Institution: University of Greenwich

Unit of Assessment: (UoA 12) – Aeronautical, Mechanical, Chemical and Manufacturing Engineering

a. Context

The Centre for Numerical Modelling and Process Analysis (Centre) is a multi-disciplinary team consisting of four collaborating research groups: **Fire Safety Engineering Group (FSEG), Computational Science and Engineering Group (CSEG)**, **Computational Mechanics and Reliability (CMRG)**, **and The Wolfson Centre for Bulk Solids Handling Technology (Wolfson).** The non-academic user group, beneficiaries and audiences for the Centre's research output is wide and varied and includes: commercial companies, both large and small, in a wide range of sectors; public sector organisations; regulatory authorities; national legislative bodies; the third sector and the general public. The main types of impact generated by the UoA include: economic (improved processes, licensing, etc); public policy (influencing legislation); society and culture (public interest and engagement in science, protecting heritage); practitioners and practice (shaping international guidelines); and environment (assist in the development of greener technology). The Centre's research groups generate impact in the following areas: **FSEG**: economic, public policy, society/culture and practitioners/practice; **CMRG**: economic and society/culture, **CSEG**: economic and environment; and **Wolfson**: economic and environment.

b. Approach to impact

The Centre strives to make its research relevant to end-users around the world. The research is applied in a wide variety of sectors such as Electronics, Heritage, Healthcare, Energy, Architecture, Naval Architecture, Aerospace, Construction, Materials Handling and Safety. Over the assessment period, the Centre has worked with more than 550 companies in over 30 countries delivering research, consultancy and software licenses to SME's such as ASH and Evaclite to multi-national corporations such as Cassidian, Bombardier and Agip; government departments and agencies in the public sector such as the Centre for the Protection of Critical National Infrastructure (CPNI) and Kent Fire and Rescue Service; international regulatory authorities such as the IMO; legislative bodies such as the Australian Senate and House of Representatives; the third sector such as the Cutty Sark Trust and the general public through their wider engagement with science.

The Centre's approach to impact during the assessment period has been to directly enable staff engagement in third leg/outreach activities such as (i) consultancy, (ii) Knowledge Transfer Partnerships, (iii) short courses and CPD, (iv) licensing of IP, (v) engagement with regulatory bodies and learned societies, and (vi) making links to the media.

(i) Consultancy projects are initiated by Centre staff or through our Business Development Manager (BDM). The university has a standard consultancy agreement which details the terms and conditions for any consultancy work to be undertaken. This is agreed between the Centre, our contracts staff in Greenwich Research Enterprise (GRE) Office, and the external organisation before any work is undertaken. In total during the assessment period we have consulted directly with over 100 companies from multi-nationals such as General Dynamics, Cassidian, Selex-ESP, Agip, Bombardier etc, to SME's such as Medway Queen, Evaclite, Ash etc.

(ii) KTPs: GRE has a dedicated KTP Manager and promotes its offer to industry through the university KTP webpage (http://bit.ly/16ycP5A). Relevant industry enquiries are passed to us by the KTP manager who, together with our BDM, helps the Centre and the company complete the application process. If the KTP application is successful, the KTP manager supports the project throughout its duration, facilitating good communications between the Centre and company. Recent KTPs include our award-winning collaboration with the Cutty Sark Trust where our expertise helped reassemble the ship to ensure it was safe. This project received best KTP project for London in 2008, and the THE Award for outstanding engineering team of the year in 2009.

(iii) The centre has been running **short courses and CPD** for industry for many years. For example, our two, five-day short courses for human behaviour/evacuation modelling and fire dynamics/fire modelling, accredited by the IFE, provide the opportunity to engage with users of fire and evacuation modelling tools. Since 1997, 560 engineers have been trained from 42 countries, 191 since 2008. Other examples include: our work with UK&RI IEEE Society where we have run a

number of one day short courses to disseminate our expertise in reliability engineering, and our bulk solids handling courses which attract 150+ paying attendees per year from industry. The Centre is supported by a short course CPD manager who helps promote these courses, and the university has dedicated facilities to run short courses

(iv) Licensing of IP is encouraged by the university. Working closely with contracts staff within GRE, standard licensing agreements have been developed resulting in a number of software sales to industry. For example, reacting to the needs and funding from the US Federal Rail Administration (FRA), FSEG developed a version of their evacuation modelling tool to address rail car evacuation (2007-2011). The railEXODUS software, released in 2012, is now licensed to the US FRA Volpe Research Laboratory. During the assessment period, the EXODUS and SMARTFIRE suite of software tools, licensed through Greenwich University Enterprises Limited (GUEL), a wholly owned subsidiary of the university, has generated over £1 million through licensing software to 314 licensees in 32 countries. The Centre has also engaged with a number of resellers worldwide to support its licensing activities.

(v) Our membership on a number of regulatory bodies is providing the opportunity for our research outputs to impact policy and industry standards. For example, Centre staff are members of government committees, international regulatory organisations such as IMO, and international professional bodies such as the IEEE, SFPE (Society of Fire Protection Engineers) and IAFSS (International Association of Fire Safety Science) where they participate in shaping professional guidelines. Our work on Prognostics and Health management of electronic systems, for example, has resulted in staff participating in the international working group writing a new IEEE standard P1856 (http://bit.ly/1a2eZy0).

