Institution: University of Lincoln

Unit of Assessment: UoA 15 – General Engineering

a. Overview

The Lincoln School of Engineering was founded less than four years ago and is the first completely new engineering school to be opened in the UK for several decades; with investment from HEFCE (through their Strategic Development Fund), the European Regional Development Fund and Lincolnshire County Council. The rationale for the School, in terms of research and teaching, was conceived in collaboration with Siemens Industrial Turbomachinery who are based in Lincoln. Siemens has located its gas turbine training facility in the same building as the School and their staff contribute to the research and teaching. Since recruiting its first students in September 2010 the School has successfully established itself in both research competency and teaching provision. Academic staff have been recruited strategically from leading UK and overseas universities, as well as from industry; taking into account their research strengths and potential. As well as a core group of experienced academics, including 6 professors, there are 13 Early Career Researchers (ECRs). Over the short life of the School its research strengths of the School have been established; for some metrics, such as doctoral completions, it is too early to provide figures. The School has been highlighted as a *best practice* case study in the establishment of new university departments; for example, in the Government-commissioned Wilson Review (exploring Business-University Collaboration), in the award a Lord Stafford Award for ground-breaking collaboration between industry and academia, and in the 2012 Times Higher Education award for Outstanding Employer Engagement. In 2012, Siemens announced that the University of Lincoln will be one of its Principal Partner Universities, alongside Cambridge, Manchester, Sheffield and Newcastle. At the forefront of the School's aims is to promote research of the highest quality and specifically to develop a sustainable research environment as a global centre of excellence in the Industrial Energy and Systems engineering sectors. As such many of its staff have core disciplines in mechanical and electrical engineering. However, the strongly integrated and interdisciplinary nature of our research lends itself to UoA 15, General Engineering. The research within the School is organised around two research groups, although some staff interests can span more than one group:

i). **Energy Research Group** (ERG)

ii). **Systems Research Group** (SRG)

Most research activities are centred in the new £7.5m Engineering Hub. The portfolio of research grants awarded over the past 3 years total more than £5.5m; from research council and charity grants to direct industry contracts. Industry awards include Napier, e2v, EADS Innovation Works, Heathrow/Manchester/Zurich airports; while public funding includes EPSRC, FP7 and the TSB; together with a major translational grant from the Wellcome Trust. Moreover, with a strategic mission to improve regional investment in high technology research and development, immediate effects have also been seen with SMEs and OEMs coalescing around the Engineering Hub to promote academic-industry knowledge transfer through regular industry breakfast meetings and networking events. To date more than 300 direct contacts have been established with businesses throughout the UK.

b. Research strategy

As the newest engineering school in the UK, our vision is to be a leading centre for engineering research and innovation with a very strong industrial engagement. The unit's Research and Enterprise Strategy is aligned with the University's strategic research aims to continuously improve the research environment; to invest in the building of key research capabilities and resources; to underpin the continued professional development of researchers; to raise the impact of research outputs; and to strengthen the postgraduate offering. We are underpinned by a desire to create an environment for cross-disciplinary research activity that promotes communication; and personal and team achievement whilst recognizing the benefits of contributing to the research priorities of RC-UK, Horizon2020 ad other recognised challenges for the 21st Century. The unit was not in existence in 2008 and so cannot reflect on its current position with respect to RAE 2008. However from the outset we sought to meet the aims outlined above, as well as the School's shorter-term

objectives are summarized below (with some examples of current progress):

