Environment template (REF5)

Institution: Durham University

Unit of Assessment: 10 Mathematical Sciences

a. Overview

The unit of assessment is drawn entirely from the Department of Mathematical Sciences, which lies at the heart of the 7 departments/schools within the Science Faculty. The importance of mathematics as the foundation of scientific research is demonstrated by the Departments very active role in 6 University Institutes and Centres: the Centre for Particle Theory (CPT), the Institute for Particle Physics Phenomenology (IPPP), the Institute for Computational Cosmology (ICC), the Biophysical Sciences Institute (BSI), the Centre for Soft Matter (CSM), and the Institute of Hazard, Risk and Resilience (IHRR), in addition to the many collaborations on a more individual basis with members of the other departments within the Science Faculty, as detailed below.

b. Research strategy

The unit contains 3 broad sub-units, namely Pure, Applied, and Statistics and Probability, reflecting the 3 headings under which the unit was assessed in RAE2008. These sub-units are further divided into the 8 research groups listed in the following table, where the members of each group are also presented. It is important to note that there are no sharp boundaries between groups, with some members having a primary assignment to more than one group and frequent interaction between members of different groups. The unit has a healthy distribution in its profile, consisting of 20 Professors (including one Fellow of the Royal Society, Ward R), 9 Readers, 6 Senior Lecturers, 16 Lecturers, 2 Temporary Lecturers and 1 Addison Wheeler Fellow.

Group	Members
Algebra	Abrashkin, Badziahin, Bouganis, Funke, Gangl, Stasinski, Stromberg*, Ward T§
Geometry	Klingenberg, Parker, Peyerimhoff, Post, Tumarkin, Felikson, Ward T§
Topology	Hunton, Kurlin, Lobb, Schuetz
Mathematical Physics	Bowcock, Chu, Dorey, Gregory, Heslop, Hubeny, Mansfield, Peeters §, Piette §, Rangamani, Ross, Smith, Sutcliffe, Taormina §, Ward R, Zakrzewski §, Zamaklar
Computational Applied Mathematics	Dondl, Kiss*, Prior×, Straughan, Wirosoetisno, Yeates
Biomathematics	Chakrabarti, Peeters §, Piette §, Taormina §, Zakrzewski §
Statistics	Coolen, Craig, Einbeck, Goldstein, Jermyn, Sayit, Troffaes, Vernon, Wooff
Probability	Hryniv, Menshikov, Wade

Table 1: The members associated with each research group. Here § denotes an association with two research groups, * a temporary lecturer and × an Addison Wheeler Fellow.

The aim of the University, the Faculty and the Department is to maintain and enhance international research excellence, together with its impact on the academic community and beyond. The development and implementation of a strategy to achieve this aim is led by the Department's Research Committee, including a dedicated Director of Research and Impact Champion.

This structure not only promotes the pursuit of research excellence in the Department, but also provides concrete support for activities such as external funding and Fellowship applications, in addition to monitoring research activity and disseminating information regarding research opportunities. Examples of specific measures include: developing an enhanced research infrastructure; ensuring that research excellence is at the core of promotion procedures and other reward mechanisms; providing support for new members of staff to develop their own independent research programmes; and investing in high-quality postgraduate facilities.

Group	Size (FTE)	Research Themes
PURE MATHEMATICS	18	
Algebra	7.5	Arithmetic algebraic geometry Algebraic cycles and K-theory Algebraic dynamical systems Algebraic number theory
Geometry	6.5	Differential geometry Discrete groups Hyperbolic geometry
Topology	4	Algebraic and geometric topology Global analysis and dynamical systems Topological robotics
APPLIED MATHEMATICS	24	
Mathematical Physics	15	Cosmology Integrability Quantum field theory String theory and gravitation Topological solitons
Computational Applied Mathematics	6	Applied analysis Continuum mechanics Finite element methods
Biomathematics	3	Dynamics of biomaterials Mathematical virology
STATISTICS & PROBABILITY	12	
Statistics	9	Bayesian (linear) statistics Generalised uncertainty quantification Nonparametric statistics Financial mathematics
Probability	3	Random walks in random environments Probabilistic analysis of large complex systems

Table 2: A list of sub-units, research groups and associated research themes.

Our strategy is designed to produce top-quality research in focused areas by providing a lively research atmosphere within a flexible structure that facilitates a rapid response to new opportunities and emerging research themes. An exemplar for such research support is the University Research Seedcorn Scheme, which provides funds to support initial investigations, feasibility studies, network discussions and other preparative activities that enhance the quality of grant applications. Seedcorn-supported projects are known to have on average more than double the success rate of other applications.

