Institution: University of Central Lancashire

Unit of Assessment: 15 General Engineering

a. Overview

Research in General Engineering at University of Central Lancashire (UCLan) resides in the School of Computing, Engineering and Physical Sciences and is presented under two themes: Digital Engineering and Mechanical Engineering. Each theme incorporates two groups which support research spanning a range of topics. These are:

Digital Engineering

Applied Digital Signal and Image Processing Research Centre (ADSIP)
Advanced Digital Manufacturing Technology Research Centre (ADMT)

Mechanical Engineering

Jost Institute for Tribotechnology (JIfT)
Energy

Research in **ADSIP** and **JIfT** has a well-established track record in signal and image processing technology and tribotechnology. Building on the success of **ADSIP** and **JIfT** in the 2008 RAE submission, strategic investment has been made to expand research into two new areas, namely: advanced digital manufacturing and energy through partnership with world leading manufacturing and energy companies.

b. Research strategy

Achievements: Since the 2008 RAE submission in General Engineering, in which 30% of research in **ADSIP** and **JIfT** was rated 3*, research in engineering at UCLan has grown significantly. The following research performance metrics have more than doubled in the REF period (which covers 5 years) compared with the 2008 RAE return (which covered over 7 years):

- the number of submitted staff has increased from 5.2 to 11.6 FTE,
- external research income has increased from £1.37m to £3.7m,
- the PhD completion rate has increased from 2.2 per year to 5.2 per year (with 26 PhDs awarded)
- the number of research students enrolled has increased from 14.38 FTE (2007) to 31.75 FTE (2013),
- the number of publications has increased, from 49 to 120 for journal papers, from 93 to 218 for conference papers and from 2 to 8 for book chapters.

During this REF period 27 Postdoctoral positions have been appointed and over 80 research collaborations have been held with partners across 14 countries.

Research in **ADSIP** focuses on the application areas of: industrial non-destructive evaluation (NDE, led by Shark), medical non-invasive diagnosis (NID, led by Matuszewski) and radiation effects and instrumentation (led by Platt). The key achievements in these areas in the REF period are: extending signal and image processing technologies for production NDE from the aerospace to the submarine sector; pioneering new clinical assessment tools for major diseases as part of our leadership of a European network and four major successfully completed ARC/EPSRC funded projects in the medical area; and development of innovative instrumentation systems such as a miniature neutron spectrometer with STFC and software for NASA's high resolution coronal imager (Hi-C).

Research in tribotechnology in the **JIfT** (led by Sherrington) at UCLan can be traced back to the late 1970's. During this REF period the state of the art resources available have attracted further industrial collaborators in automotive, aerospace, machine component and surface engineering sectors. Work with these new partners has led to novel developments such as: measurement of the lubricating film extent for piston-rings in firing engines, improved understanding of coatings for aircraft applications, and particularly notable contributions to the understanding and prediction of

threaded fastener behaviour. In **Energy,** research in the nuclear engineering industry (led by Francis) has simulated gas flows in industrial equipment leading to operational improvements on site, while work by Fragaki in energy management has led to effective quantification of strategies for energy balancing in large scale integration of renewable energy systems.

Strategic Development: High value manufacturing and energy related industries, including nuclear engineering, play an increasing role in the national economy and are a priority on the industrial, economic and environmental agenda worldwide. In addition, UCLan is located at the centre of one of the world's most important regions for aerospace and nuclear manufacturing. The research development strategy for General Engineering during the REF period has responded explicitly to this landscape leading to an investment of £2.46m by the University to support a stepwise expansion in research based around existing capabilities. Of this, £1.72m has been invested to establish **ADMT**, by expanding **ADSIP** research into the manufacturing domain. Working in close collaboration with prime manufacturing companies, this has led to the world's first Tele-immersive Digital Manufacturing facility (TiM) as our vision of the affordable and internet accessible factory for the future. A further investment of approximately £0.74m from the University was allocated to support activities in nuclear energy. An additional external award of £1m from BAE Systems was used to develop research across a wide portfolio of energy and power distribution activities. Research in **Energy** covers topics including policy management, security and societal response, alongside the engineering research returned here.