- To support a culture that recognises research excellence and its appropriate dissemination (e.g. establishing national/international partnerships and organising/contributing to international conferences/workshops).
- To provide an environment to facilitate sustainable growth by the appointment of leading research academics, research fellows and postgraduate researchers. (e.g. academics have been recruited from the University of Michigan, IIT Delhi, Politecnico di Milano, and NTU Athens).
- To promote research excellence through the publication of research outcomes in high-quality learned society journals, and contributions to international conferences (e.g. Over 250 papers published since the School's formation in Dec. 2009).
- To foster strategic research collaborations with regional, national and international organizations and respective research councils. (e.g. research partnerships with US Navy, NRC Canada, DSTO Australia, US Homeland Security, National Research Labs, South Africa; also international advisers/reviewers for the research bodies of Qatar, USA Department of Energy, Sweden, South Africa, India, Poland, Hong-Kong, etc.)
- To continually improve and expand our technical infrastructure to increase the breadth and depth of both fundamental and applied multi-disciplinary research. (e.g. £7.5m Engineering Hub plus an additional investment of £450k for facilities)
- To provide an in-house environment for wider intellectual inter-disciplinary debate, innovation and academic enquiry. For instance, the School's Engineering Hub regularly hosts external research symposia and network events (e.g. IoP, IET, and IMechE)
- To be receptive to timely opportunities in high-technology market sectors that the School's research outputs can penetrate (e.g. two spin-out companies launched (ISDI Ltd - IET Innovation Award winner 2012, and Immersive Forensics Ltd); laser ignition system and diagnostic tools for Siemens global fleet of 15 MW gas turbines; contributions to OECD-IAEA world energy report).
- To achieve best possible performance in REF 2014 and other open measures of research standing, so demonstrating our appropriate status for both academic and commercial research communities.

The evidence that the unit has met these objectives is manifold. Since its emergence in Dec. 2009, School academics have averaged over 80 technical research publications per-annum in learned society journals and conference proceedings, so underpinning our commitment to high quality research, including prize-winning papers from Prof. Owen (RAeS Gold Award, 2012) and Prof. Stewart (IMechE, 2010).

Clear communication and direction from the Director of Research during staff- and research-committee meetings to regularly highlights the importance of impact and provide guidance to staff of mechanisms to promote impact from their research, and how to evidence it using all resources available to the School. Researchers (academic and postgraduate/post-doctoral colleagues) are actively encouraged to record impact throughout research projects and beyond, through the development of case studies. Even though the School has only been in existence for less than four years, its research is already being applied in industry and significant impact is emerging.

To encourage a broad portfolio of applicable and, hopefully, disruptive research, the School is organised into two multi-disciplinary but interrelated research groups, each headed by internationally recognised professorial leaders in their respective fields. Some of the achievements of the two groups against their research objectives are outlined below:

i) **Energy Research Group** (ERG)**,** led by Prof Bingham, conducts fundamental and applied research on many aspects of power and energy production, distribution and control, with key application sectors in low carbon/emissions engines, gas turbines, energy storage and peak power buffer technologies, smart energy and renewables research. Examples of the fundamental research is the optimisation of fuel-air combustion processes for ICE and gas turbines, extending

the life-in-service of combustion chamber hardware, and CHP systems to maximise the efficacy of integrated low- and high-grade heat sources (Dr J. Stewart (left Aug 2013), Prof Bickerton, Prof Owen); with Jin's research into laser-induced fluorescence/phosphorescence (LIF/P), Mie/Rayleigh/Raman scattering, and Particle Image Velocimetry (PIV), for imaging of premixed and non-premixed flames, fuel sprays and combustion focussing specifically on the automotive sector. Success of the research, and its industrial application, is evidenced by long-term on-going collaborations with Siemens, Napier Turbochargers and Mitsubishi. Owen's thermofluid modelling expertise is being applied to research into the aerodynamic design of ship superstructures to improve the operational envelope for maritime helicopters – working with the MoD, BAE Systems and the University of Liverpool. His research has led to the Type 26 future Combat Ship being the first ever to be designed for optimal helicopter availability. His collaboration in this area also extends to the US Navy and the national defence laboratories of Canada and Australia. Bingham has a longstanding track record for the research and development of renewable and energy harvesting technologies (both built environment and transport sectors) and acted as a British Council academic representative in Qatar in 2011. His research also encompasses the social and behavioural aspects of driver actions on the energy efficiency of electric vehicles, and through experimental driving trials, has shown that ~30% energy savings can be made by appropriate driver education and enlightened city centre planning.