To prosper in increasingly challenging economic conditions, a future strategic aim is to increase the diversity of the source of our research income stream, by supplementing UK Research Council funding with an increasing contribution from other sources; particularly, European Research Council funding and income from industry. Support in this task is provided by the University Research Office, which contains dedicated EU Research Officers, and the Durham Business and Innovation Services, which encompasses teams of professionals to support business engagement, the commercialisation of research, consultancy and analytical services. It is responsible for the facilitation of several projects including Knowledge Transfer Partnerships (KTPs), business partnerships with industry, Durham's Enterprise Incubator and the regional blueprint business planning competition. The Department has a particularly strong record with KTPs, having held 6 (this is more than any other mathematics department in the country) including 3 within the assessment period with the Northern Doctors Care Group and Summit Media. The Department also includes the Statistics and Mathematics Consultancy Unit (SMCU), which was established in

October 1996 to attract commercial research and consultancy work to the Department and its members of staff. It plays a crucial role in providing the Department with a focus for external liaison for outside and commercial organisations.

The unit is very cosmopolitan, with 16 nationalities represented amongst its members. This naturally generates an international outlook, as evidenced by the fact that during the assessment period the members of the unit have collaborated with researchers in 28 countries.

The three broad sub-units, namely Pure, Applied, and Statistics and Probability, reflect the three different headings under which the Department was assessed in RAE2008. As detailed in Table 2, and illustrated in Figure 1, there are further subdivisions within each group, but it should be stressed that the divisions between these groupings are not sharp. There is frequent interaction between members of different groups, a fact that is reflected in the diverse audiences attracted by the many seminar series within the Department. The Department also has strong interdisciplinary links with other researchers in the University, through the CPT, IPPP, ICC, BSI, CSM and IHRR.
An exemplar of such interdisciplinary research is the Tipping Points project of the IHRR, funded by The Leverhulme Trust. One of the four Tipping Points projects concerns the Mathematical Basis of Tipping Points, and is led by two members of the Department (Goldstein, Straughan), with funding of £300K to support two research associates based in mathematics (see section **e)**.
In addition to interdisciplinary research generated through Institutes and Centres, there are several collaborations on a more individual basis, including with members of the Departments of Earth Sciences, Engineering and Computer Sciences, Geography, and Physics.

An important part of our research strategy is the preservation of time for our academics to pursue their own research programmes and to develop new research collaborations whilst enhancing those that already exist. To facilitate this activity the Department provides financial support for travel and also encourages its members to apply for external funding to enable further interaction within the international community, supported by regular periods of research leave. Furthermore, a visitor programme exists in the form of the Grey College Fellowships, which provide room and board for up to four academics a year to visit the Department for extended periods during term-time. The Department also administers the Blaise Pascal Fellowships, which provide support for shorter visits at any time of year. During the assessment period these Fellowships have been awarded to mathematicians of extremely high standing, both from within the UK and abroad. Together with the provision of an active and stimulating environment of seminars and discussion groups (during term-time there is, on average, at least one research seminar per day) this vibrant activity creates a Department that promotes research, generates a lively graduate student body, and provides links to the wider mathematical community.

