Institution: University of Surrey

Unit of Assessment: UOA 10 Mathematical Sciences

a. Context

The key themes in the Department's current and future research strategy for impact relate to Biosciences, Fluids & Weather and Space Technology, supported through Public Engagement (Section b). These themes are sub-areas of the research groups in the Department, as some themes are more natural than others for impact on the non-academic sector (e.g. string theory and branches of pure mathematics have more limited opportunities). The main non-academic user groups, beneficiaries and audiences together with the main types of impact are grouped as follows:

Biosciences (including Life & Social Sciences and Industrial Ecosystems): key user groups are companies (Pfizer, GSK, Syngenta, MedImmune, Novartis), government institutions (Animal Health and Veterinary Laboratories Agency (AHVLA), Royal Surrey County Hospital, Radcliffe Infirmary, King's College Hospital), and semi-academic institutions (Diabetes Trials Unit, Surrey Sleep Research Centre, Robens Centre for Occupational Health & Safety). Impact involves health improvement, environmental and economic impact, cultural enrichment and public engagement.

Fluids & Weather: key user groups are UK Met Office and the companies Offshore Wave Energy Ltd (OWEL) and ITPower Ltd. The UK Met Office is a national institution with international impact, with research at Surrey contributing to the next generation forecasting model. The two wave energy companies have headquarters in Bristol and feed into a national strategy for wave energy, with Surrey providing underpinning mathematical modelling. Impact is environmental, economic and sustainable, and includes public engagement and the creation of new products (contribution to the design of ocean wave energy harvesters).

Space Technology: this area emerged from the dynamical systems research group, leading to an astrodynamics research direction joint with the Surrey Space Centre. The principal end users in the UK are Surrey Satellite Technology Ltd and Astrium Ltd, both international companies. Engagement during the REF period has included collaborative research via a Marie-Curie Training network, EPSRC CASE award, and the employment of PhD graduates in the sector. The impact involves the creation of new products (contribution to the design of satellites), a training programme as well as indirect economic and environmental impact.

b. Approach to impact

The Department has always been opportunistic in its interaction with non-academic users (industry, schools, hospitals and the general public), welcoming enquiries from potential beneficiaries. Although an 'impact strategy' based on this approach has not been formalised before, there have been a range of successes, and recently these have dovetailed with EPSRC priorities through the ERIE, MILES and OWEL projects, and EU priorities through the AstroNet and Marie-Curie Training Networks. The following highlighted themes which have not only enhanced our research environment but also contributed to our developing impact strategy (section c):

Biosciences (including Life & Social Sciences and Industrial Ecosystems): Impact has arisen in different ways. The Biopharma Skills project played a key role in starting the Pfizer interaction, whilst interactions with The Radcliffe Infirmary and the Diabetes Trials Unit (Vitamin D project) arose due to a requirement for statistical analysis. The AHVLA, the Royal Surrey Hospital, Surrey Sleep Centre and Robens interactions have long-standing contacts with members of the department. Through MILES (*Models and Mathematics in Life and Social Sciences*), an EPSRC-funded *Bridging the Gaps Programme*, the brokering of partnerships between mathematics and other disciplines and contacts outside of academia is being formalised and accelerated, e.g. through "Industry and Stakeholder Days" which brings together end users and academics in a sandpit environment. The university is funding a post-MILES programme called "Collaboration Surrey". The theme of "industrial ecosystems" emerged entirely through ERIE (*Evolution and Resilience of Industrial Ecosystems*), an EPSRC-funded project which runs until 2016, joint between sociology, computing, Centre for Environmental Strategy (CES), and mathematics. One facet of ERIE is the use of regional workshops where problems are identified and participatory modelling is used, honed back at Surrey and then fed into the next meeting, to create a model for the end user group (e.g. the impact case study on the Humber region).

Fluids & Weather: Regarding meteorology, all external focus is towards the Met Office and its close-knit network of academic contributors which also includes Exeter, Leeds, Oxford and Reading. The principal conduit for Surrey is the National Centre for Earth Observation (NCEO), which is a major NERC-funded enterprise, with Roulstone the national team leader for data assimilation (DA). A second source of meteorological impact is PhD funding: the Surrey EngD programme on sustainability which currently has 2 PhD students embedded at the Met Office, and the new NERC-funded Doctoral Training Partnership with Reading. The ocean wave energy harvesting project was initiated by industrialists contacting the Department due to an interest in a research project on sloshing. The interaction started as a consultancy and has now expanded into an EPSRC-funded collaboration which runs until 2016.

Space Technology: Astrodynamics research was initiated in 2002 in collaboration with Surrey Space Centre (SSC) and Surrey Satellite Technology Ltd. (SSTL) and has focused particularly on the work of PhD students (5 graduated since 2008; 3 in progress) supported by EPSRC, EU, overseas scholarships and Department funds. Two former PhDs have entered employment in the space industry, one overseas and one with SSTL. The European Space Agency (ESA) was a partner in the EU Marie-Curie Research Training Network *AstroNet I* (2007-10) led by the Surrey team, and is now joined by 5 companies from across Europe, including Astrium Ltd, SSTL and Clyde Space Ltd, in the successor Training Network *AstroNet-II* (2012-2015), which continues to provide a comprehensive academic-industry training network for PhD students and postdocs.