During the census period, ERG jointly hosted the EPSRC-funded Airport Energy Technologies Network (AETN), (EPSRC EP/H003150/2), directed by Prof. Stewart, and was tasked to undertake low-carbon research specifically in the field of aviation. ERG gained particular recognition for its research into energy recovery from landing aircraft, resulting in further research funding for the Integration and Automation of Low Carbon Vehicle Operations (EP/H004424/1) in collaboration with Nottingham, Liverpool and Loughborough Universities, and Manchester- and Zurich-Airports.

Recognition of the international status of ERG research staff is shown by their involvement in high profile European consortia – conducting front-line research for future aerospace technologies. Examples include examining power and distribution architectures for a new generation of high altitude airships (MAAT multi-body aircraft, FP7 ID 285602), and technologies for vector thrusting of aircraft (ACHEON, FP7 ID 309041). More direct EU and overseas recognition includes f Locatelli appointment as Dissemination Co-ordinator of the European Cost action "The Effective Design and Delivery of Megaprojects in the EU". Low carbon technologies and efficiency savings are at the heart of ERG research, and extend to collaborative modelling and control of the thermal environment of domestic buildings.

ERG has a five-year roadmap to extend its power/energy renewable and harvesting technologies and CHP/bio-fuels research for micro generation systems. More generally, ERG aims to be an international leader in the research and application of advanced 'big data' control for industrial power generation systems.

ii) **Systems Research Group** (SRG): is led by the new Head of School, Prof Tim Gordon, who joined from the University of Michigan. He is currently the Chair of the standing committee on Vehicle-Highway Automation at the Transportation Research Board of the National Academies of Science and until recently Vice President of the International Association of Vehicle System Dynamics (2007-13). SRG conducts application-driven theoretical and applied research on dynamics, high-tech industry technology, artificial intelligence, artificial immune and multi-objective optimisation systems for a broad portfolio of real-life, real-time engineering problems.

In collaboration with the School of Computer Science, we support the design and characterisation of CMOS microelectronic devices, especially imagers. We possess full CAD design platforms (academic/commercial licences) and universal test equipment for imagers to EMVA standards. Through a spin-off company, with CMOS designers across Europe working on different projects and excellent relationships with leading foundries, we design and supply wafer-scale CMOS imagers to global healthcare companies. A highlight was the development of the world's largest radiation-hard CMOS imager for medical applications. The 13 cm-square imager is the result of an EPSRC consortium grant, headed by Prof Allinson: and has led to a further award of £1.6m from the Wellcome Trust to provide instrumentation for improved proton therapy treatments for cancer sufferers. In recognition of his personal contribution, Allinson was made a MBE for Services to Engineering (2012). Additionally, his work on wafer-scale imagers received the IET Innovation

Prize for Electronics (2012).

Bhattacharya's research on computational neuroscience has led to breakthroughs in thalamocortical circuitry neuro-modelling to facilitate the detection of anomalies found in EEG readings for conditions such as Alzheimer's and Parkinson's disease. SRG is beginning to establish itself for expertise in photonics and power laser research through providing applied research solutions for industrial, biomedical and life-science sectors. In collaboration with the National Centre for Food Manufacturing, SRG have successfully completed trials of a new laser technology for improved food packaging integrity; collaborators include Marks and Spencer, Bakkavor and Proseal. Other research led by SRG includes plasma-initiated shockwave investigations for detonators and micro-ablation debris control. Members of SRG are also working with Bingham on sensor-fusion for prognostic and diagnostic techniques to provide fault detection and remedial strategies for sub-15 MW industrial gas turbines, in order to maximize unit operational availability. This is now being adopted by Siemens as remote 'early warning' tools on its fleet of industry gas turbines.