A key strategic aim described in RAE2008 was an improvement in the research infrastructure, and in particular the specialized high performance computing facilities available to members of the Department. This aim has been successfully achieved in impressive style, with the creation of the Department's Condor cluster. An initial investment in 2010 of £81K from the University's Capital Infrastructure Fund, combined with further investment by the Department, has brought the cluster to its current strength of 152 quadcore computers. The great success of this cluster has been recognized by the University through an additional investment of £57K in 2013 from the Capital Infrastructure Fund. This will provide an additional 60 quadcore computers, with a corresponding significant increase in RAM and CPU speed, making this a substantially more powerful Condor cluster and a major Department facility capable of accommodating cutting edge research. This complements the University HPC cluster (Hamilton) described later. The infrastructure has also been improved through an upgrade to the Department's specialized Access Grid videoconferencing facility, used in the MAGIC consortium (see section **e**).
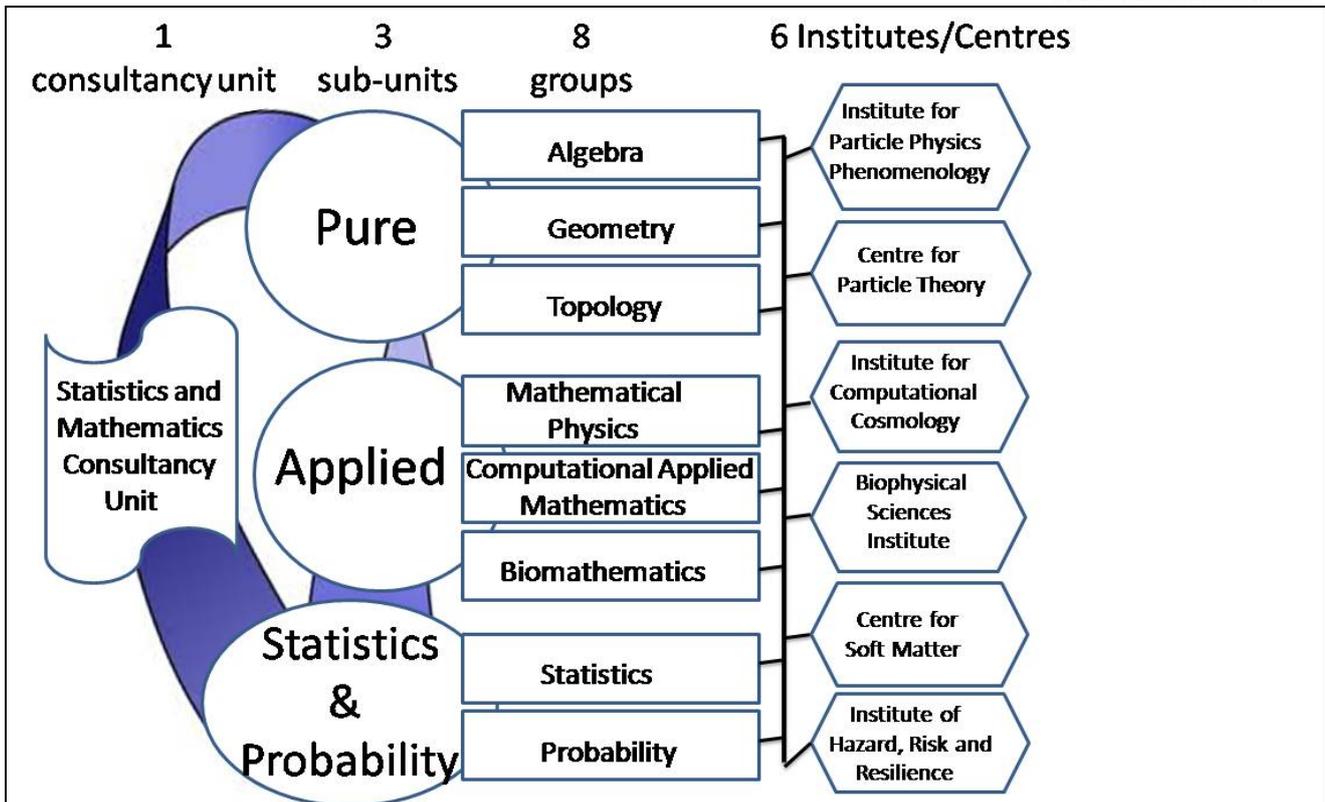
Figure 1: A diagrammatic representation of the structure and links between sub-units, research groups, institutes, centres and the consultancy unit.

When hiring new staff, the strategy is to look for the best available candidate, with preference for the existing three broad themes, together with an emphasis on the appointment of strong young researchers. Since RAE2008 the staffing of the Pure sub-unit has seen considerable changes. This has often been the result of members of the Department moving to prestigious positions elsewhere, an example being Dr Belolipetsky, a Lecturer in the Department until 2012, who now holds the Chern Chair in Geometry at the Instituto Nacional de Matemática Pura e Aplicada, Rio de Janeiro, Brazil. Movement of staff to esteemed positions, as in this example, demonstrates that the Department is very successful in identifying and appointing young researchers that are rising stars in their field. The changes in the Pure sub-unit have presented an opportunity to continue this strategy and make some shifts in emphasis in the research areas covered, to reflect emerging and hot topics, while maintaining the overall themes in which this sub-unit is strong. For example, a notable gap in the RAE2008 profile was mathematical analysis, and so a strategic decision was taken to move into this area with the appointment of Badziahin, who works in analytic number theory, and Post, who works on the analytic theory of operators on manifolds.

