Institution: Lancaster University

Unit of Assessment: UoA10 Mathematical Sciences

a. Overview

This submission is based around four research groups within the Department of Mathematics and Statistics: Analysis, Algebra, Statistical Modelling and Statistical Methods in Medical Research. Henceforth we will use *pure mathematics* to refer to the first two groups, and *statistics* to refer to the latter two. Examples of research areas covered by these groups:
Analysis: Noncommutative probability and operator algebras; Banach algebras; stochastic processes and random matrices.
Algebra: Homological algebra, algebraic geometry and topology; geometric group theory and group representations; Lie theory and quantum groups; combinatorics.
Statistical Modelling: Computational statistics; extremes; wavelets and locally-stationary time series.
Statistical Methods in Medical Research: Design and analysis of clinical trials; survival and longitudinal data analysis.

The research environment within the mathematical sciences at Lancaster is enhanced by interaction with strong research groups in *social statistics* (based in the Department of Mathematics and Statistics, but submitted to UoAs linked to application areas); *statistics for biomedical and health sciences* (based in the Medical School); and *operational research* (based within the Management School, and jointly running the EPSRC-funded STOR-i Doctoral Training Centre). Altogether Lancaster boasts one of the largest groups in statistics and operational research in Europe, with over 40 faculty and over 70 PhD students.

How the research groups relevant to this submission have developed during the census period:

	Faculty (FTE)		**RAs (FTE)**		**PhD Students (FTE)**		**Research Income (per year per FTE submitted)**	
	Dec 2007	Dec 2013	Dec 2007	Dec 2013	Dec 2007	Dec 2013	RAE2008 (£K)	REF2014 (£K)
Pure	9.0	16.3	1	4	5	12	1	11
Statistics	13.6	16.2	4	7.6	14	33.5	26	64
All	22.6	32.5	5	11.6	19	45.5	18	36

b. Research strategy

Achievement of Strategic Aims

Our research strategy has been set following regular reviews of our research in which we involve external experts from the international academic community and users of our research. Key strategic aims during the REF census period were:

1. *To expand and develop pure mathematics.* We have had a two-phased strategy: consolidation of the pure group's strength in analysis, followed by expansion to include a vibrant research group in algebra. This began prior to RAE2008, and has accelerated during the REF census period: in December 2007 we had 9 faculty in pure mathematics (8 in analysis, 1 in algebra), as compared with 16.3FTE now (8.3 in analysis, 8 in algebra). This expansion included the appointment of Lazarev, Dales and Elek to new professorial positions.

2. *To develop closer links with industry*. Appropriate industrial collaboration gives access to stimulating research challenges that motivate transformative research as well as providing an alternative source of funding. Historically the department had strong industrial links within medical statistics, but we have purposely and substantially widened our set of industrial collaborators. This has built upon the appointment of a member of staff from industry with a role that has had a focus on developing new links with industry. This has led to:
   - Industrial funding from over 20 different companies during the REF census period including co-funding for 22 PhD students, funding for a research fellow and 5 RAs, and a commitment to co-fund 30 PhD students post 2014;
   - Substantive industrial support for research council grants applications including the STOR-i Doctoral Training Centre (over £1.6M cash and £5M in-kind support for 2 successful grant applications); and industrial involvement in PGR training activities and on advisory boards.

- An increase in overall research funding from £600K per year in RAE2008 to £900K per year for REF2014, with the proportion from industry increasing from under 5% to over 25%.

Industrial applications have motivated fundamental statistical research such as the modelling of spatial extremes, detecting changepoints in big data, and inferring structure in images.

3. *To strengthen PGR provision, recruitment and training.* This has been achieved through:
   - Establishing the £6.7M STOR-i Doctoral Training Centre. Its success is evidenced by its achievement of the highest grade at its mid-term review, and the recent successful renewal of the Centre with £12.6M of funding from EPSRC, Lancaster University and industry.
   - Substantial University investment in studentships (over £600K during the census period).
   - Leveraging additional industrial funding, and involvement in training, for PhD students.