SRG has a 5-year roadmap to enhance its pedigree as an international research leader in healthcare imaging (in association with University-wide developments) and AI systems including neurocomputing. SRG is also committed to invest in new facilities to support research into intelligent on-the-road automotive safety systems, whilst pursuing new materials surface processing technologies to facilitate reduced industrial resource wastage and greater food manufacturing productivity.

c. People, including:

i. Staffing strategy and staff development

We are supported by the University's People Strategy, a comprehensive range of policies around employment, equal opportunities, research management and ethics, each with an element designed to support research activity. The staffing policy is strongly linked to the unit's research strategy, in particular through the objectives for increasing research capability, and providing Continuing Professional and Personal Development (CPPD) and mentoring support. The University actively supports the Concordat to Support the Career Development of Researchers. It has introduced minimum academic standards regarding research productivity within its annual appraisal system. Research success is recognised directly through research-related financial incentives and indirectly through the research leave scheme that is open to all categories of contracted staff. In addition, all researchers have a mentor as part of the research element of the CPPD framework. Staff are assisted in identifying opportunities for funding and collaborative ventures, and to develop effective grant applications through our Research and Enterprise team. Each College has a Director of Research and Business Development Manager. Staff can make bids to an annual Research Infrastructure Fund of £500k.

The School's Director of Research is responsible for academic staff research attainment to ensure the strategic aims of the School are achieved. Transparency of the expectations, mechanisms and support are conveyed and guided through the School's Research Committee and other staff meetings. The research imperative is well understood by all members of the School, as is its Research Strategy. A culture for increasing academic research creativity is a priority for the School in order to significantly increase the number of research students, assistants and fellows, and promote wider external income generation opportunities. Regular interaction, direction and mentoring from senior staff are considered paramount in supporting ECRs and others. Staff at all levels are encouraged to attend courses to enhance the efficacy of their research skills and are encouraged to improve their research exposure through the provision of invited seminar series, and through frameworks of *Vitae the Researcher Development Framework* and *The Concordat to Support the Career Development of Researchers*. Equality and Diversity is embedded in the University's HR Strategy and is supported by the *Athena Swan Charter*. Staff are also required to undertake training for PGR supervision. More than 30% of academics are from outside the UK, and some 20% are female. The University has a healthy number of talented young academic staff and has established the *Lincoln Early Career Network* to facilitate peer-support. The School has an annual staff review to assess each individual's research contributions and outputs, and monitor their progress for their own career development. More intensive guidance, mentoring and support are given to researchers requiring assistance to strengthen their research profile. The School

encourages individual and collective membership on external bodies, e.g. EPSRC College, EU committees, technical committees, working groups and professional societies where it is possible to influence policy and inform staff of UK and European research directions.

ii. Research students

Every research student is a member of the University's Graduate School, which offers research education and career development programmes and a support network for all students. Research students obtain additional support to present their work at seminars and at the annual Postgraduate Student Conference, to get work published, to identify potential research funding and to learn skills transferrable to their future careers. This is in addition to the extensive online and physical library facilities and IT support that are available.

In the first two years, while the staff base was being developed, priority was given to recruiting postdoctoral research assistants/fellows, so building up quickly a strong research capability. Postgraduates were then gradually recruited so that the School currently has 10 PhD students, spanning fields of self-balancing of high-speed shafts, high efficiency power conversion, renewable technologies in safety critical systems, remote monitoring and diagnostics of a global fleet of industrial gas turbines and intelligent video using novel CMOS imagers, among others. Outputs stemming from post-graduate PhD researchers have generated a further £180k of research income through the intermediate benefits of their research over the past two years. Post-graduate researchers are monitored at frequent intervals to provide feedback on their progress towards ultimate degree completion, in accordance with the University's Research Policy and Ethics procedures. Due to the initiation of the School so late within the census period, candidates reading for a PhD have yet to complete.

