Institution: University of Greenwich

v10

Unit of Assessment: (UoA 15) – General Engineering

a. Context

Under this UoA, the University is returning three research groups drawn from the School of Engineering (SoE) and the School of Computing and Mathematical Sciences (SoCMS):

- **Centre for Numerical Modelling and Process Analysis (CNMPA)** (http://cnmpa.gre.ac.uk/), is a cross-school centre. The CNMPA is focussed on research in developing computer models for multi-physics/multi-scale predictions, numerical optimisation, failure analysis, reliability and maintenance of engineering structures. Due to the highly inter-disciplinary nature of its work, the CNMPA is returning six ARs to this UoA, (**Berry**, **Deere**, **Deng**, **Wang**, **Xie** and **Zegan**) as well as four to UoA 11, nine to UoA 12 and seven to UoA 13.
- **Sustainability in Civil Engineering Research Group (SCERG)** (http://www2.gre.ac.uk/about/schools/engineering/research/groups/scerg), is based in the SoE. The SCERG was established in 2009 by, and continues to be led by Prof Amir **Alani**. The SCERG undertakes research in the associated areas of applications of non-destructive methods in civil engineering and structures in general (and in particular bridge and tunnel monitoring), environmental engineering (sustainable drainage systems), geotechnics (numerical modelling of soil and materials) and concrete technology. The SCERG is returning six ARs to this UoA (**Aboutalbai**, **Alani**, **Chen**, **Dussaillant, Faramarzi** and **Tee**).
- **Centre for Innovative Product Development and Manufacturing (CIPDM)** (http://www.gre.ac.uk/cipd), is based in the SoE. The CIPDM was established in 2006 by, and continues to be led by Prof James **Gao**. The CIPDM undertakes research in the areas of new product development, collaboration and knowledge management in the supply chain, and product lifecycle management. The Centre focusses in particular on new enabling technologies, methods and processes. The CIPDM is returning two ARs to this UoA (**Gao** and **Melis**).

The main impact beneficiaries for these groups are a wide range of businesses and industries, with particular focus on the sectors of fire safety, aeronautical, naval, automotive and process engineering, manufacturing and civil infrastructure. The types of impacts that end-users benefit from are better designs for aircraft, ships and handling equipment, as well as improved service life for civil infrastructure, such as bridges and tunnels. Non-academic users of our research include companies in sectors such as engineering design, manufacturing, healthcare, energy, aerospace, and safety, as well as public authorities.

b. Approach to impact

Our approach to achieving impact for our research, since 2008, has been a broad one, comprising the following highly interdependent key elements:

i. **Many of our basic research projects have been undertaken in collaboration** with business and industry and we involve such partners at the early stage of developing such proposals. eg EPSRC Grant EP/I032150/1, with Southern Water, Yorkshire Water, The Clancy Group and the British Concrete Foundation, DEFRA LINK Grant AFM 206 in collaboration with Brookfield and the EU FP6 NACRE project (EU contarct no 516068) in collaboration with Airbus, Dassault Aviation, EADS, Rolls-Royce and 21 other European partners.

ii. **Through UK and EU government-funded collaborative projects**, we have achieved significant levels of knowledge transfer into business and industry, eg KTP7105 in collaboration with GSK, KTP6806 in collaboration with Gutteridge and KTP7263 in collaboration with Welding Alloys, as well as EU BENEFITS (ref 4177) in collaboration with both UK and French industry.

iii. **Through EPSRC CASE, EU and other PhD studentships fully funded by business**, eg BAe (grant nos EP/C537688/1, EP/G501424/1 and EP/H501258/1), Ford (grant no EP/K504361/1), United Biscuits (EU FP6 Marie Curie 512247), Unilever (EU FP7 Marie Curie 264722), Hydro Aluminium (business funded) and Cummins Power Generation (business funded).

iv. **Short courses and workshops**. The CNMPA has delivered its suite of industrial short

courses in the area of bulk solids handling to a total of 677 delegates since 2008, as well as its five day short courses for human behaviour and evacuation modelling and fire dynamics, accredited by the IFE. The CIPDM has also provided a range of industry workshops to the manufacturing sector.

v. **Consultancy work with industry**. Since 2008, the CNMPA has undertaken consultancy projects valued at more than £1m for businesses and industry across the globe, including BASF, P&G, Unilever and GSK, whilst CSERG has undertaken concrete structural testing consultancy valued at more than £500k since 2008.

vi. **Licencing of our software tools** (eg EXODUS and SMARTFIRE). These tools have now been licenced to 314 users in 35 countries throughout the world, generating over £800k in licencing fees to the University.

The development and implementation of these approaches is strongly supported by the central Greenwich Research and Enterprise office (GRE). For example, GRE have a dedicated KTP manager to support KTP project development and management, as well as an IP manager to support patent filing, software licencing, etc.