Public engagement: Outreach has been an integral part of Department's history; a recent example is the publication of Roulstone's book (joint with John Norbury, Oxford) on the history of numerical weather forecasting (*Invisible in the Storm: The role of mathematics in understanding weather*, published by PUP). It has attracted international media attention resulting in articles (e.g. Scientific American), reviews (e.g. Nature, Guardian) and radio interviews. With the advent of the MILES programme, public engagement has been formalised, organised and expanded in conjunction with the Faculty marketing office. Recent successes showcasing innovative approaches to public engagement include Laban's geometry of dance, FAMELAB and research-based stand-up comedy (performed at the Bright Club Guildford and at the Edinburgh fringe!).

Departmental Support: The Department has strongly supported outreach and impact activity. For example, £45k (supplementing £25k from external sources) has been committed to Collaboration Surrey, extending the MILES programme to post 2014, whilst a one-month postdoc position was provided to assist in the initial stages of the wave energy project. The Department also contributed to a workshop on climate science (May 2011) to facilitate expansion of weather/climate research into the international realm, and has contributed to PhD funding for astrodynamics projects and a recent joint PhD project with AHVLA. The Faculty has its own marketing team and regular meetings with them are used to feed into outreach activities. A research blog, linked to the main Department website, is used to ensure that research highlights are shared with the general public.

Support from the University: The Department is supported in its approach to impact by the University's Research and Enterprise Support (RES) team. As well as providing KT expertise to ensure the commercial exploitation of research, RES provides project management for the key partnerships and requisite commercial, legal and IP expertise to help enable the creation of impact.

c. Strategy and plans

The unit has conducted a review of the impact activity since 2008, highlights of which are included in Section b, and understands the value in creating a more formalised structure and support around impact. The successes in the period have informed the unit's strategy for achieving impact going forward. The review has also highlighted activities that could be better exploited, and in some cases work has already begun on these. The key elements include plans to:

Staffing related initiatives:

- Update annual staff appraisals to recognise and reward achievements in impact, and recognise excellent impact at University level through annual impact awards.
- Increase exposure and dissemination of impact activity within the Department through the appointment of an 'Impact Champion' who will report to the Mathematics Research Committee.
- Strengthen our alumni programme to ensure that our graduates remain advocates for the Department's research and technical capabilities throughout their careers.

Specific initiatives:

- Maintain and build-on long standing relationships through periodic updates, aiming to understand business needs and outlining our research plans to end users at an early stage.
- Develop Collaboration Surrey, a university funded venture which plans Collaboration Café events, small grants scheme, Themed Networking events, Industry and Stakeholder days, Behind the Scenes tours, and Meet the Expert events.
- Continue to expand work with pharmaceutical companies; e.g. the impact case study on drug discovery with Pfizer has now been expanded to include MedImmune.
- Continue to support socio-economic modelling through ERIE and its role in underpinning environmental and sustainability initiatives such as the Humber region project with potential expansion into other areas of the UK.
- Further expand mathematical meteorology for underpinning of national weather forecasting in conjunction with NCEO and NERC. DA research will also be applied to other areas.
- Continue to support the wave energy project with OWEL, which has an anticipated 20-year timeline, through advising on how the development of technological solutions can best be informed by recent mathematical research insights.
- Further utilise the AstroNet II Network to strengthen relationships with participating companies and seek opportunities to place students within the companies, with research clearly aligned with the next generation of UK and EU priorities on space.
- Grow outreach activities, with a designated Department marketing officer, research blog, and a pro-active Faculty marketing team, as well as an independent public engagement pathway through MILES and Collaboration Surrey.
- Include non-academic placements as an option in MMath and PhD training programmes, and maintain links with graduates (of both UG and PG programmes) that have moved to non-academic institutions (e.g. the AVHLA connection started this way).

d. Relationship to case studies

The four case studies exemplify the approaches to realising impact in section b. All arose due to individual initiative and were then developed with full Department support. The particular mechanisms are described below;

Case Study 1: “Modelling the evolution of a bio-based economy in the Humber region”

Surrey’s CES had an existing relationship with the Humber region and brokered a partnership between an ERIE Mathematics-Sociology team and key regional stakeholders who acted as gateways to regional networks. Modelling was proposed, its role recognised, a relationship formed, interaction developed and evolved, leading to the fully developed case study.

Case Study 2: “Exploiting nonlinearity in operational data assimilation for weather prediction”

This case study started through interactions within a network between the Met Office, University of Reading and University of Surrey. The Surrey team leader became aware of an open problem at the Met Office in DA and formulated a long term project to provide a solution. The research outcomes were fed back to the Met Office, and also opened up new avenues of enquiry and these are now the basis of new directions in DA research, under the umbrella of NCEO.

Case Study 3: “Modelling and analysis of ocean wave energy extraction devices”

The OWEL project started with an ocean industry firm contacting the Department, having seen a particular body of research that addressed their needs. Initially, the Surrey team offered advice and consulting. It was soon realised that Surrey could contribute in a more substantial way; the project is now robustly funded and multi-faceted with the Surrey team contributing in several directions as part of a long-term plan.

Case Study 4: “Guiding drug discovery by prediction of in vivo efficacy of monoclonal antibodies”

This case study arose due to two key factors. The company contacted individuals directly, the staff responded positively and the Department was supportive. Secondly, the BioPharma Skills Project provided a conduit to facilitate the interaction. This combination evolved into a fully developed impact case study. The project is expanding and now includes other pharmaceutical companies.