Further new additions to this sub-unit are Bouganis and Stasinski, who strengthen the algebra group with their work on Iwasawa theory, arithmetical algebraic geometry and representation theory of reductive groups over finite rings; Felikson and Tumarkin, who add their expertise on hyperbolic geometry and Coxeter groups to the geometry group. The topology group has added new talent with the appointment of a Professor and a Lecturer, namely Hunton and Lobb, providing expertise in algebraic and low-dimensional topology in addition to providing new links with the geometry and algebra groups. There is also a current temporary lecturer in the algebra group (Strömberg). All these appointments are clear examples of the above strategy in action. Furthermore, Professor Tom Ward has recently joined the Department, via his university position as Pro-Vice-Chancellor (Education), and brings his expertise in algebraic dynamical systems, ergodic theory and number theory.

The Applied sub-unit has seen fewer staff changes. Strength in Mathematical Physics has been maintained, and this group remains one of the largest in the country, working on string theory and gravitation, on quantum field theory and integrability, and on topological solitons; it is also active in

cosmology. Two new lecturers have been appointed since RAE2008, namely Heslop (now a reader), whose expertise lies in supersymmetric quantum field theory, and Peeters, who works both on string theory and biomathematics. This group continues to have strong links with the University's Physics Department, principally through the CPT. In addition to collaborative work between individual members of the two units, there is a joint colloquium and a jointly run MSc course, together with graduate lectures attended by PhD students from both units. A notable development is the growing level of interaction with the Pure sub-unit, in particular in the area of quantum field theory and scattering amplitudes (Gangl and Heslop), which was the subject of an LMS symposium in Durham in July 2013 entitled Polylogarithms as a Bridge between Number Theory and Particle Physics. There are also links with Newcastle University via an STFC consolidated grant. Critical mass in the Computational Applied Mathematics group has been built with the addition of two new lectures, Dondl and Yeates, plus a temporary lecturer (Kiss) and an Addison-Wheeler Fellow (Prior). Dondl works on the evolution of phase boundaries and pattern formation, while Yeates is an expert in magnetohydrodynamics. The growth of this group is reflected in the appointment of two PDRAs. A further research development since RAE2008 has been the increasing investment in the Biomathematics group, which interacts with the University's Biophysical Sciences Institute. Initial membership of this group came from selected members of the existing Applied sub-unit (Peeters, Piette, Taormina and Zakrzewski) devoting a part of their research time to problems in the area. It has since been consolidated with the creation of a new permanent post (Chakrabarti). As discussed above, there has been an emphasis on the appointment of young researchers, of high promise, as again demonstrated by this example.

The Statistics and Probability sub-unit has also seen an influx of new talent since RAE2008, with the appointment of a Reader (Jermyn), a Senior Lecturer (Wade), and two Lecturers (Sayit and Vernon). The Statistics subgroup continues to develop foundational and methodological work, while at the same time fostering increasingly successful involvements with large interdisciplinary collaborations with potentially high industrial and social impact. Some of this is achieved by membership of the various University Institutes described earlier, whilst other success in this area is generated through the Consultancy Unit (SMCU). The new appointments bring fresh expertise in the areas of shape modeling, spatial statistics, random spatial models, stochastic processes and financial mathematics.

c. People

i. Staffing strategy and staff development

The University Strategy of strengthening internationally competitive research guides the Department's staffing policy, as detailed above. We endeavour to enable all staff to achieve their full potential, and we provide particular support to less experienced members, as described below. A significant amount of work in the subject is done in collaboration, and even if done individually, is greatly influenced by discussions with other workers. The Department aims to facilitate this by creating a lively and productive environment for research. We seek to maximise the opportunity for research of all our staff, by giving them as much time as possible to follow their research programmes, particularly the younger members of staff, who are given reduced administrative and teaching duties in the early stages of their careers. We encourage a flow of visitors, and more general external links, in particular through the Grey and Pascal Fellowships mentioned above. We maintain a flexible policy of permitting staff to make research visits or attend meetings throughout the year, and provide funding for these activities and for research visitors.

When academic vacancies arise, rather than target a particular area, we usually choose to look at a wide pool of applicants and to select an outstanding candidate whose research shows clear individuality, but which fits well with existing activities. Within these parameters, we seek to maintain a healthy balance between ensuring a critical mass in each broad research area, and investing in diversity. All posts are advertised internationally, and consistently attract an international field of applicants, a fact with is reflected both in the shortlists for our posts and in the spectrum of final appointments.