Vision: Building on our established capability and strategic development over the REF period we have identified the following "grand challenges" for the future:

- To transform future manufacturing by extending TiM to big-data driven cloud manufacturing in collaboration with centres of excellence in manufacturing.
- To revolutionise health monitoring by developing ubiquitous, non-contact, non-invasive and self-diagnosis tools based on our pioneered measurement modalities.
- To improve radiotherapy delivery through mathematical modelling of cancer cell response to ionising radiation
- To develop neutron detection and spectrometry for new applications including ISIS Chipir, European Spallation Source and fusion reactors.
- To be pioneers in the field of "tribotronics" by developing active tribological components including active machine elements, surfaces, coatings, lubricants and additives through collaboration with European industrial and academic partners.
- To develop ground breaking, integrated, intelligent energy management systems for large and small scale use.

Meeting these grand challenges during the next REF period is being supported by establishment of an Engineering Innovation Centre (EIC) with a £15m investment from the university. This development will provide a multi-disciplinary, multi-sector environment for the cross-fertilisation of ideas and practice between academics and research practitioners from industry and the public sector to develop innovative solutions for industry and the world at large.

c. People, including:

i. Staffing strategy and staff development

Targeted recruitment over the REF period has grown the number of research active staff, partly by replacing departing "teaching-only" staff with new lecturers pursuing active research programmes. This submission includes five new staff, almost 50% of those returned. All new staff have a probation objective to identify their contribution to research and support the strategic direction of the School. The University strategy is to recruit internationally and to follow a policy of equality and diversity to ensure the strongest candidates are attracted and this UoA submission reflects that approach.

In addition to the recent appointments that are included here, several other staff are being supported to develop their research to a level commensurate with being submittable in future REF

exercises. We also support Research Associates to develop experience and outputs, positioning them as competitive candidates for permanent academic appointments in the future. Two of the staff submitted in this return were formerly Research Associates of **ADSIP** and **JIfT**.

Exploitation of research developments to deliver impact is a key focus for the University and the School. The School has also appointed two staff with industrial background to develop our links with local manufacturing industry, enabling the delivery of benefits from our research to local business. This is further supported by staff in the Innovation & Enterprise Service of the University, including "champions" for Advanced Manufacturing and Energy, who are able to develop strategic partnerships on the School's behalf.

A number of paid sabbaticals have been provided to individual academic staff and groups to facilitate both individual and team research. Staff can also access a portfolio of training which includes: meeting funding body bidding requirements (UK and EU); collaborating with industry on both commercial and academic research; supervision of research students; and project management to deliver on funded research programmes. New staff have an identified mentor and all staff have an annual appraisal that assesses their development needs. This may include addressing any support needed to develop their activity with, or for: funding bodies, professional bodies, peer review of journal articles, state-of-the-art instrument training, interdisciplinary working and their ability to work in a wider context beyond their specialist research topic. Further, appraisal objectives include appropriate and specific targets relating to publications, research student supervision, funding applications and delivery on funded projects.

Staff development is also supported by international academic visits and exchange. Numerous visits and exchanges of scholars have taken place during the REF period. This includes staff visits and exchanges through the **ADSIP** led Engineering and Computational Sciences for Oncology Network (ECSON) and the UCLan Distinguished Visitor Programme for example from universities in Germany, France, Italy, Poland, and Norway to **ADSIP**, and visitors to **JIfT** from UK industry and universities overseas, notably Sweden and China. These visits have led to joint publications and grant applications; co-authoring of the Best Paper in the Medical Image Understanding and Analysis (MIUA) conference; and participation in the Medical Image Computing and Computer Assisted Intervention conference (MICCAI) grand challenges for stenosis detection in 2012 and mitosis detection in 2013.

Visiting and Honorary Research Staff: In addition to the many visitors associated with collaborative research within General Engineering, there are a number of distinguished key individuals who support research on an extended basis and hold formal visiting or honorary positions. These include: Prof S Glavatskih (KTH, Sweden), Dr G. Jones (Waters Corporation), Prof H. P. Jost (President, International Tribology Council), Dr M-T Ma (AVL China Technical Centre), Dr M Pywell (BAE Systems), Prof E Roberts (European Space Tribology Laboratory), Prof M Soejima (Kyushu Sangyo University, Japan), and Prof K. Watanuki (Saitama University, Japan).

ii. Research students

Our aim is to provide a stimulating, supportive and inspiring environment for research students to thrive and ensure timely completions; during the REF period 26 doctoral degrees have been awarded.