d. Income, infrastructure and facilities

The University of Lincoln has made a step-change investment in science/engineering facilities during the census period, and this process will continue with £100m scheduled for investment over the next decade. The new, purpose-built Engineering Hub (EHub) provides all staff access to diverse, state-of-the-art research facilities and the close daily proximity of staff encourages frequent cross-disciplinary communication. The co-location of Siemens Global Product Training facilities and equipment in the EHub directly enhances industrial research collaboration and provides access to otherwise inaccessible testing platforms, such as large-scale atmospheric chambers for advanced combustion research. The School has also procured (and commissioned) a new direct-drive high-power (60 kW peak), high-speed (20,000 rpm) dynamometer facility with low inherent torque ripple (through use of custom designed induction machines) to investigate and validate new control mechanisms for accommodating the non-linear dynamics of high speed industrial rotating shafts, e.g. automated modal balancing mechanisms for high-mass/high-speed shafts, and invested in new research facilities for the testing and optimisation of bio-fuels yield. The investment in laser (incl. CO_2, and Excimer) and materials/metrology instrumentation laboratories (incl. scanning electron microscope, white light interferometer, goniometer) is central to underpinning materials surface processing, micro-machining, controlled wettability studies, and controlled growth of stem cells. For the CMOS imager design work we possess comprehensive academic and commercial software platforms for design, simulation and characterisation; together with a custom "universal" instrumentation for comprehensive imager characterisation – performed to European Machine Vision Association standards and better; and traceable to primary reference standards. For more extensive testing, especially for radioactive and non-visible radiation, we have access to STFC Diamond Light Source, University of Birmingham Cyclotron, iThemba Laboratory for Accelerator Based Sciences, South Africa (Proton Therapy Facility), NHS Radiotherapy Suites and several industrial test facilities.

Academics have submitted proposals in excess of £6.6m since the emergence of the Engineering School, of which more than £5.5m has been secured to date, covering over 30 individual projects. The current proposal success-to-submission ratio is better than 1:2. The year-on-year supported research income has successively increased from £93.4k in 2009-10 to more than £3m in 2012-13. Key to the rapid increase of its income generation profile is industrial collaboration and large multi-site collaborations. By way of example, and in recognition of the resident expertise, Siemens alone has invested £1.5m in five research projects over the previous three years. This partnership is founded on a unique research Framework Agreement, negotiated between the two parties, which

provides an overarching contract to cover issues such as IP, confidentiality and schedules of payments etc. so that projects can be rapidly progressed and research outputs disseminated in a timely manner. This research Framework is now considered as the foundation for all new Siemens-University collaborations.

Total direct industrial and charity supported spend on research, between 2010-2013, is: £817k

Total funding body (EPSRC/FP7/KTP etc.) spend on research, between 2010-2013, is: £1.17m

Expansion and Investment
Building on the success of the School of Engineering research portfolio, the University is committed to the establishment of new cross-disciplinary research-lead STEM Schools (Electrical and Electronic, Chemistry, Applied Mathematics), including an underpinning commitment for the establishment of a £12m second phase of Engineering 'new-build' expansion to substantially enhance the current research and development base. This is in addition to the University's recent announcement to support a £14m Science and Innovation Centre for the co-location of academics and commerce, which aims to provide a world-leading environment for research.

e. Collaboration and contribution to the discipline or research base

Awards

November 2011: the School of Engineering partnership with Siemens won the *Lord Stafford Award*, which recognizes the best in collaboration between businesses and universities across the Midlands.

December 2012: *Principal Partner status for Siemens research*, along with Cambridge, Manchester, Newcastle and Sheffield – making it a primary research centre for all Siemens UK research.

November 2012: In recognitionn of the strategic success of the Lincoln-Siemens partnership in academic pursuits and research, the School of Engineering won the *Times Higher Education award for Outstanding Industry Engagement*.