Mentors are appointed for all new lecturers; they are experienced permanent members of staff,

usually in the same subject area as the new appointee. The mentor provides guidance and advice on a range of issues, including aspects of research such as grant applications and conference organization. A mentor is also appointed for each research assistant or Fellow (where appropriate, this is normally the grant-holder). Members of staff are given a lighter teaching load for their first few years (for example, new lecturers begin with a 60% load), and little administration, so that they may dedicate more time to developing their research. The University's promotions policy aims to motivate staff to enhance their research profile, while also, where appropriate, encouraging them to foster the impact of their work on the wider society, as explained in more detail in REF3a.

The University provides extensive initial and continuing professional development programmes for academic staff. Training on research student supervision forms part of the Postgraduate Certificate in Teaching and Learning, which is mandatory for all new academic staff. Staff also have the opportunity to attend further workshops on good practice in supervision in their disciplines; these sessions are delivered by experienced supervisors drawn from the Faculties and the Academic Staff Development Office. As part of its continuing professional development programme, the University provides regular opportunities for experienced supervisors to update their knowledge and skills. It also seeks to recognise excellence in research supervision through the Vice Chancellor's awards (one of which has been won by a member of the unit); winning statements are featured in the University's newsletter, Quality Enhancement at Durham, which goes to all members of academic and research staff.

More general professional development programmes include workshops on making research grant applications, career planning for contract research staff, and writing up research for publication. The Department also runs its own seminars and workshops geared to the specific needs of mathematicians, under the leadership of its Staff Development Officer. In order to allow younger members of staff to engage with the wider community, we particularly encourage them to attend seminars, workshops and meetings, or make research visits to other universities and research institutes. We take as flexible a view as possible to rearranging teaching commitments so that opportunities to attend important conferences or make contacts are not missed. The Department has a policy of financial support for travel (both UK and overseas), administered by the Head of Department. In addition, staff are encouraged wherever possible to apply for external support for their travels. It is Departmental policy for all members of staff to take one full term of Research Leave in every nine, on average.

The Department carries out the Concordat to Support the Career Development of Researchers, the implementation of which is overseen by the University's Human Resources Department. This commitment to the Concordat is exemplified by the following pair of quotes, which are taken from http://www.dur.ac.uk/hr/researchstaff/:
"Durham University is committed to the Concordat and supporting its valued Research Staff."
"The Concordat Implementation Group (CIG) oversees the implementation of the Concordat - this has included the production of a Gap Analysis and Action Plan. CIG monitors the implementation of the action plan and its effectiveness."

All young staff are strongly encouraged to apply for research grants via the EPSRC first grant scheme and the unit currently has one PDRA on such a grant. Credit is given in the unit's workload formula to acknowledge the managerial responsibilities associated with a PDRA.

During the assessment period, the following held personal research fellowships or awards in the Department (* denotes temporary staff): Chu (EPSRC Advanced Fellow), Gregory (Royal Society Wolfson Merit Award), Krishnaswami* (EPSRC PDRF), Post (Marie Curie Fellow), Prior* (Addison-Wheeler Fellow), Taormina (Leverhulme Research Fellow), Vernon (EPSRC Personal Mobility Fellow), Withers* (Royal Commission for the Exhibition of 1851 Fellow), Zamaklar (EPSRC Leadership Fellow), Zegers* (EPSRC PDRF).

The unit will be applying for Athena Swan silver status, after the recent award of bronze status to the Faculty of Science, and supporter status of the LMS Good Practice Scheme.

ii.   Research students

Recruitment. The "Prospects in Mathematics" conference was set up in Durham with startup money from the Nuffield foundation. Its success has now elevated it to an LMS-funded rotating event held at several universities and it will return to Durham in 2013. The Department also organizes a popular annual one-day event in St Mary's College, funded by the Willmore Foundation, for prospective graduate students, with the title "What is research in pure mathematics?".

Research Training. Each postgraduate research student is supervised by a team of two supervisors, and there are frequent (normally weekly) meetings between the student and one of the team, to ensure high quality research training and monitor progress. Each research group provides lecture courses and seminars to bridge the gap between undergraduate level and that required for research, and to provide specialist knowledge. The opportunities on offer include:

- Lectures on Particles, Strings and Cosmology, divided into 24 topics and delivered in 308 hours of lectures, with supporting tutorial classes. This is run jointly with the Physics Department under the aegis of the Centre for Particle Theory, and is compulsory for all first year students in the Mathematical Physics group.
- The MAGIC programme, which runs a wide range of over 30 postgraduate level lecture courses in mathematics (each consisting of either 10 or 20 hours) and is delivered using Access Grid videoconferencing technology. MAGIC is a consortium of 19 universities, with Durham typically delivering two of the lecture courses from its specialized videoconferencing facility, established in the Department in 2006.
- One-week intensive courses on general topics in Statistics and Probability, run twice per year in collaboration with Newcastle University, as part of a 3 year rolling programme started in 2006.
- One-week courses in the Academy for PhD Training in Statistics (APTS), in which Durham is a member institution.
- 24 modules from the MSc in Mathematical Sciences.
- Student-only seminar series and journal clubs running in all sub-units.