   We now have a range of new training opportunities in the mathematical sciences; greater involvement from industry in our PGR provision; and increased recruitment to our PhD programmes. Many of our PGR activities have been highlighted as best-practice by EPSRC.

4. *To increase our international research profile.* We believe that developing a strong network of collaborators is of particular importance for early career researchers and that funding collaborations is a cost-efficient way of supporting research. We have been pro-active by:
   - Running the British Council funded UK-India (UKIERI) research collaboration network - *Quantum Probability, Noncommutative Geometry and Quantum Information* (2008-2012; £160K) involving 4 other UK universities, and 6 leading institutions in India.
   - Initiating the LMS funded network, *Quantum Groups, Operators and Noncommutative Probability,* with the Polish Academy of Sciences and the University of Leeds.
   - Setting up strategic partnerships with the Naval Postgraduate School (US) and with Statistics for Innovation (Norway), supported by £75K from Lancaster University.
   - Providing new sources of funding within the UoA for individual research visits: these have financed around 50 research visits during the census period.

Strategic Vision:

Our strategic plan for the coming years involves substantial growth in mathematical sciences research, both supporting existing research strengths and investing in new groups in probability, statistics for large data problems, and geometric rigidity. The initial steps involve making 10 appointments over the next two years. Specific plans include:

- *Establishing a strong research group in probability.* Probability is viewed as a natural growth area at Lancaster given its potential for bridging research between the pure mathematics, statistics and OR groups; and its relevance to research problems proposed by existing industrial collaborators. We aim to grow this area to a group of 8 academic members of staff.
- *Being at the forefront of research that tackles the challenges of fitting complex models to large data*. This is a theme that cuts across our research groups in computational statistics, extremes and wavelets and locally-stationary time-series; and is central to the recent £2.4M EPSRC programme grant *i-like* (joint with Warwick, Oxford and Bristol). Our existing strength in this area, strong academic links and access to challenging applied problems through our industrial collaborators, makes us ideally placed to realise this aim. We will grow our expertise in this area through setting up a new group in statistical machine learning.
- *Developing a world-leading group in geometric rigidity theory.* We see an opportunity to build on the expertise of Power and Schulze, our broader expertise in analysis and algebra, and existing interdisciplinary contacts, to establish a group at the forefront of this rapidly developing and increasingly important area. We aim to develop core research leading to application across science (e.g. molecule and zeolite symmetry) and engineering (e.g. auxetic materials and robotics), with significant potential impact.
- *Enhancing opportunities and support for visitors to Lancaster.* Our current visitor scheme has greatly added to the vitality of the research environment since its inception 5 years ago, and we will substantially increase this activity. A particular focus will be to fund longer-term high-profile visitors to Lancaster. We have a University commitment of an additional £160K over the next 8 years to fund this.
- *To see continued growth in collaborative research with industry*. Building on our strong reputation with industry and STOR-i's recent renewal we aim to increase the scale of our joint

activities with industry partners. In particular we see opportunities for moving beyond a model of interaction that rests primarily on PhD projects and training, to one with more and larger scale joint research projects.

- *To consolidate our reputation for excellence in PGR provision*. We will make our novel training courses (aimed at developing such skills as leadership and public engagement, specifically for students in mathematical sciences) available nationally using industrial funding of £50K to support external attendance. We will also increase the range of opportunities for our students to enhance their experience through suitable external placements during their PhDs. As part of this we will take advantage of a University commitment to fund an additional £140K for our strategic partnerships (both existing partnerships and new partnerships with the University of Washington and Northwestern University). In addition we will establish an industrial internship scheme for which we already have commitments from industry and £120K from the University.

c. People, including:

i. Staffing strategy and staff development

Strategy

We have almost doubled the size of pure mathematics at Lancaster during the census period through a planned diversification of expertise. We now boast one of the UK's largest groups in modern analysis, and have created a similar-sized research group in algebra, with a broad range of expertise from algebraic geometry to combinatorics. To maintain coherence during this expansion, appointments have been made at the interface of analysis and algebra (Hillier and Elek). Our growing strength and reputation is evidenced by the fact that the many recent appointments have come from leading international institutions: Elek (Budapest; 2009 recipient of the Alfred Renyi prize for outstanding performance in mathematics research), MacDonald (UBC), Schulze (York University, Canada) and Levy (EPFL). The vitality of the research environment of pure mathematics is reflected in the substantial increase in RAs and PhD students since 2008.

