Institution: Lancaster University

Unit of Assessment: 10 - Mathematical Sciences

a. Context

Our primary pathway to impact is through direct collaboration with end-users, developing novel statistical solutions to their real-life problems. Since the early 1990s impact has been central to the statistical research that we undertake. In particular we work with (i) industrial sectors including defence, energy, finance, manufacturing and pharma; and (ii) government agencies such as the Environment Agency, the Department of Transport and the Home Office. Our work is making an impact in: **health** (such as developing efficient designs for clinical trials), **environment** (better design of offshore installations), **public policy** (impact on design standards of ocean-going bulk carriers) and the **economy** (assessing the effect of consumer goods on personal appearance).

b. Approach to impact

Strategy

The statistics group at Lancaster has a strong tradition of collaboration with end-users, and a track record of research that has led to impact, particularly in sectors linked to the environment and medicine. Instead of first doing generic research followed by a separate attempt to get end-users and potential beneficiaries interested in applying it, much of our research is motivated by its potential impact on important real-life problems, is carried out in collaboration with end-users, and has the potential to lead directly to impact. The primary pathways to impact are directly collaborating with end-users and producing research outputs that are easy for them to implement.

Our impact strategy is centred upon maintaining existing research collaborations with end-users, and developing new ones; creating a culture in which impact of research is valued highly by all staff; and both resourcing and rewarding staff for achieving the maximum impact from such collaborations. This has influenced appointments, our use of resources, and the development of support structures within the UoA to facilitate such collaborations.

During the past 5 to 10 years we have deliberately attempted to develop and strengthen our level of interactions with users. This has seen a step-change in the number of collaborative research projects we are involved in, partly by expanding our range of collaborators into areas such as defence, energy, and manufacturing. These changes have been achieved through:

- Appointments just prior to the REF census period: Whitehead, who had a track record of working extensively with pharmaceutical companies; and Eckley, who moved from a senior position at Shell, motivated by a desire to see academics and industry collaborate more effectively to develop high quality research which can deliver impact.
- Collaborating more strongly with the OR group, at Lancaster. This was initiated through the joint appointment of Glazebrook to both the statistics and OR groups, and has enabled us to tackle industrial problems at the interface of statistics and OR.
- Use of UoA resources to support collaborative activities. For example through earmarking £150K to co-fund PhD studentships with industry in 2008/9 (prior to establishing a similar co-funding model when starting the EPSRC-funded STOR-i Doctoral Training Centre in 2010).
- Leveraging the reputation and activities of STOR-i and the Medical and Pharmaceutical Statistics Research Unit (MPS) to support and develop new collaborative research opportunities and partnerships with the potential for future impact.

Evidence of the success of these activities is that the proportion of research funding from industry has risen from 5% to 25%, with the funding of 22 PhD students and 6 PDRAs, during REF; and we have already secured industry co-funding for an additional 30 PhD students from 2014.

Facilitating collaborations with end-users.

Our experience is that developing a UoA-wide approach to **partnership with end-users** is the most efficient way to achieve successful collaborations. This allows us to embed an 'excellence with impact' culture across the UoA and offer broader engagement opportunities for our partners. We aim to develop long-term partnerships, as they are most likely to lead to substantive impact.

We have achieved this over the REF census through a two pronged approach under the broad umbrellas of STOR-i and MPS. Both are run in collaboration with non-academic partners. They have helped us develop both a visibility and reputation with end-user groups that gives us a strong platform for developing collaborative research projects that are likely to lead to impact.

Whilst the primary aim of STOR-i is to develop future research leaders in statistics and OR, it is also an ideal vehicle for facilitating broader interactions between academic researchers and potential industry collaborators. There are substantial attractions to industry from being able to interact with our large cohort of graduate students who are working within a skill-shortage area.

Specific relevant activities across STOR-i and MPS include:
- A member of staff (Eckley) who leads the comprehensive industrial partnership programme and supports new members of staff as they begin to work in partnership with industry.
- Networking opportunities with practitioners from a range of companies who are directly involved in the activities and management of STOR-i or MPS.
- A range of activities aimed at developing new contacts with end-users, including industrial problem solving days, where companies can present an open research problem they have to our students, and get feedback about how statistics and OR could be used to tackle it; and an annual workshop to which potential industrial collaborators are invited.
- The opportunity for potential new industrial partners to work collaboratively with researchers at Lancaster through part-funded PhD projects, or through Masters dissertation projects.

An example of the success of this approach is the long-term partnership that has been developed with Shell. During the census period they have funded 6 PhD students and 4 interns on projects linked to extremes and changepoints. Their motivation for this continued support is that the body of research they fund is impacting on how they assess risk of oil installations. Evidence of the value of these partnerships to our large range of industrial collaborators is seen from the substantial support (£1.1M cash and £4.1M in-kind) they committed to the successful renewal bid for STOR-i.

Culture of Impact
The presence of leaders who are personally committed to impact has enabled us to develop a culture where impact is highly valued. This is achieved through mentoring, and one-to-one training and support on how to work successfully with end-users. To further stimulate this culture we embed interaction with end-users within the day-to-day research environment through encouraging and supporting research visits by collaborative end-users. A number of our collaborators have been awarded honorary positions at Lancaster (Southworth, Astra Zeneca; Jonathan, Shell Research; Lamb, JBA Trust), and regularly contribute to activities of research groups.