Academic Collaborations and Board Membership
As well as numerous collaborations with leading UK and overseas universities and research laboratories, the international recognition of staff has spawned significant global academic research links during the REF period, including:

- Allinson – Department of Energy, USA; Swedish Research Council, Universities Research Council Review Committee, Hong Kong; National Research Laboratories, South Africa; European Free-Electron Laser, Hamburg.
- Owen – US Naval Academy, US Navy (Navair & Navsea), NRC & DRDC Canada, DSTO Australia, UK MoD, BAE (Surface Ships & Military air).
- Bhattacharya – Istanbul Technical University, Turkey; National Science Foundation, USA; Virginia Tech, USA.
- Bingham – QNRF, Qatar; Al-Ain University, UAEU.
- Geordiadis – Lublin University of Technology, Poland.
- Gordon – Chair of standing committee on Vehicle-Highway Automation at the Transportation Research Board of the National Academies of Science (Washington DC).
- Jin-SH – Kyung Hee University and Korea Institute of Industrial Technology, Korea.
- Stewart – UniMoRe and UniBo, Italy.
- Locatelli – Aalto University School of Science, Finland; University of Siegen, Germany; Universidad politécnica de Madrid, Spain.

Example Industry Research Collaborations
Among the many companies currently liaising with the School of Engineering, current active research programmes, with direct contributions, include:

- Mitsubishi (£87k); Napier TurboChargers (£92k); Marks and Spencer (£18.5k); Siemens, SITL (£1.5M); e2v (Lincoln) (£26k)

With others acting as partner or project consortium members, include:

- Esponential design Lab. S.A. (eDL), Uruguay; Aero Sekr S.p.A. (ASKR), Italy; LogisticNetwork Consultants GmbH (LNC), Germany; Engys Ltd., UK; US Navy, DSTO Australia, NRC Canada, DSTL, MoD, BAE; Elekta AB, Sweden; PerkinElmer Inc, USA.

Examples of Leadership in Academic Community (during REF review period)

Allinson – MBE for Services to Engineering (2012); IET Innovation Prize for Electronics (2012); Visiting Professor, University of Oxford; Co-founder of two spin-off companies Immersive Forensics Ltd and ISDI Ltd); UN representative for joint UK-USA bilateral programme on anomaly detection; member of EPSRC and BBSRC Colleges (panel member and chair). Wolfson Laboratories Refurbishment, Royal Society.

Bhattacharya – Reviewer for UKIERI funding applications; Co-host and Chair of special session on Computational Neuroscience, IEEE BIC-TA 2010; Invited organiser of workshop session at CNS 2013 (Organisation for Computational Neuroscience).

Bingham – British Council academic representative for UK-Qatar collaborative links on Energy Security, 2011; Editorial Board of Energies, MDPI; 2 IMechE Part G invited papers; invited presentation, AECS 2010.

Chen – Member of IEEE Control Society; System, Man and Cybernetics Society; Computational Intelligence Society. Member of Network on Artificial Immune Systems.

Geordiadis – 2× Marie Curie Fellowships (2009, 2010); Polish Academy of Science member (Nonlinear Sciences).

Gordon – Vice President of the International Association of Vehicle System Dynamics (2007-2013); Jubilee Visiting Professor at Chalmers University, Sweden; Recipient of the 2012 Kenneth M. Reese Outstanding Research Scientist award at the University of Michigan.

Lawrence – Editor-in-Chief International Journal Lasers in Engineering.

Locatelli – Dissemination coordinator of EU Cost Action "The Effective Design and Delivery of MEGAprojects in the EU"; Invited Speaker at Annual Asia-Pacific Nuclear Energy Forum on SMRs, Berkeley, CA; Invited speaker at Int. Atomic Energy Agency Technical meeting, 2009; Member ANIMP for Transportation and Logistic. 3 recent papers form part of OECD-IEA report on Nuclear Energy and Renewables.

Owen – EPSRC College; UK representative on TTCP-AER-TP2 & NATO AVT-217; during REF review period Editorial Board of Measurement & Instrumentation & J Energy Institute; RAeS Gold Award for best paper 2012.

Saddawi – invited paper Energy and Fuels, ACS.

Stewart – Recipient IMechE 2011 Charles Sharpe Beecher Prize for Aerospace; Co-Director Airport Energy Technologies Network.

Srivastava – Technical program committee member of FIE and Design Automation and Test (Europe).