Institution: University of Leicester

Unit of Assessment: UoA10 Mathematical Sciences

a. Context

The Department of Mathematics has three world-leading areas of expertise which lead to impact: mathematical modelling (MM) in which we search for equations which can be directly applied to solve real world problems, computational modelling (CM), in which we develop methods and tools to solve on computers equations which arise through mathematical modelling, and Data Approximation (DA) where we apply a range of statistical and non-statistical methods to gain intelligence from (usually) large data sets.

The types of users we are actively engaged with are:

1. **Large companies** in various sectors, which need academic services in MM, CM, and DA. Such companies tend to have industry standard software which solves standard problems, but is incapable of analysing more complex problems. Our formal partners here are Weatherford and Alstom, with more informal relations with Citigroup, EON, and DeLoitte.
2. **SMEs**, which need academic institutions for R&D partnerships, helping them to solve problems and develop technologies which support their businesses. Examples of our partnerships include: Apical of Loughborough, a company which develops advanced image processing technology for a wide variety of applications, with whom we have an industrially funded PhD student, and PetScreen, based at the business incubation unit BioCity, in Nottingham, which provides and develops advanced veterinary diagnostics to fight cancer in cats and dogs.
3. **Large public sector organisations**. These organisations usually have their own R&D departments and we aim to provide a high-level academic service in MM, CM, and DA. The Unit regularly collaborates with the British Geological Survey (BGS). We also partner internationally with leading hospitals including the State Research Institute for Medical Problems of Northern Regions (Russia) which includes a research institute and a network of hospitals. A member of our Department has participated in an international collaboration with NASA.
4. **Health service organisations** abroad including the Curie Institute in France; a private non-profit foundation operating a world famous research centre for biophysics, cell biology & oncology and a hospital specialising in the treatment of cancer.
5. We also engage with **schools and the general public** to inspire interest in mathematics.

b. Approach to impact

1. **Interdisciplinary collaboration within the University**

Through collaboration with colleagues in Geology in an NERC-funded project, we worked with the BGS. The Research Assistant taken on for this project became involved with a follow-on project with oil and natural gas company Weatherford, which now funds MM activity to improve industrial processes. Similar interdisciplinary collaboration with Engineering has led to potential interaction in fluid modelling at Alstom. Recognising the potential for creating impact from our work in this way, we have developed interdisciplinary themes intended to collect expertise from across the University, in data mining and in computational modelling. These collaborations enable us to apply our mathematical technology in a wide variety of areas, increasing its capacity for impact.

2. **Fostering Partnerships and Networking**

The unit recognises the value of developing a network within industry and the public sector. For this reason, we have organised a series of meetings and one-day workshops for industry, local government and non-commercial organisations. Each workshop focuses on a real-world challenge. In preparation for each workshop, we conduct a pilot study of the needs and challenges facing the participants. We also run an annual workshop for actuaries, which brings together University and private sector researchers to discuss issues of mutual interest. To create this network, we use institutional resources including the University of Leicester's Innovation Partnerships scheme, which funds short-term collaborations with industry and the public sector. Finally, national and international research networks are very important as a route for developing impactful research but also to widen the potential links with society for impact.

3. Knowledge Dissemination Events

The unit recognises the importance of knowledge dissemination and understands that the sharing of research findings through industrial conferences, workshops and exhibitions plays a crucial role in enabling impact. We take part in a variety of public and industry-facing events, most recently attending the "Stratified Medicine – Opportunities for Business" event, organised by the University of Leicester's business engagement hub Space IDEAS Hub at which our partners from Institut

Curie (Paris) and PetScreen (Biocity, Nottingham) presented the impact of our joint R&D work on their activity. We also recently hosted a Data Mining event for the Leicester Start-Up group which led directly to new links with an SME, Scicasts (Leicester) and with Leicester County Council.

4. **Industrial co-supervision of undergraduate and master projects, and PhD internships**

Each year, around 50 undergraduate and masters level projects involve industrial partners from the private, charity and public sectors. These partnerships demonstrate the Unit's capability in solving commercial problems. As well as helping our students prepare for their mathematical careers and improve their employability, the projects are often the first step towards a more sustained and long-term R&D partnership between external partners and academic staff. Additionally, some students have done short placements with companies, including Citigroup in London, Apical (Loughborough), Piran Partners LLP (Windsor), Alliance & Leicester bank (now Santander) and other companies. This year PhD students have done internships with RiskCare (London) and Asset Intelligence (Leicester).

5. **Sustaining alumni relationships**

We have recognised the valuable contacts that can be made with external partners through our former students. We make efforts to keep in touch with our alumni and this strategy has already resulted in several impactful relationships including collaborative work with Citigroup (London), and Phoenix (Peterborough)..