UCLan has a dedicated Research School Registry (RSR) that supports the recruitment, induction, progression and examination of postgraduate research students. Students are placed in a programme of support with compulsory and optional elements. Compulsory elements are formed from a tailor-made subject-specific training programme which lasts throughout the entire project and may incorporate a mixture of specialist training obtained through attending appropriate modules, internally at UCLan, or externally, for example at EPSRC summer schools. All Research Students must attend induction and pass a University Certificate in Research Skills, assessed by the Director of Studies and Supervisory Team using project based output. As a progression condition, all Research Students are required to complete this successfully. An optional

complementary training programme based on a personal development plan is also available to all students through in-house courses tailored for Research Students. Each student is required to keep a Progress File recording acquired competencies, activities and achievements. Within the School and University various mechanisms and practices are used to provide a stimulating environment for cross-fertilisation of ideas. These include reading groups, research seminars (some sponsored by Engineering Institutions or funded projects), company-led workshops and an annual (competitive) University wide postgraduate conference. All students are expected to present their work at international conferences, including our own international conferences and workshops, such as "LUBMAT" and the International Conference on Emerging Security Technologies. They are also supported to attend specialist student only events such as the "RADFAC" Student Workshop, IMechE "Mission of Tribology", British Machine Vision Conference (BMVC) Postgraduate Workshop and "Tribology UK", thereby facilitating exposure to current research and helping to develop contact networks.

Examples of student achievement externally include: global runner-up in the IET "Present Around The World" (PATW) competition (representing the UK after winning local, regional and national heats), "Best Paper" in the BMVC Workshop, appointments to postdoctoral positions and employment in prestigious academic research institutes such as: Imperial College (London), Oxford University, Bristol University, and responsible positions in world leading companies in the UK and overseas such as: EADS, Tata Steel, Leica and Wartsilla.

d. Income, infrastructure and facilities

Income: Over the REF period external research income has increased to **£3.7m** from £1.37m in the last RAE period. This includes significant average annual increases from several key funding sources, including: Research Council and UK Government body income – both up by a factor of almost 4.5; UK industry income - up by a factor of almost 10; and EU income - up by a factor of more than 3. Increases in income have been accompanied over the REF period by grant announcements totalling around **£6.7m**. UCLan's Funding, Development and Support (FDS) Unit undertakes full costing of research and related activities and the Business Partner Unit is responsible for the financial management / audit of projects once a grant has been awarded. New research programmes with external partners are guided by UCLan's Innovation and Enterprise Unit and Strategic Development Services e.g. writing contracts / letters of agreement and revenue sharing agreements, the identification of IP, Licensing and IP ownership.

The value of external grants awarded to **ADSIP** since 2008 is about £1.7m. The funding profile is diverse and includes: EPSRC for speculative medical image processing research for radiotherapy (EP/H024913/1) and for energy harvesting powered wireless sensor networks in unmanned aerial vehicles (UAVs) (EP/K020331/1), MRC for large-scale multi-centre longitudinal clinical trial for joint acoustic emission (MR/K025597/1), EU FP7 for developing innovative face based health monitoring mirror (SEMEOTICONS), MOD for developing ultrasonic tomography for submarine NDE (FSM/006 and FSM/032), RGF for innovative civil applications of UAV (GAMMA**),** and STFC for exploiting the patented invention of a miniature neutron spectrometer (POCF1213-08).

The total value of external grants awarded to **ADMT** is around £2.1m since 2008. The funding profile reflects a strong partnership with centres of manufacturing excellence such as: Warwick WMG on flexible and reconfigurable manufacturing systems funded by EPSRC (EP/K019368/1), with major manufacturing primes such as BAE Systems in digital manufacturing execution (DERiC), with sector organisations and supply chain companies such as ERDF-funded projects on digital manufacturing technologies (DigitME), and with other research groups such as **Energy** on energy based production optimisation and smart metering through EPSRC case studentships and a KTP with Bglobal.

