Institution: The Open University

Unit of Assessment: B10 Mathematical Sciences

a. Context

The main non-academic user groups and beneficiaries of The Open University's (OU) mathematics and statistics research include (1) the public, clinical practitioners and health workers, due to our work in medical statistics, (2) the public and the economy, through technological applications of theoretical physics, and (3) the public, through our extensive public engagement activities aimed at improving the understanding and uses of mathematics and statistics.

(1) Impact of medical statistics research
Statisticians in the Department work on methodological subjects that are motivated almost entirely by important real-world applications with considerable societal impact, albeit often indirectly. For example, our work on medical statistics, mainly carried out by **Paddy Farrington**, **Paul Garthwaite**, **Kevin McConway** and **Heather Whitaker**, has huge impact. Highly significant examples are given in our two impact case studies, associated with **Farrington** and **Garthwaite**.

Another example of ongoing medical statistics research that has had huge impact is the work of **Farrington** on the detection of outbreaks of infectious diseases. In 1996 his work led to an algorithm called robust Poisson regression (RPR – also known in the literature as 'the Farrington method') for detecting the occurrence of such outbreaks. The algorithm is applied to large databases of incidences of infectious disease or syndromic reports (eg coughs and sneezes) such as those gathered by the Health Protection Agency (HPA), now called Public Health England, and NHS Direct (or NHS24 in Scotland), searching for evidence of emerging outbreaks. It monitors all the 4000+ infectious diseases listed on the HPA database and has been in continuous use at the HPA since 1996, as well as being used by several other national surveillance agencies.

From 2009 to 2013 the performance of the RPR algorithm has been further enhanced by research at the OU in collaboration with statisticians at the HPA and Health Protection Scotland, with funding totalling £650k from the NIHR and the MRC. The aim has been to increase the sensitivity of the algorithm, reduce the false detection rate, and provide new tools for method evaluation and comparison for large multiple surveillance systems. The RPR algorithm continues to be one of the most robust and versatile systems available for outbreak detection, with a lasting public health impact.

(2) Impact of theoretical physics research
The applied group's research is heavily motivated by real-world problems. For example, **Michael Wilkinson** works at the interface between statistical physics and fluid dynamics, exploring applications in meteorology and astrophysics. Other work has technological applications, with consequent economic and societal impact. A highly important example is **Andrey Umerski**'s work in the field of `spintronics', which attempts to exploit the spin and magnetic moment of electrons in solid state devices. The field has already revolutionised the hard disk industry, being primarily responsible for the approximately one thousand-fold increase in hard disk storage capacity over the last twenty years.

As described in the impact case study 'Hard disks based on tunneling magnetoresistance', **Umerski**'s work on MgO based tunneling systems directly contributed to this development. His pioneering work is now the basis of magnetic random access memory (MRAM), a new type of non-volatile memory that is being actively developed and may someday replace both hard disks and existing random access memory. His recent publications (*Phys. Rev. Lett.* 104, 217202 (2010) and *Phys. Rev. B* 83, 052403 (2011)) may well lead to further vast improvements in hard disk storage capacity, and in the application of MRAM. Furthermore his predictions in another paper (*J. Appl. Phys.* 111, 053909 (2012)) promise to solve the fundamental problem inhibiting the development of MRAM, namely, how to write information with low current density.

(3) Impact of public engagement

Presenting mathematics and statistics in an attractive way to the public is in the interests of society as a whole. In particular, innumeracy and the misinterpretation of quantitative information cause problems at all levels, including the shaping of government policy. It is a normal and deeply embedded activity in the Department to seek to share mathematics and statistics knowledge as widely as possible. For example, we have given and organised many 'popular lectures' to large audiences, including those by **Robin Wilson** as Gresham Professor of Geometry (2004–2008).

Our public engagement work also encourages young people to study mathematics and statistics. For example, in recent years we have run Royal Institution Masterclasses at Bletchley Park, Bradford (with Bradford University), Manchester (with the Museum of Science and Industry) and Worcester (with the University of Worcester). **Katie Chicot** is a director of the UK Mathematics Trust, which advances the mathematical education of school students, through organising national mathematics competitions and training for the International Mathematical Olympiad team.

Some significant examples of public engagement, based on OU research expertise, are as follows.