Statistics research at Lancaster has consistently been strong; its large group has ranked in the top 5 in terms of QR income in all previous RAEs. Our staffing policy in statistics has been to build on those areas of existing strength that we consider to be gaining in importance within modern statistics. Examples include creating one of the largest UK groups within wavelets and locally-stationary time-series, around Eckley, through the lectureship appointments of Killick (submitted to UoA19) and Nunes; further strengthening our computational statistics groups, through appointing Neal as a reader, and our extremes group, by the appointment of Eastoe.

Across all appointments we have purposefully maintained a healthy and sustainable staffing profile. Currently close to half of our academic staff are 40 or under, and just under half are at senior lecturer, reader or professorial levels.

Three members of staff have held competitive research fellowships: Skalski (EPSRC postdoctoral fellowship 2007-2010, £173K), Jaki (NIHR career development fellow 2011-2015, £328K), and Hampson (MRC career development fellow 2012-2016, £349K). Skalski was awarded the Kazimierz Kuratowski award, for the best Polish mathematician under 30, in 2008.

Staff development and support

We believe that the development and support of all staff is key to the success of our research groups. This is an activity in which we have a strong track record, with half of our professorial staff achieving that status through internal promotions based on strong research-led cases. We support research development at a number of levels, including:

Research groups and networking. Our research groups provide a supportive framework for developing research. Each runs its own programme of activities, including: visitor programmes, specialist seminar series, reading groups, away days and social activities. Many groups benefit from the involvement of academics from other universities and Lancaster departments, and from our industrial partners. This diversity adds substantially to the vibrancy of our activities. For example, the extreme values group has industrial members from Shell, AstraZeneca, JBA Consulting and Yorkshire Water; while the analysis group benefits from close involvement of researchers from the Polish Academy of Sciences.

Appraisal of staff is organised around research groups to ensure a strong focus on advice about and development of individuals' research activities. Research group activities are supplemented by seminar series in statistics and pure mathematics. Staff are strongly encouraged, and supported, to disseminate their work and to network through conference participation.

Support for collaborations. We have an earmarked fund to help build and sustain strong research collaborations through visits and visitors. Around 10 grants are awarded each year, with almost all staff having received a grant during the census period. Priority is given to early career staff. The impact of these funds has been considerable: they have led to £1M of successful grant applications and to more than 20 co-authored publications. Staff also benefit from the opportunities to collaborate with our strategic partners. The success of these activities is seen by an extra £300K we have obtained from the University to support longer-term visitors and international research partnerships from 2014 to 2022.

Supporting early-career staff in building their research teams. We encourage and support all staff to take on supervision of PhD students: all submitted staff appointed prior to 2012 are supervising at least one student. The allocation of University studentships favours early-career staff, and such staff receive support to bid for additional students and PDRAs. To ensure quality of supervision, new supervisors attend a University-run training course and have, as co-supervisor, an experienced member of staff who provides scientific input into, and helps oversee, the project.

Research incentivised in workload allocation. In 2012/13 over 55% of staff time was linked to research-related activities. Key features of work allocation include:

- Support for new staff through a substantially reduced workload: a reduction of non-research related duties of 30%, 20% and 10% respectively for the first three years.
- Incentivisation of research through substantial credit, equivalent to a 20 hour lecture course, given for supervising PhD students, and additional research time given in recognition of external research income.
- Sabbaticals. During the census period 12 members of staff benefited from a total of 100 months of sabbatical leave.
- Flexibility to allow staff to have periods away from Lancaster outside sabbaticals. During the census period staff have been long-term participants in research programmes held at the Statistical and Applied Mathematical Sciences Institute (US), the Isaac Newton Institute, and Queensland University of Technology.

