council for research excellence) resulting in the recruitment of students from several prestigious Universities including Tsinghua and Beijing. Prof. R Mishra received the **Jewel of India** prize 2012 for "Excellent research by a non-resident Indian" with strong research collaborations with, IIT Delhi and IIT Kanpur.

Keynote presentations: Profs Jiang, Scott, Blunt, Ball and Iwnicki are recognised experts in their field and have given keynote lectures and seminars internationally. A key highlight for Prof Jiang was the organisation of events with the **Royal Society** i) Chair: Satellite Meeting on Precision Measurement, 14-15 Jul 2011, ii) Leading Chair: Royal Society Scientific Discussion Meeting, Ultra-precision engineering - from physics to manufacturing, 21-22 Mar 2011, iii) Chair: Royal Society International Scientific Seminar on Functional Structured Surfaces, 22-23 Nov 2010. Jiang's two papers (2011; 2012) were featured by *Proc. R. Soc. A* and *Meas. Sci. Technol*. On three occasions, Blunt and Bills have been invited speakers at the **Royal College of Surgeons**. Prof Jiang was a leading **Guest Editor** of an issue of the *Phil. Trans. R. Soc*. A370/1973 (2012).

Advisory Roles: Prof Jiang is a key advisor to the **National Measurement Program**, and **a Panel member of ARC 13 Research Assessment (2007-2013)** for the University of Halmstad, Sweden**.** Scott and Jiang are highly active members of the International Standards Organisation (**ISO**) committees and have been involved extensively in developing 22 international standards in Metrology and Machine safety. Prof Blunt is a member of the editorial board for the Journal of **Precision Engineering** and the IOP Journal **Surface Topography: Metrology & Properties.** Prof Iwnicki is deputy chairman of the Railway Division of the I Mech. E. and currently Editor for the IMech E Journal Pt F of **Rail and Rapid Transit**. Prof Myers is an active member of ISO TC39-SC2 Machine Tools.