In **Mechanical Engineering** the total value of external grants awarded is around £2.9m since 2008. This includes 7 EPSRC CASE Awards in energy (with BAE Systems) and tribotechnology (with Shell Global Solutions) and an industrial research contract of £1m from BAE Systems to support research in energy, a major ERDF project to develop innovative small wind turbine technologies (IsWind, X01692PR) and research contracts with commercial organisations to

support research in tribotechnology such as Goodrich aerospace and Goodrich aerospace / Rolls Royce JV (bearing coating materials), and AVL Simulation (piston-ring pack lubrication).

Infrastructure and Facilities: Existing facilities for research have been exploited alongside major developments of new infrastructure during the expansion of research in General Engineering.

In **Digital Engineering** a major development has been the establishment of the world's first Tele-immersive Digital Manufacturing platform (TiM) as our vision for the factory of the future. It consists of reconfigurable plug-and-play work cells linked by conveyer belts and mobile robots, and is equipped with digital tracking and sensing technologies to provide multiple data threads (such as process performance, product deviation and energy consumption) for adaptive manufacturing execution with web-based remote control and monitoring. In terms of ICT infrastructure, TiM is the first and only facility in the university sector having the latest industrial surveillance and fault-tolerant adaptive security networking system provided by Cisco. Other state-of-the-art specialist facilities include: 3D Visualisation Suite supported by EON Reality with a wide range of immersive display systems (from head mounted display to reconfigurable 3-wall cave) and interactive devices (from data gloves to multi-modality tracking systems), the "PACCAR Robotics and Vision Laboratory" which has a range of high-resolution/high-speed 2D/3D/4D imaging systems, mobile robots, and a high performance computing cluster for computational image analysis.

Resource development and investment which supports **Energy** in **Mechanical Engineering** has been focused round significant installations of infrastructure associated with Intelligent Energy Management capability at UCLan's Preston and Westlakes campuses. This includes: a ground source heat pump, solar panels, a 20kW wind turbine generator dynamometer and a 5kW demonstration wind turbine. This has been further supported by specialist simulation software packages such as GH-Bladed and GH-Windfarm and blade prototype manufacturing facilities. Excellent pre-existing facilities for research in tribotechnology in **JIfT** have been extended over the REF period by installation of new equipment. Notably, these include an automated calibration module for a Micromaterials Nano-test Platform (which already included nano-indentation/nano-scratch/nano-impact/fatigue and high temperature modules), a new thrust washer test apparatus, an inverted microscope with a full suite of image processing capabilities and a specimen viewing camera upgrade to our Scanning Electron Microscope which now includes the EDAX Genesis x-ray analysis, Be detector, solid state cooling and digital image capture system mentioned in the 2008 RAE return. General manufacturing facilities have also been recently improved by procurement of three CNC Milling Machines at a cost in excess of £100K and a metal laser cutter costing around £300K, providing increased capability to develop prototypes and components for research projects.

e. Collaboration or contribution to the discipline or research base

Collaboration and contribution: Collaborative and interdisciplinary research closely linked to user needs is reflected in all of our research. Examples of such collaborations are described below.

In **Digital Engineering**, interdisciplinary developments within the university include: dynamic hand gesture recognition for direct sign writing for the deaf community developed through collaboration with sign linguists, multi-modal biofeedback based virtual reality for hand motion rehabilitation of cerebral palsy and stroke patients through collaboration with physiotherapists; a comprehensive 3D dynamic facial articulation database developed with psychologists and clinical consultants; and the world's first interactive and immersive two player table tennis game developed through collaboration with sport scientists.