Support for Research Staff. In addition to the support mechanisms described above RAs have a mentor, available to offer advice independent of the formal appraisal system and line-managers. To prepare research staff for future academic or professional careers, care is taken to ensure that they develop skills beyond the confines of their particular research project. They are given the opportunity to gain experience in a wide range of teaching and supervisory activities, in all cases with appropriate mentoring and support. There are many opportunities for RAs to engage in events run by industrial partners and to widen their knowledge of relevant career choices. We are committed to the Concordat to Support Career Development of Researchers, and Lancaster has achieved the European Commission's HR Excellence in Research Award.

Equality and Diversity. Lancaster University holds an Athena Swan bronze award; the department is a supporter of the LMS Good Practice Scheme, and is pro-active in supporting equality and diversity. Academic duties are assigned to staff in a way that allows for parental and caring commitments. The University provides a Pre-School Centre, and academic timetabling takes account of family commitments, allowing flexible working. The workload of two female staff members returning from maternity leave has been both reduced and structured so as to encourage a resumption of active research. The Department of Mathematics and Statistics has considerable experience of dealing with disabilities.

ii. Research students

Developing our PGR provision has been one of the main aims of the department, and is aligned to one of Lancaster's strategic goals. Initiatives included:

- Developing innovative training methods as part of our Centre of Excellence for Teaching and Learning in Postgraduate Statistics (£4.5M, 2005-2010), which we have used and enhanced through the activities of the EPSRC-funded STOR-i Doctoral Training Centre.
- Engagement with industry through a scheme which co-funded PhD studentships on projects with industry. This formed the blueprint for STOR-i, which has a strong emphasis on industrial engagement. STOR-i received substantial financial and in-kind support from industry, with over £0.3M per year of in-kind support towards training and supervision. The success of the industrial engagement and novel training was highlighted as best practice at its mid-term review; the level of engagement will double with EPSRC's recent renewal of STOR-i.
- Support from the University has included the award of 1 or 2 University-funded PhD studentships each year throughout the census period. This has been used strategically to support our growth of pure mathematics, and has led to a strong cohort of PhD students across analysis and algebra. These studentships enable us to attract high quality overseas students, which we have achieved through using our research partnerships with institutes in India and Poland. One such student, Kania, won the 2013 Dean's award for the best PhD student across the Faculty of Science and Technology at Lancaster.

During the census period we have seen a strong growth in PhD numbers, with students in areas linked to this submission more than doubling (from 19 to 45.5). During this period, 5 of our PhD students were awarded fellowships at academic institutions: Wadsworth (Cambridge), Nixon (the Heilbronn Institute), Papastathopoulos (Bristol), Prangle (Reading) and Kania (the Polish Academy of Sciences). Papastathopoulos was awarded the Eleneio Doctoral Thesis award for the best PhD thesis in statistics written by any Greek student in 2011-2012.

Recruitment. Through a range of activities, we make students aware of PhD opportunities in the mathematical sciences, both at Lancaster and more widely. Our comprehensive recruitment activities have been highlighted as best practice by EPSRC. As well as standard advertising we:

- Run 4 or 5 recruitment roadshows per year. These have been at Lancaster and at 7 partner universities, including Bristol, Edinburgh and Warwick. They showcase the opportunities for postgraduate study in statistics, and emphasise the range of career options that a PhD in statistics can lead to. Roadshows have had involvement from industrial collaborators, as the link between research and impact has been a key factor in many students' interest in a PhD.
- Run an internship programme each summer, in which 12 undergraduates from a wide range of universities come to Lancaster to do 8-week research projects, with a view to giving them a taster of what a PhD would be like. This has proven successful, with 70% of interns going on to a PhD within the mathematical sciences, including a number of students whose undergraduate background is not mathematics, and who would not naturally make such a choice.