- **Jeremy Gray** and **Robin Wilson** were academic consultants to the BBC4 series *Story of Maths* (average audience: 389k), presented by Prof. Marcus du Sautoy (University of Oxford) with **June Barrow-Green** as an expert contributor. **Ian Short** was academic consultant to the BBC2 series *The Code* (average audience: 1.76 million), also presented by Prof. du Sautoy. The OU continues to support the BBC's charter obligation to 'educate' through our contributions to TV and radio programmes, arising from our close connections and influence with BBC producers.
- **June Barrow-Green**'s 'Poincaré and the Three Body Problem', which describes Poincaré's seminal 1889 memoir providing the mathematical inspiration for 'chaos', is the standard monograph on the subject and a best-selling volume in the history of mathematics. She has made many media appearances to discuss this topic, as an expert contributor in the BBC4 TV programme *High Anxieties: The Mathematics of Chaos* (2008), Melvyn Bragg's BBC Radio 4 programme *In Our Time* (discussing the solution in 2006 of the Poincaré Conjecture) and the BBC Radio 4 programme *Woman's Hour* to discuss the work of Sonya Kovalevskaya.
- **Kevin McConway** has been academic advisor to the BBC Radio 4 programme *More or Less* since 2005. This covers mathematical and statistical ideas in the media, and other Department members have been interviewed on it. **McConway** has also appeared on BBC Radio 4's *Today* programme and other radio stations to discuss statistical applications, and he is a regular 'expert speaker' on Statistics in the Media to audiences ranging from the National Audit Office to 'Skeptics in the Pub', where topics of wide interest from science, history, psychology and philosophy are discussed.
- **Uwe Grimm**'s work on quasicrystals led to his successful bid for an EPSRC public engagement grant to organise the exhibit 'How Do Shapes Fill Space?' at the Royal Society Summer Science Exhibition 2009, and to develop workshop activities in collaboration with the Royal Institution. His exhibit featured tilings with great visual appeal and links to architecture and the arts, and to current research on quasicrystals. About 5000 people attended the exhibition.
- The work of **Phil Rippon** and **Gwyneth Stallard** on complex dynamics led them to discover a new structure for the escaping set of an entire function, called a spider's web. One of their spider's web pictures was exhibited in 'The Art of Mathematics', organised by Prof. Lasse Rempe-Gillen at the BA Festival of Science 2008 and at the Victoria Gallery, Liverpool in 2009.

(4) Impact of consultancy work

Robert Brignall worked at the Heilbronn Institute, University of Bristol, from 2007 to 2010, and has an ongoing contract for consultancy work there. While this work is classified and so cannot be disclosed, his earlier work for the Heilbronn Institute has had significant impact.

Paddy Farrington was appointed in 2012 as an expert statistical witness to the Tribunal de Grande Instance de Paris, to advise on the high-profile 'Affaire Médiator'. The experts' 700 page report may have significant impact on certain practices within parts of the French drugs industry.

b. Approach to impact

As indicated in Section a, as well as our environment statement and two impact case studies, Department members involved in the medical applications of statistics have close and regular contact with medical practitioners and statisticians working within the NHS and elsewhere, and their research agendas are often driven by the statistical needs within that medical environment.

Department members involved in public engagement have strong ongoing connections with organisations that facilitate this engagement, such as the BBC and other media, the LMS and the RSS. They also emphasise this aspect in bids for research funding.

Applied mathematicians whose work has potential real-world applications attend international conferences where large numbers of experimentalists are present. They have built a formidable base of experimental contacts leading to a variety of collaborations and potential impacts. For example, **Grimm** organised the conference APERIODIC'09 jointly with Prof. Ronan McGrath (an experimentalist at Liverpool University) to facilitate the exchange of ideas. **Umerski** was one of only three theorists to work on the 'Spin@RT: Room Temperature Spintronics' project, a £2 million EPSRC-funded consortium consisting mainly of experimentalists from the universities of Cambridge, Durham, Leeds, Exeter and Edinburgh. Moreover, Dr Aidan Hindmarch of Durham University was recently awarded a £93k EPSRC grant (EP/L000121/1) to attempt to experimentally validate the predictions of a paper of **Umerski**'s (*Phys. Rev. B* 83, 052403 (2011)).

The Department itself takes a positive attitude to all areas of its work that have the types of impact described above, and these areas are regarded positively within the University's promotion system.

c. Strategy and plans

The Department will continue its approach to developing impact in the areas of medical statistics and public engagement, which are working well. Moreover, the OU's project, 'An Open Research University', which is one of eight funded by RCUK under the scheme 'Catalyst for Public Engagement with Research', aims to embed public engagement with research within The Open University's overall strategic planning for research from 2012 to 2015. The University has an active research communications strategy that widely disseminates the Department's research outcomes.

In applied mathematics, the possibility of real-world applications is regularly included in bids to the EPSRC and elsewhere. In addition to the work of **Umerski** mentioned earlier, **Wilkinson**'s work on turbulent aerosols in his paper (*Phys. Rev. Lett.* 97, 048501, (2006)) has the potential to give a new fundamental understanding of rainfall, relevant to terrestrial meteorology as well as to climate on other planets, which he will pursue. This may have significant impact, for example, on the design of instruments for astrophysical observation.

There is an emerging energy research group, mentioned in REF5, led by **Ben Mestel** and Prof. William Nuttall (OU, Professor of Energy), with the potential for significant non-academic impact.

Finally, the OU is implementing a new research awards management system, which includes a section for capturing post-award research impact that will focus our attention further in this area.

d. Relationship to case studies

The three case studies are representative of ongoing work in the Department with potential impact outside the academic world. Each of them arises from research and development, driven by methodological improvements required to enhance and widen their applicability and impact.