Within the region, TiM has been developed as a flagship project as a result from application-pull from the regional manufacturing sector (including companies like BAE Systems, Heinz, PACCAR and Rolls-Royce) and technology-push from the technology providers (such as Cisco, Fanuc, National Instrument, Omron, SAP and SMC) and provides a stimulus to inspire developments in world leading manufacturing. Other exemplars include: rapid NDE for large and complex shaped aerostructures, ultrasonic tomography for future submarine inspection, innovative UAV application development, measurement guided radiotherapy as a new concept for cancer treatment delivery,

joint acoustic emission as a new clinical tool for knee health monitoring, and dynamic 3D scanning as a new imaging modality for facial dysfunction assessment, in collaboration with various centres of excellence in the UK (such as Christie Hospital and the Universities of Manchester, Lancaster, Liverpool, Liverpool John Moores, Salford, Sheffield and Warwick).

In Europe, computational image analysis has been conducted in collaboration with 19 organisations and 5 hospitals from 6 countries through the **ADSIP**'s role as coordinator of the ESCON European network which includes top research organisations such as French National Institute for Research in Computer Science and Control (INRIA) and Italian National Research Council (CNR). Radiation effects research has been conducted in collaboration with 16 partners from 7 countries. It included participation in the SEEDER consortium with major industrial partners from the UK and Sweden, including MBDA(UK), Aero Engine Controls, QinetiQ and Saab. A significant part of this work is with leading single-event-effect (SEE) test facilities in North America and Europe (Los Alamos, TRIUMF, TSL), developing facility benchmarking techniques, and improving test protocols. This work is informing new facility development in Europe including the European Spallation Source and most notably, through our close collaboration with STFC and CNR, the world-leading Chipir beamline at ISIS.

Research in General Engineering influences international standards through participation in the IEC Technical Committee 107 "Process Management for Avionics". UCLan is the only university in the UK with a US Space Act Agreement covering our collaboration with NASA Marshall Space Flight Center (MSFC). Our current collaborative work with NASA MSFC and the Harvard-Smithsonian Astrophysical Observatory on the High Resolution Coronal Imager (Hi-C) for solar observations will be extended to a reflight (Hi-C2) and the Marshall Grazing Incidence X-ray Spectrometer (MaGIXS) both as part of NASA's sounding rocket programme. Other noteworthy international collaborations include: near infrared imaging of hand veins for biometrics and vascular diagnosis with North China University of Technology in Beijing through a Distinguished Visiting Professorship funded by the Beijing Municipal Higher Education Commission under the Outstanding Talents Programme, and condition monitoring of metallurgical equipment for the biggest steel industry in the world through a Visiting Chair Professorship awarded by the China State Key Laboratory of Hybrid Process Industry Automation System and Equipment Technology under the China Iron and Steel Research Institute Group.

In **Mechanical Engineering** examples which illustrate the impact of collaboration on practice include the work of **JIfT** and Bolt Science Ltd. who market professional training courses and commercial software products based on the findings of research into the performance of threaded fasteners which has established significant improvements in the understanding of vibration induced loosening and which we anticipate will widely benefit the safety of bolted components helping to prevent accidents such as the Potters Bar and Greyrigg rail accidents. Collaborations between **JIfT** and Goodrich Aerospace / Goodrich Aerospace Rolls Royce JV aim to replace currently used lead bronze substrates and lead-indium coatings in components in their products. (**JIfT** have benchmarked the materials in current use and evaluated of a range environmentally-friendly, lead free, coatings which may be used in new generation systems.) Work with Sellafield Ltd. Nuclear Ventilation Engineers has confirmed the source of high oxygen content in alpha glove-boxes. The work has informed company developments that have reduced inert gas usage in some facilities to 25% of previous usage. Studies of compartment fire dynamics in underground repositories, funded by the Nuclear Decommissioning Authority Radioactive Waste Management Division have provided temporal heat transfer predictions for use in waste package reaction studies for safety case purposes. Collaborative research in energy with BAE Systems has provided software tools for development of intelligent energy management systems and networks, UAVs and wind energy engineering for general use.