Training and Support. The scale of our large postgraduate community and our partnership programme with industry enables us to offer PhD students a unique set of opportunities, broadening their mathematical training as well as providing transferable skills relevant for researchers in the mathematical sciences. Examples include 'presenting statistics to a lay-audience' (run by prize-winning journalist Michael Blastland), 'societal aspects of statistics research' (Hetan Shah, executive director of the Royal Statistical Society), problem solving days looking at application of statistics to industrial problems (5 per year, with companies such as BT, KSS fuels, Shell, ATASS, NNL and Unilever), 'writing for different readerships' (Julian Champlain, Editor of RSS magazine Significance) and 'R-package development' (Markus Gesmann, Lloyds).

We strongly believe that students benefit substantially from experiencing a variety of research environments, and we ensure that they have opportunities to do so. Our industry partners provide a research fund (£60K per cohort, with funding secure for cohorts starting their PhDs from 2011-2019) which allows students to make competitive applications for funding to support medium-term visits to leading international research groups. Additionally, students on projects co-funded by industry typically spend between 3-6 months with the industrial partner during their PhD.

Under various external funding arrangements, students have spent similar periods in centres such as the Institut Curie in Paris, ISI Bangalore, IMSc Chennai, EPFL Lausanne, the University of South Carolina, the Home Office, Novartis, Scottish Government and the National Library of

Congress in Washington DC. We also facilitate industrial placements for our PhD students (e.g. with Shell and BT). Over and above this, all students are guaranteed travel funds of at least £2K to attend conferences and meetings, with substantially more for grant-funded students.

All students undertake broadening training within mathematics. Lancaster is a major supporter of the taught courses centres, with all PhD students required to take courses put on by APTS, MAGIC or NATCOR. To supplement opportunities available both through these EPSRC taught course centres and from over 20 postgraduate courses run by the Department, we started a regular series of statistics masterclasses in 2012. These cover important areas of current research and are given by leading international researchers. Recent examples include courses by Sen (Ohio State), Ryan (Auckland), Nelson (Northwestern), Rue (Trondheim) and Davison (EPFL).

Four of our students have been awarded short-term fellowships through the EPSRC doctoral prize scheme, and its predecessor PhD plus, since 2011. This gives some of our best students an invaluable opportunity to develop research independence, and to capitalise on work initiated during their PhD studies; and we have convinced the University to fund similar 1-year fellowships within statistics and operational research annually for 9 years from 2014.

Appraisal and Monitoring. All students have their own Higher Degree Committee to oversee progress, chaired by an independent member of staff. The student is able to discuss any issues with the chair outside the formal meetings, and the meetings themselves help prepare students for defending their thesis at viva. Monitoring is overseen by a senior member of staff. Our proportion of PhD submissions within 4 years for students starting since 2005 is over 90% (33 out of 36).

d. Income, infrastructure and facilities

Infrastructure and Facilities

Departmental facilities have been significantly improved by the opening of the £3.4M Postgraduate Statistics Centre in 2008. This building houses purpose-built lecture rooms with podcasting and video recording facilities, a dedicated room for video-link transmission and receipt of MAGIC lectures, computing labs, conference space, offices, formal meeting rooms for group activities, open plan learning zones and mixing space for socialising and informal work discussion. One of the architects' aims was the creation of a vibrant building filled with natural light to encourage students and staff to interact in a relaxed and informal way. Experience to date suggests they have been successful. The Centre adjoins the existing department building so all staff and research students are still located together despite the increase in both staff and student numbers.

Staff have access to the Department's own computer support (2.6FTE computer technicians) and computer cluster (nearly 500 computer cores, 800GB of memory). These computing facilities are supplemented by access to Lancaster University's High-End Computing cluster (1700 computer cores, 8TB of memory, 32TB of high performance filestore). The University cluster is extensively used by researchers in the mathematical sciences (around 5% of total CPU time which corresponds to over 300 CPU years annually).

Grant Income and Support

Overall external funding has increased, with an average research spend of £890K per year, as compared to less than £600K per year in RAE2008. This reflects an increase in grant activity across the whole UoA; with grant income increasing from £9K to £150K per year in pure mathematics, and from £570K to £740K per year in statistics. Staff are encouraged to consider a broad range of opportunities; we currently have substantial funding from research councils, government agencies, industry, the NHS, charities, and major US research funders.