Students benefit from a variety of the courses listed above, according to their specific research needs, and actively participate in both national and international student-specific events supported by LMS, EPSRC, STFC, IOP, RSS, BUSSTEP and MAGIC, which Durham often hosts. The University provides a comprehensive programme of generic key-skills skills development for its postgraduate research students, with topics such as giving presentations, academic writing, use of online information sources, time management and preparing for PhD examinations. A menu-driven approach is adopted, based on a comprehensive Training Needs Analysis that students undergo, in discussion with their supervisors, during the first month of their program; this is then reviewed at least annually. Skills development is shaped by the Research Councils' Joint Skills Statement.

Training for teaching. First year research students take the opportunity to be involved in the teaching of our undergraduate modules, while second and third year students are encouraged to develop their mathematical teaching skills by giving undergraduate small group tutorials and assisting with computer classes. For all these teaching activities, they are first required to participate in University training sessions and also in specialised Departmental training sessions, sharing best practice for mathematical teaching and exchanging information on expected standards. They are assigned an individual mentor to train them, who together with the student, will prepare the teaching activities and evaluate performance.

Progress monitoring. The Department's Postgraduate Studies Committee, chaired by the Director of Postgraduate Studies, provides support and monitoring of graduate students, aided by the University's Graduate School, of which every student is a member. Each graduate student is also a member of one of the University's Colleges or Societies (normally Ustinov College, which is dedicated to graduate students), and these play a leading role in pastoral support for students.

Each student prepares an annual report on his/her activity and progress during the preceding year, and is interviewed by two members of staff (neither of whom is the student's supervisor); the Department also operates a formal procedure for assessing whether first-year students may progress to their second year. The Department encourages research students to attend conferences and summer schools which will benefit their development, and gives full financial support; in practice most students attend at least two such activities each year. The result of such conference attendance is discussed with the supervisory team, to make sure that active participation is maximizing the impact of this activity.

Career progression. The employment of the 75 PhD students who graduated during the assessment period spans a wide variety of areas such as financial services, information technology, education, environmental protection, the energy industry, and government. The employing companies include: BAE Systems Detica, FoundationCampus Limited, Mercer, Metaswitch, PricewaterhouseCoopers, Shell, Sungard Availability Services, and The Food and Environment Research Agency. 17 of the graduating PhD students went on to postdoctoral positions at institutions that include Durham, Kent, Leeds and Warwick Universities in the UK, Dublin Institute of Advanced Studies in Ireland, Fribourg University in Switzerland, Ghent University in Belgium, Humboldt University (Berlin) in Germany, Max Planck Institute (Bonn) in Germany, Melbourne University in Australia, National Normal University in Taiwan, Sao Paulo University in Brazil, University of the Witwatersrand in South Africa, and Zhejiang University in China. 14 of this cohort now have academic positions; 1 as a Reader at Leeds University and 2 as Lecturers at the Universities of Durham and Manchester; and internationally, 5 in Saudi Arabia, 2 in Egypt, 2 in Libya, 1 in Pakistan and 1 in Thailand.

Other aspects. We strongly encourage students to participate in, and to take, initiatives for their own learning beyond their research project. Examples are involvement in seminar and conference organisation, in supervision of undergraduate summer research projects, and informal meetings with visiting researchers. The postgraduate students in the various research groups organise regular student seminars, in which they present their own research results to an audience of their peers. The unit has also provided financial support and infrastructure for conferences initiated and organized by PhD students (including two HEP Young Theorists Conferences and a Student Holography Meeting, all held in Durham).

d. Income, infrastructure and facilities

The centrepiece of the Department's infrastructure is its computing facilities, and in particular its high performance computing capabilities provided by the Condor cluster. Created in 2010 it has so far received investment from the University's Capital Infrastructure Fund to a tune of £138K, in addition to regular financial support from Departmental sources and EPSRC. This has brought the cluster to its current strength of 152 quadcore computers, with an additional 60 quadcore computers with increased RAM and CPU speed to be added in 2013. This hybrid cluster of high performance graphical computers provides the specialized facilities required to perform intensive state of the art computations of both algebraic and numerical form.