Leadership and Awards: A number of staff in this UoA have been recognised for outstanding intellectual contributions or contributed through high profile leadership or awards during the REF period. Examples of these are:

- Prof Arnell is the recipient of the 2012 Tribology Silver Medal. This is a major award recognising significant career contributions to the discipline of tribology presented by the

Tribology Trust

- Prof Matuszewski is the coordinator of a large European network (ECSON) with partners from 6 European countries and has been a Visiting Professor in the Universities of Cergy-Pontoise (France) and Otto-von-Guericke Magdeburg (Germany).
- Prof Shark was awarded the Visiting Chair Professor of the China State Key Laboratory of Hybrid Process Industry Automation System and Equipment Technology in 2012 and the Distinguished Visiting Professor of Beijing Higher Education Commission under the Outstanding People Programme in 2009. In addition, he is also an associate editor of two international journals (IJCAT & IJMIC).
- Prof Sherrington is Administrative Secretary to the International Tribology Council (ITC) with responsibilities to support the operation of an alliance of tribology societies from over 35 member countries. This includes support to ITC "In Session" meetings attended by representatives of member countries to select venues for the 4 yearly "World Tribology Congress" which is attended by over 1200 delegates.

Further exemplars of leadership and achievement by staff returned are summarised below:

- Advisory board membership: IEC TC107 Atmospheric Radiation Working Group (developing IEC standard IEC/TS62396), Lancashire Manufacturing Strategy Group, Northwest Autonomous Systems Programme Steering Committee, STFC ISIS Scientific Advisory Panel for Chipir, Liverpool John Moores Professorial Appointment Panel.
- Research Council roles: Member of EPSRC Peer Review College; Proposal reviewer of Medical Research Council, Royal Society, and grant bodies in Cyprus, Greece, Hong Kong and Italy; Panel evaluator of European Research Council, and EU Research Executive Agency; EC Expert Evaluator; Referee for the Swedish Foundation for Strategic Research, Dutch Technology Foundation STW User Committee member.
- Work Package Leader: Growing Autonomous System Mission Management Applications (GAMMA - Project value >£9m, 8 partners), Semeiotic Oriented Technology for CardiOmetabolic Risk Self Assessment and Self Monitoring (SEMEOTICONS – Project value >Euro 5m, 10 partners).
- Organisation of Conferences and Workshops: 2014: LUBMAT; 2013: LUBMAT, "Affective State Recognition in Human Computer Interaction" in IEEE CYBCONF, "Future ICT-Enabled Manufacturing Execution" and "Smart Technologies for Civil Applications of UAV" in IEEE SMC, "Modelling Tools for Complex Diffusion Processes" in VISAPP, Tribology at Sea (IMechE); 2012:"Recent Advances in Affective Computing" in IEEE SMC; 2011: International Conference on Emerging Security Technologies, "Analysis of Microscopy and Reconstructive Images for Applications in Medicine and Biology" in IEEE ICIP, Workshop on "Image Processing Techniques and Applications"; 2010: ECSMIO in VISAPP; 2009: Workshop on Interdisciplinary Assessment of Knee Arthritis , ECSON Workshop; 2008: Workshop on Future Manufacturing in Northwest.
- Conference committee membership and Session Chair: ICISP, ICWAPR, IEEE ICIP, IEEE SITIS, IEEE IV, IEEE MediViz, IEEE SMC, IEEE FG, IEEE CYBCONF, RADECS and VISAPP, Leeds Lyon symposium, NORDTRIB, World Tribology Congress IV and V, LUBMAT.
- External Examination responsibilities (PhD): Including Universities of Bath, Birmingham, Cardiff, Nottingham, Lancaster, Leeds, Liverpool, Loughborough, Sheffield, in UK and Bergen INRIA, Orleans, Madras, Toulouse and Vigo outside UK.
- Journal Editorial Board Membership: Proceedings of the IMechE (Part J) Engineering Tribology (Sage), Advances in Tribology (Hindawi), IET editorial panel member of "Delivering London 2012: ICT enabling the Games"; Scientific World Journal;
- Professional Institution Positions: IMechE Tribology Group Committee, (Chairman of Awards Panel (IMechE, Tribology Group Committee), Member of BINDT Aerospace Executive Committee, IET Vision and Imaging Network Executive Committee, Tribology Group Committee (IMechE),
- Awards and Patents: Shortlisted in Times Higher Education Research Project of the Year Award 2011 (with Lancaster University); Best Papers in BINDT NDT in 2009, BMVC Workshop 2011, MIUA 2012; one US Patent and one UK patent (pending).