A key objective throughout the review period has been developing new links and funding opportunities with industry. A member of staff with industrial experience has undertaken an industrial liaison role, supporting staff in forging such links. During the census period we have had financial support from over 20 companies, including a Research Fellowship funded by Roche; had funding for 5 further RAs, and have acquired co-funding for over 50 PhD studentships (30 for students starting post 2014). Our success in this area of funding is attested to by it now accounting for 25% of grant income during REF, as opposed to less than 5% for RAE2008. These links have also been important in terms of the support they have given to research council grant applications,

being an integral component of the original £6.7M STOR-i Doctoral Training Centre bid (£1M contribution from industry), the £12.6M bid for renewal for STOR-I (£5.2M contribution from industry) and the £270K EPSRC grant on locally stationary energy time-series to Eckley (support of £90K from 4 companies).

A prioritised use of internal funding is for the development of grant applications, supporting visits to potential collaborators and funding required for preliminary research. To date this has led to 6 successful major research council grants (total income to Lancaster in excess of £1M).

The department has a research committee that advises all staff on opportunities for external funding, aids the preparation of bids, helps to leverage University and industrial support and arranges mock interviews. An example of the support we give early career staff is a strategy where we developed contacts with clinical groups so as to identify the most timely research areas in medical statistics. These formed the basis of the successful fellowship bids of Jaki and Hampson.

Over and above this, grant applications are supported through the University's research support office which provides advice on their costing, preparation and administration, along with the production of final reports. The University has a contracts office that offers essential assistance with the drawing up of contracts; this is particularly important for industry-funded research grants.

e. Collaboration or contribution to the discipline or research base

Support for Research Collaborations
We are committed to developing research through high quality collaborations. As well as supporting individuals, we have a number of strategic links that involve groups of researchers.

From 2008 to 2012 we ran the British Council funded UK-India research collaboration network *Quantum Probability, Noncommutative Geometry and Quantum Information*, involving 4 other UK universities, and 6 leading research institutes in India - IISc and JNCASR (Bangalore), IMSc (Chennai) and ISI (Delhi, Kolkata, Bangalore). The network funded co-organised conferences and exchanges at all levels, including 2 one-year post-doctoral research visits to Lancaster and 3 six-month PhD student visits to India. It helped launch 7 academic careers, with RAs proceeding to positions in India, Europe and the US. Since 2012 we have run an LMS-funded research network, *Quantum Groups, Operators and Noncommutative Probability*, with the University of Leeds and the Polish Academy of Sciences. To date this has funded conferences with extended research visits at each of the nodes. Collectively these networks have spawned 8 strong research collaborations.

In 2010 we set up strategic partnerships with Statistics for Innovation (Oslo, Norway) and the Naval Postgraduate School (Monterey, US), supported by £75K from Lancaster University. These partnerships involve exchange of researchers and PhD students and joint research projects (currently we have four PhD students on projects co-supervised with these partners). Recently we have secured £140K from Lancaster University to continue these and develop similar partnerships with the University of Washington, and Northwestern University. We are also one of four institutions (with Bristol, Oxford and Warwick) involved in an EPSRC programme grant in statistics on intractable likelihood. This grant involves substantial collaborations, including academic visits, co-supervision of RAs, and virtual joint reading groups.

We have a strategic partnership with Novartis, with funding of over £80K from them since 2008. This involves joint PhD supervision and funding, and staff exchange. We are also working with Liverpool, Manchester and Bangor through the MRC North West Hub for Clinical Trials methodology; and with MRC centres in Cambridge and London through the MRC Network of Hubs for Trials Methodology Research.

As mentioned previously, we also support research collaborations through a competitive fund that all staff can apply to. As an indication of the number and type of visitors - in recent years we have had over 20 multi-day visits to Lancaster per year (average length one week). These include visits by Berger (Duke), Carlson (Georgia), Davis (Columbia), Davison (EPFL), Goswami (ISI Kolkata), Koszmider (IMPAN, Warsaw), Odell (Texas), Parshall (Virginia), Rue (Trondheim), Schlumprecht (Texas A&M), Sinha (JNCASR, Bangalore), Thevenaz (EPFL) and von Sachs (Louvain).