Members of the Department have access to the "Hamilton" High Performance Computing service, run centrally by the University, which spent £750K on Hamilton 4 in 2009, and £500K on Hamilton 5 in 2011. The Department also has an annual subscription that provides access to the "Cosmos" Supercomputer based in Cambridge, which is Europe's largest shared-memory single-image system with 1840 cores on Intel Xeon SandyBridge-EP processors and 31 Intel Xeon Phi processors each containing 60 cores.
The Department has a specialized facility providing Access Grid videoconferencing technology. This is used extensively in its role as a member of the MAGIC consortium, which delivers around 500 hours of postgraduate lectures per year over 19 universities. The Faculty has also funded a research project on innovative widescreen classroom design, including a teaching room equipped for this ongoing initiative.

The diversity of the unit's income stream is demonstrated by the following examples of funding

obtained during the assessment period from awards over £50K:
- EPSRC, £3.2M from 18 grants, plus £1.7M from Doctoral Training Grants.
- STFC, £3.7M from 4 grants, plus £1.5M in PhD studentships.
- The Leverhulme Trust, £300K from 1 grant.
- NERC, £540K from 2 grants.
- The European Commission, £580K from 2 grants.
- KTPs, £510K from 3 awards.

In addition, there has been funding totaling more than £800K from various industrial partners, One North East and the London Mathematical Society.

The focus of Departmental activity on consultancies and professional services is the SMCU, with annual turnovers of over £100K. Commercial clients of the SMCU include the Home Office, BTexact Technologies,Thorn lighting Ltd., Philips Components Ltd., UK Government, Czarnikow Sugar Ltd., University hospital of North Durham, Energy Scitech Ltd., Roxar Ltd., Environment Agency, Ikeda-Hoover Ltd., Johnson Controls Ltd., NEDL, Northumbrian Water, Imperial College London, SilentNight Furniture Ltd, Summit Media Ltd, Viskase Ltd., and the UK charity SCOPE. In addition, a member of the unit (Craig) has supplied research-based professional advice to the European Food Safety Authority in relation to its Guidance Documents on Probabilistic Exposure Assessment for Human Risk from Pesticides and on Assessment of Risk to Birds and Mammals; and to the Residue Chemistry Expert Group of the Organisation for Economic Cooperation and Development. For more details of consultancy activities see REF3a.

e. Collaboration and contribution to the discipline or research base

Personal research fellowships and awards held in the Department during the assessment period include: a Royal Society Wolfson Merit Award (Gregory), an EPSRC Advanced Fellowship (Chu), an EPSRC Leadership Fellowship (Zamaklar), a Leverhulme Research Fellowship (Taormina), a Marie Curie Fellowship (Post), an EPSRC Personal Mobility Fellowship (Vernon). In addition, temporary staff held two EPSRC PDRFs (Krishnaswami and Zegers), a Royal Commission for the Exhibition of 1851 Fellowship (Withers) and an Addison-Wheeler Fellowship (Prior).

The Department has strong interdisciplinary links through the CPT, IPPP, ICC, BSI, CSM and IHRR. An excellent example of such interdisciplinary research is the Tipping Points project of the Institute of Hazard, Risk and Resilience, funded by The Leverhulme Trust. One of the four Tipping Points projects concerns the Mathematical Basis of Tipping Points, and is led by two members of the Department (Goldstein, Straughan). It uses data provided by two of the other projects (on Rapid Neo-glacial Transitions in the North Atlantic; and Financial Crisis in the Banking Sector) to develop mathematical representations and apply techniques of nonlinear dynamical systems analysis and Bayesian methods. This funds two research associates based in mathematics. The statistics group is also involved in a large number of interdisciplinary collaborations, including the NERC funded RAPID project for climate science, CASE studentships with SHELL and FERA, JIBA project and deconvolution project for industrial collaborations, enviro-toxicological and industrial work.