Our success in developing such a culture can be seen by how individual staff are pro-active in taking advantage of opportunities which may lead to impact when they arise. For example, Eckley used contacts within Unilever to arrange three days of research meetings between Lancaster and Unilever. This led to Unilever funding an RA and 4 PhD students to research into statistical methods to analyse the large amount of data collected by data-loggers. Neal took advantage of contact made by Business Safety Systems Ltd to do exploratory research into how to predict work absences which has led to funding of a Knowledge Transfer Partnership.

Support of and Reward for Staff.
Over and above the support described above, there is funding available, both at a UoA and a faculty level, for staff to develop links with end-users, and to explore impact of research.
This often involves funding for visits to or from the potential end-users from HEIF funds and the university's EPSRC impact accelerator account.

Key to the take-up, and hence impact, of new statistical methods is the availability of appropriate software. We provide training for researchers to develop software, generally in the form of R packages; and encourage an outlook that the production of such packages is a central part of research. The potential for enabling impact can be seen by the publication of the changepoint package leading to contact with numerous end-users and to the underlying statistical algorithm being developed for inclusion in the NAG suite of routines.

Lancaster also rewards the impact of research through criteria for promotions, that specifically recognise "activities designed to ensure that appropriate impact of research (outside academia) is achieved". This criterion was important in the successful professorial promotion of Eckley.

Examples of Impact
Through MPS our research has impacted more than twenty clinical trials during the REF period, leading to designs that shorten trial duration, reduce the numbers of patients used or make

possible a trial previously considered infeasible. Collaborative work with Southworth (AstraZeneca) has led to a new method for evaluating clinical laboratory safety data, work that was awarded the 2012 RSS/PSI Statistical Excellence in the Pharmaceutical Industry award.

We have a large number of on-going research projects in STOR-i with ATASS, BT, DSTL, KSS, Man Investments, MBDA, the Met Office, Shell, SSE and Unilever. These projects are focussed towards impacts that will occur after 2013. For example, they include developing methods to detect the build-up of deposits during drilling, and Bayesian methods for estimating price-elasticity of demand. A current Knowledge Transfer Partnership with BT uses stochastic modelling to understand interference of transmitted TV signals, so that BT can commercially exploit the use of TV Whitespace that has recently been made available.

Our statistical research with end-users contributes to impact case studies submitted to UoAs 3 and 20. The first of these involves novel spatial statistical methods that are used to more effectively implement a WHO programme for preventing blindness in sub-Saharan Africa. The second concerns impact on Home Office policy, and tools that are used in parole decisions.

c. Strategy and plans

Our long-term plan is to employ our established approach to impact, which is fully embedded in our research philosophy, and to exploit our strong reputation for our collaborative work with end-users. For MPS we see an opportunity to expand through increased links with companies within the EU. As part of this we intend to focus more on pre-clinical and paediatric trials: areas we view as increasingly important ones for the application of novel statistical methods. Using the renewal of STOR-i as a springboard we plan to develop stronger links with existing partners, and create links with new collaborators. These include IBM, whom Lancaster has signed a strategic partnership with, EDF, SAS, Scottish and Southern Energy and Winton Capital.

Additionally this approach will be enhanced by the following areas of growth and new initiatives:
- *Defence and Security:* we see this as an area for growth, building on recently-started projects with DSTL, a research partnership with the Naval Postgraduate School in the US, and potential new links through Security Lancaster, an inter-disciplinary centre at Lancaster.
- *Big data:* We plan to set-up a new research group in statistical machine learning, which will have a strong focus on impact. This group will work with and complement our existing research strength in modelling of complex stochastic systems. Already we have a number of industrial partners (e.g. IBM and Unilever) who are very keen on collaborating with us in this area.
- *Rigidity:* this is a multi-themed area of mathematics and applications in which we already have strength but see potential to expand from our theoretical-base to create an internationally recognised centre of researchers who actively engage with end-users. In particular, the stimulus for current theoretical research in this area comes from engineering, such as smart micro-engineering, robotics, material science and biochemistry.
- *Changepoint detection*: this is a recurring research theme across many distinct application areas (e.g., projects with BT, Shell and DSTL). We aim to capitalise on opportunities afforded by leading a forthcoming Isaac Newton Institute programme and our recent creation of a critical mass of researchers in this area.
- *Research Impact fellowships*: To ensure maximum future impact from our large-range of existing collaborative research projects we will fund a series of post-doctoral impact fellowships. These will give the fellows time to further develop ideas from their PhD as appropriate for specific industrial applications. Lancaster has already committed to fund nine one-year impact fellowships from 2014-23. We aim to secure additional funding from industry, either directly or indirectly through leveraging Lancaster's impact acceleration account.

The **key metrics** we will use to assess progress by the next REF will be the amount of industrial funding, the number of new impact-driven research groups, the research outputs of the impact fellows and their inclusion within case studies, the level of diversification of our industrial partners, and the increase in the number of PhD projects co-funded with industry.

d. Relationship to case studies

All case studies stem from collaborative research projects. Our impact on both the design of flood-defences and on spatial risk assessment of flooding come from long-term partnerships with end-users: demonstrating the gains of such partnerships in producing substantial and sustained impact.