(vi) Media links: Our research and enterprise activities have received extensive media coverage over the assessment period, informing the public of our work as well as future industry partners and policy makers. To achieve this we work closely with the university PR department who engage with media outlets in the UK and overseas. Examples include a BBC 'Horizon' documentary based on FSEG research, entitled, "How to Survive a Disaster" (first broadcast 10/03/09 on BBC1, http://bbc.in/15noerY) which attracted a 1.7 million viewer audience representing 7% of the audience that night (http://bit.ly/17BHAJx). Other programs include the Channel 4 documentary "Terror at Sea" (first broadcast 31/01/12 on Channel 4, http://bit.ly/17BIXHU) which followed the sinking of the Costa Concordia. Prof Galea commented on evacuation issues (the programme attracted a massive 3.4 million viewers (http://bit.ly/17BJjP1)) and also on BBC Radio 4 Today (4 March 2012, http://bit.ly/GAKPrP).

To support these activities we have access to the dedicated BDM, the KTP Manager and other personnel within the GRE Office who handle contracts and IP issues. The university also has a PR department who support the Centre in its engagement with the media through media training and advice. Since 2008 the university has invested £711K of HEIF funding to seed fund these activities, leading to a commercial return in excess of £2.9m over the assessment period.

Our PhD students and ECRs are trained in an environment where contact with outside organisations is direct since most research projects involve industry, local authorities, or decision making bodies. This embeds skills in dealing with end users and carrying out impact-focused research. Furthermore, placing our recent PhD graduates in high tech industries further strengthens our links with these industries. During the assessment period our graduates have joined large organisations such as: Arup, ANSYS, CD-ADAPCO, Ricardo, Mentor Graphics, Mercedes Formula 1, EDF, Subsea 7, Hughes Int, IPT Brazil, Capita Symonds, Tata Steel, and Schenck Process. These links with industry through our trained graduates helps strengthen industry partnerships with support of the university Alumni office.

In addition, many of our EU, TSB, Research Council, and other overseas government projects involve collaboration with industry where knowledge transfer between the Centre and industrial partners occurs. We make frequent use of the 'Lambert' contracts and toolkit to agree IP ownership issues at the pre-proposal submission phase, encapsulated within a project collaboration agreement. An example of how we have engaged with end-users in this type of project is the EU FP6 NACRE project (http://bit.ly/185eJw7) in which both our software tools -

airEXODUS and SMARTFIRE - were adapted and used in the analysis of fire/evacuation for a future concept Blended Wing Body (BWB) passenger aircraft for Airbus. This 35 partner, four year project demonstrated that the BWB was viable from a passenger safety view point and could satisfy evacuation certification requirements, bringing this aircraft a step closer to reality. A paper describing the project published in the Royal Aeronautical Journal won the Society's bronze prize in 2011 and results were reported in the popular scientific and engineering literature (*Flight International* and *The Engineer*).

c. Strategy and plans

The Centre aims to continue its 30 year practice of working closely with local, national and international business and industry to provide cutting edge solutions to their most challenging problems. New, recently awarded projects such as £18M EPSRC initiative – Underpinning Power Electronics – and the EU-FP7 project NextFactory, provide the Centre with the opportunity for impacts in the energy and additive manufacturing sectors, while projects such as the EU-FP7 IDIRA IP provide the Centre with the opportunity for impacts in the security sector. Our goals are:

- to become the leading modelling Centre in both power electronic systems design and additive manufacturing, two sectors that will see significant growth in the next five years;
- expand our world leading safety research to encompass security;
- engage in TSB and KTP projects to help promote our research outputs into industry;
- improve reach and market penetration of our IP such as our software tools;
- secure £8.5M funding from UK, EU (eg Horizon 2020) and international government and industry organisations to support our collaborative work with industry.

Our plans to achieve the above goals are to:

- expand our strategic partnerships with overseas resellers to assist in sales of the Centre software in various geographical areas worldwide;
- encourage staff to join EU networks such as EPoSS (European Platform for Smart Systems Technologies)
- develop an impact plan for each new research and consultancy activity;
- disseminate the research/consultancy findings widely and to a mixed audience, not just to academic journals;
- expand our involvement in rule/standards making bodies such as IMO, ISO, BSI, IEEE.
- The Centre subscribes to the University Balanced Workload Model which specifically identifies staff time aimed at achieving research impact and reach in the external community.

d. Relationship to case studies

FSEG research is the theme characterising the impact described in *case study 1*. The case study demonstrates how our early research into human behaviour and evacuation simulation in the aviation sector led to the development of the EXODUS suite of evacuation modelling tools which are licensed to commercial and research users around the world. The decision to license this technology to users has meant that the modelling tools resulting from FSEG research have been used in major design projects in aviation (eg A380), maritime (eg CVF), and building (eg Pentagon) industries. Furthermore, the fundamental research into human behaviour undertaken to develop these tools has gone on to have impact in public policy (eg Australian aviation safety requirements) and professional practice (eg guidelines for ship evacuation analysis IMO MSC Circ 1238).

The research described in *case study 2* details our research on the structural behaviour of heritage ships using computational models and failure analysis. The study details our modelling work on composite structures and how this was applied, uniquely, to aged maritime structures. Working through Knowledge Transfer Partnerships we used our technology to support the conservation of the world famous Cutty Sark clipper ship located in Greenwich which was reopened by the Queen in 2012. Our research was also used to restore the Medway Queen (Heroine of Dunkirk). Extensive media coverage was obtained on these projects – particularly our work with the Cutty Sark Trust.