Examples of Research Driven Impact

CNMPA: Early fire evacuation research from the mid 1980s through to the mid 1990s, primarily fire and evacuation modelling related to aircraft, was funded through a series of UK CAA grants. In the mid 1990s, CNMPA won two EPSRC grants, (GR/K38250, 1996-1998)) to explore fire and evacuation in aircraft and (GR/L5674901, 1998-2000) to explore modern approaches to CFD fire simulation. These grants lead to the development of the airEXODUS evacuation software and the SMARTFIRE fire simulation software. These initial projects in turn lead to a large number of additional funded research projects in fire and evacuation modelling funded by for example; EPSRC, EU (Frameworks 4, 5, 6 and 7), UK Government (HO, Cabinet Office, ODPM), MoD, FRA (USA), DOD (USA), Leverhulme Trust, TSB (Canada), etc and a large number of industrial projects funded by for example; Lloyds Register, Airbus, Bombardier, Jet Aviation, Agip, Borealis, Battelle Memorial Institute, etc. This research has lead to the further development of the EXODUS and SMARTFIRE software which now includes the following suite of specialist tools: airEXODUS, buildingEXODUS, maritimeEXODUS, railEXODUS and SMARTFIRE. This suite of commercial software has users in 35 countries around the world ranging from engineering consultancies, research labs, universities and government authorities.

In bulk solids handing an EPSRC project, “Quality in Particulate Manufacturing” (EPSRC GR/M15057/01) led to the development of a whole series of new instruments and process models for measuring and predicting the caking, segregation and degradation tendencies of powders in industrial processing, problems collectively worth some £9Bn pa to the UK alone, the project was “highly commended” in IChemE “Chemistry Innovations” award 2006. Since 2008, well over a hundred companies around the globe have used the direct outputs from the initial QPM project, either embedding the techniques directly or funding studies (mostly between £10k and £150k, totalling over £2M) at the University on their own materials and plants, including the world’s largest biomass energy project (conversion of the 3.96GW Drax power station from coal to biomass), in which the design of the new £205M fuel handling plant was critically informed by QPM techniques and their derivatives. A subsequent high impact project was the Economical Powder Flowability Tester funded by DEFRA (LINK AFM 206), to develop a new instrument for the measurement of the flow properties of powders, suitable for non-powder-experts to use in formulation, quality control and development of powder processes. In the three years since launch, this instrument has sold over 200 units world-wide and is in use by over 80 different companies across pharmaceuticals, food, minerals, fine chemicals and equipment supply sectors, making it already the most widely used method for measuring the flow properties of powders. This instrument was short-listed for the Times Higher Education Awards 2010 and the IChemE awards 2010 and made the list of the top 100 inventions in 2011 in the US.

SCERG: Under EPSRC Grant EP/I032150/1, SCERG is working with Southern Water, Yorkshire Water, The Clancy Group and the British Concrete Foundation to improve the safe assessment of underground concrete pipes. In particular, two models a) a stochastic finite element method and b)

an evolutionary method, have been developed and validated. We expect these models to be employed extensively in predicting the remaining safe life of such pipelines, which represent a multi-billion pound infrastructure investment in the UK alone. SCERG is also working with a range of businesses and local authorities in the area of non-destructive testing of concrete structures (bridges and tunnels in particular) including Amey, Atkins, Drilline, Kent County Council and Leica.

CIPDM: Through a series of EPSRC CASE studentships in collaboration with BAe Systems (grant nos EP/C537688/1, EP/G501424/1 and EP/H501258/1), CIPDM has developed and embedded in-house collaborative product development technologies. This work has also involved Cummins, Edwards Vacuum and Rolls-Royce.

c. Strategy and plans

A key strategic aim of the UoA is to continue and expand the impact-generating activities set out under b. above.

Over the coming years, our expansion plans include the following elements:

- Expand our world leading safety research to encompass security.
- Engage further in EU, TSB, EPSRC CASE and KTP projects to help transfer our research outputs into industry.
- Improve reach and market penetration of our IP through patents and software tools.
- Secure £4M in collaborative R&D funding from UK, EU (e.g. Horizon 2020) and international government and industry organisations to support our collaborative work with business and industry.

Our plans to achieve the above goals are to:

- Support staff to join EU networks to further expand our impact into Europe.
- Develop an impact plan (using the RCUK Pathways to Impact categories) at the inception of each new significant research activity.
- Disseminate our research findings widely and to a mixed audience, beyond academic journals.
- Expand our involvement in standards bodies such as ISO, by joining standards-setting committees.

d. Relationship to case studies

CNMPA research in the area of fire safety engineering is the theme characterising the impact described in case study 1, which sets out the core work of the Fire Safety Engineering Group (FSEG) within CNMPA. The case study demonstrates how, employing approaches i, ii, v and vi set out in b. above, our early basic research into human behaviour and evacuation simulation in the aviation sector (funded by CAA and EPSRC) lead 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 around the world has meant that the modelling tools resulting from the FSEG research have been used in major design projects in aviation (e.g. A380), maritime (e.g. CVF), and building (e.g. Pentagon) industries. Furthermore, the fundamental research into human behaviour undertaken by the FSEG to develop these tools has gone on to have impact in public policy and professional practice.

Research in the area of quality assurance of particulate materials, undertaken within the CNMPA, is the theme characterising research and industrial outreach in case study 2. The case study again demonstrates how, employing approaches i, ii, iii, iv and v in particular, as set out in b. above, our basic research (funded by EPSRC in collaboration with business) to develop techniques for prediction of the level of “quality loss” in handling of particulate materials through conveying, storage and logistics processes has achieved impact in manufacturing industry. This enabled new manufacturing processes and new products to be better analysed prior to committing to their final design or formulation, and existing ones to be improved through the running of “what-if” studies to test potential modifications to eliminate the difficulties. In addition, the detailed study of many industry plants processing solids led to a deep insight into the common problems, their causes, and the properties of the particulate materials that control this behaviour. Beneficiaries include GSK, Unilever, Imerys, Lafarge Cement and Mars.