Interdisciplinary Research

We believe that strong interaction with research users can benefit research across the whole of the mathematical sciences, and is particularly important within statistics to motivate new research directions. The following three examples illustrate these benefits across the spectrum of our research. In computer-aided design the inherent mathematical models for geometric design present fundamental problems in the area of geometric rigidity and constraint systems; problems that recur in engineering design and in models in material science. Collaborations with industry and engineers have led to new results for determining the rigidity of complex structures. The challenge of designing a multi-arm clinical trial in HIV therapy that allows inferior treatments to be dropped at interim analyses led to a new approach in trial design and analysis. Work with Shell research on extremes of waves has led to new spatial models for extremes. Across these three examples, the interdisciplinary research has led to numerous high-quality publications, including a paper in the Journal of the LMS and two in Biometrika.

Interdisciplinary research collaborations are mainly through joint research projects involving co-supervision of PhD students. Within the University we have joint research projects with Management Science, Applied Social Science, Computing, Lancaster Environment Centre, Medicine, Psychology and Sociology (over 20 such PhD projects). Staff are involved in grants with veterinary scientists at Massey (NZ), psychologists at the University of South Carolina and numerous medical collaborators in the UK and abroad.

In recent years we have focussed particularly on building partnerships with industry. We run a range of activities aimed at developing new links, such as: giving companies an opportunity to present open research problems, co-funding research internships with SMEs, and providing a mentoring system to support staff who are new to this form of inter-disciplinary research. We consider the availability of software to be key to the uptake of new statistical methods by practitioners, and support software development through training on producing packages in R.

Contribution to the discipline

- **PGR recruitment and training.** Many of our PGR activities are organised to benefit students across the whole of the UK: we have run our recruitment roadshows in collaboration with 7 UK universities; our masterclasses are open to any PhD student, with funding provided for up to 10 external students to attend each one; and we have invited students from other universities to attend our problem-solving days. We also support EPSRC's taught course centres: NATCOR is led by Lancaster; we run at least one MAGIC course per year; and we have hosted APTS and NATCOR courses. Staff have also given graduate level courses both in the UK (as part of the EPSRC-funded Graduate Training Course in Statistics hosted by Newcastle) and abroad (courses in Spain, Italy and Nigeria covering topological field theory and functional analysis).
- **Workshop and Research Programme Organisation.** Staff have organised over 25 workshops, conferences and research programmes. These include the 6-month programme *Risk, Rare Events and Extremes* (Bernoulli centre, Switzerland, 2009), the conference *Group Representations and Related Topics* (Lausanne, 2010), the 17th European Young Statisticians Meeting (Lisbon, 2011), and the workshop on *Rigidity of Periodic and Symmetric Structures in Nature and Engineering* (Kavli Royal Society International Centre, 2012). Staff are organising a 4 week-programme at the Isaac Newton Institute on *Inference for Changepoints and Related Processes*, and on the organising committee of a 6-month programme at the Fields Institute on *Abstract Harmonic Analysis, Banach and Operator Algebras*, both to be held early in 2014.
- **Strategic Roles.** Staff have been members of EPSRC, ESRC, ESF and NHS panels for allocating research funding, as well as Chair of the Scientific Council of the EPSRC Science and Innovation Award (CRISM) at Warwick University.
- **Support of Learned Societies.** There has been strong involvement in the activities of learned societies. Within the Royal Statistical Society we have had a member of Council, two members of the Research section and a vice-chair of the Applied Probability section. We have had a member of the LMS Research Policy Committee and the Vice-Chair of the Ethics Committee of the European Mathematical Society.
- **Editorial Positions.** During the REF census period Whitehead has been one of four editors of Statistics and Medicine and staff have served on the editorial boards of 15 academic journals, including Biometrika and that of the LMS.