6**. Community Engagement**

The Unit recognises the value of engaging with the wider public and, in particular, the role it can play in inspiring young people's interest in science, in line with priorities identified in the Government's STEM Review (Science, Technology, Engineering and Maths). The Leicester research group on the mathematics of Aperiodic Patterns and Tilings has been particularly successful in achieving these impacts through public engagement, at times working alongside independent science promotion organisations such as The Royal Institution and The Royal Society. This area of research has a particularly visual aspect, which makes it immediately attractive and interesting to children and young people - and to adults with no mathematical expertise. Research problems and solutions have been translated into posters, models, hands-on puzzles and projects to promote enthusiasm and interest and exhibited widely in the UK.

c. Strategy and plans

The University has recently started to implement an ambitious and positive enterprise strategy. There has recently been a substantial increase in Enterprise and Business Development (EBD) support for the College of Science and Engineering (CSE), including the appointment of a new business development manager (BDM) based in the College, with a team of three, including a contracts manager and a commercialisation manager. The University have also appointed a very experienced Director of EBD, who has led the development of a detailed, user-focussed business plan, which was prepared in consultation with enterprise leads for the various Colleges and includes restructuring and expansion of the central EBD office to support the enterprise and impact priorities in the individual Colleges, and enhanced and targeted support for early stage enterprise projects through Proof of Concept and Prospect Funds.

At its inception in 2009, the College of Science and Engineering initiated a business development group (BDG). To provide strategic overview for this group the College has a Business and Industry Advisory Board, which has external membership. The BDM chairs the BDG, and the group has provided a forum for development and dissemination of good practice. A particular strategic development arising from BDG has been the creation of three College Business Fellows (CBF) within the department. The role of the fellows is to develop business links within their area of expertise, and to secure the engagement of colleagues in the College in this activity. The Department has created a new post of Impact Coordinator (Levesley), who will liaise with business and industry for the purpose of communication of departmental capability. He is now a Visiting Research Fellow at BGS, and is negotiating a placement with Weatherford and/or Alstom. He will apply for a Royal Society Industrial Fellowship to support this activity. He is working directly with the three CBFs supporting three thematic areas, MM, DA, and CM. These fellows are funded by Weatherford (approx. 100K per year) and internal college funding. Our plans for impact are most specifically in (1) Data collection, storage and analysis: to support social services (partners

Leicester County Council), to develop diagnostic tools for liquid-borne cancer (partners Avacta); to develop models for adaptation and mitigation of climate change (BGS); (2) Computational tools for fluid flow in industry, including reservoir simulation (partners Weatherford, Alstom, and BGS). To support this development the College is establishing strategic framework agreements with major companies, e.g. with Alstom Power; (3) Analytic modelling for mining applications (partners Weatherford). To support this activity we have a PDRA (Goldobin) working on specific projects which should lead to commercial impact; (4) Visualisation (partners Apical). To support this activity, the University invested £ 33K pounds into the setup of the Visual Intelligence Laboratory. The Laboratory hosts a high-performance workstation for large-scale parallel computations with GPUs, 3D projector, and a touch-screen computer. Through our industrial contacts (Apical LTD) we have recently hired two new members of staff to support research in this area with the total amount of external funding to support these posts exceeding the value of £130K; (5) Modelling of financial instruments (partners CitiGroup, RiskCare, RBF network); (6) Impact of pests on potato yields (partners Plymouth, DEFRA).

In our forward strategy we will continue what has worked well, as outlined in the previous section: the use of EBD to help develop links with SMEs; the recruitment of more CBFs in the next REF period; the continued development of national and international networks; the running of undergraduate and master-level projects, and the use of PhD students as interns.
Additionally we will: (1) Develop more formal relationships with companies and organisations. The BDM is negotiating a memorandum of understanding with Alstom. The University is working with BGS also on such a relationship. These relationships will free up more targeted resource to work on projects of mutual interest; (2) The developments of more formal academic networks, linked to industry: the UK approximation theorists (Levesley, Hubbert and Baxter (Birkbeck), Davydov (Strathclyde) are developing in collaboration with RiskCare and NAG (John Holden and Robert Tong), a network which seeks to provide algorithms for high dimensional data fitting to the finance industry; (3) Development of internal management structure: we will include management time in the projects for, for instance, writing business facing reports, meeting with senior colleagues in external organisations, and overseeing the use of resources inside the unit; (4) Extend the use of study leave to encourage industrial collaboration. Currently study leave arrangements are supporting Levesley to develop links with BGS and Weatherford, and Tyukin to develop the link with Apical. (5) Extend the engagement of colleagues with external organisations. We currently have around 40% of staff actively engaged with external partners and we plan that this will grow. The University has a policy of promotion, increment advancement, and achievement award based on enterprise activities. This is a key tool in encouraging staff.

d. Relationship to case studies

All the submitted impact case studies are the realisation of the strategy presented.
The work of Prof. Brilliantov with co-authors has been used by National Aeronautics and Space Administration (NASA) to evaluate the planned flybys of the spacecraft of the Cassini mission in 2009-2010, allowing the mission designers to calculate the danger of the Cassini Spacecraft colliding with dust in the Enceladus plumes and jets. This project is the result of the highly international collaboration, and the wide expertise of Prof. Brilliantov. Impacts on the policies and practices of the State Institute for Medical Problems of Northern Regions in Russia, affecting clinics and practical medicine. Following application of the mathematical “order in chaos” theory of correlation adaptometry (one case study). This is also a result of the strategy of highly international and interdisciplinary collaboration. Now, the impact of these methods becomes wider and it is used in the background of very recent methods of crises anticipation.
Impact on advanced veterinary diagnostics to fight cancer in cats and dogs. The system of the risk estimation for canine lymphoma through risk maps uses the recent results in data cartography and nonlinear principal component analysis. It is already implemented as a tool for online diagnosis (PetScreen, BioCity). The maps of risk are also used for human cancer analysis at Institut Curie, France. This collaboration started up as a Business Innovation Partnership, funded by the University.