Members of the Department have a wide variety of external collaborations at both national and international level, as one might expect from a unit containing 16 different nationalities. During the assessment period our staff have been heavily involved in international collaborations in Australia, Belgium, Brazil, Canada, China, Croatia, Cyprus, Egypt, France, Germany, Greece, Hungary, India, Ireland, Italy, Japan, Korea, Libya, Poland, Portugal, Russia, Spain, Sweden, Switzerland, The Netherlands, Ukraine, and USA. The results of these collaborations are reflected in the variety of co-workers that appear on the papers submitted for assessment to REF and indicate the international reach and significance of the research performed in Durham. These international collaborations, together with many others at a national level, are fostered by the Department's support for its academics to visit other institutions, by its visitors programme, and in the active participation of the Department in networks and symposia, as listed below:
- The LMS funded networks: the North British Mathematical Physics Seminar; the North

- British Geometric Group Theory Network; the Warwick-Nottingham-Durham-Sheffield Number Theory Seminar; Yorkshire and Durham Geometry Days; Mathematical Methods in Reliability.
- The annual Integrable and Conformal Field Theory (ICFT) conference.
- The UK COSMO conference network.
- The ERC FP7 network GATIS (Gauge Theory as an Integrable System), as a node.
- The International Research Staff Exchange Scheme for the ERC FP7 network ISAQS (Integrability, Symmetry and Quantum Spacetime), as coordinator.
- The NSF network GEAR (Geometric Structures and Representation Varieties), as a node.
- The EPSRC project MUCM (Managing Uncertainty in Complex Models), as a node.
- Training weeks and seminars of the local group (Durham and Newcastle) of the Royal Statistical Society.
- The LMS Durham Symposia, funded by EPSRC. These have been hosted in the Department since 1974. Two or three symposia per year bring together groups of mathematicians focused on a well-defined and carefully targeted theme of current scientific importance chosen from the entire range of the mathematical sciences.
- The European Cooperation in Science and Technology network The String Theory Universe, as a node.

Within the assessment period, members of the unit have been managing/executive editors of the journals: Bulletin of the London Mathematical Society (Ward T), Ergodic Theory and Dynamical Systems (Ward T), Geometriae Dedicata (Parker), International Journal of Modern Physics D (Gregory); and members of the editorial boards of: Abhandlungen aus dem Mathematischen Seminar der Universität Hamburg (Funke), Acta Mechanica (Straughan), AIMS Library of Mathematical Sciences (Dorey), Asymptotic Analysis (Wirosoetisno), Australia and New Zealand Journal of Statistics (Craig), Bulletin of the London Mathematical Society (Hunton), Classical and Quantum Gravity (Gregory, Ross), Dynamical Numbers (Ward T), Dataset Papers in Physics (Smith), General Relativity and Gravitation (Hubeny), ISRN High Energy Physics (Heslop, Smith), Journal of Mathematical Analysis and Applications (Straughan), Journal of Physics A (Dorey, Sutcliffe), Journal of the Polish Safety and Reliability Association (Coolen), Journal of Risk and Reliability (Coolen), Journal of Statistical Mechanics: Theory and Experiment (Dorey), Journal of Statistical Planning and Inference (Coolen), Journal of Statistical Theory and Practice (Coolen), Journal of the London Mathematical Society (Hunton), Living Reviews in General Relativity (Rangamani), Markov Processes and Related Fields (Menshikov), Mathematical Methods in the Applied Sciences (Straughan), Meccanica (Straughan), Proceedings of the London Mathematical Society (Hunton), Quality and Reliability Engineering International (Coolen), Statistics (Einbeck), The Open Software Engineering Journal (Wooff), Transactions of the London Mathematical Society (Hunton), TransNav (Coolen).

There have also been the following guest editorships: IEEE Transactions on Pattern Analysis and Machine Intelligence, Special Issue on Shape Analysis and Its Applications in Image Understanding (Jermyn); International Journal of Approximate Reasoning, Special Issues on Imprecise Probability in Statistical Inference and Decision Making (Coolen, Troffaes) and Imprecise Probabilities: Theories and Applications (Coolen); Journal of Physics A, Special Issue on Quantum Integrable Models and Gauge-String Duality (Dorey); Journal of Risk and Reliability, Special Issues on Uncertainty in Engineering Risk and Reliability (Coolen, Troffaes) and Risk and Reliability Modelling of Energy Systems (Coolen); Journal of Statistical Theory and Practice, Special Issue on Imprecision in Statistical Theory and Practice (Coolen, Troffaes).

In addition to one-off memberships of EPSRC and other panels, members of the unit have served in the following capacities during the assessment period: Chair of the Committee of Professors in Statistics (Goldstein), Chair of the Royal Society Research Grant Board A (Ward R), Member of the Associate Faculty of the African Institute for Mathematical Sciences and of the AIMS-Ghana Steering Committee (Dorey), Member of the British Mathematical Colloquia National Scientific Steering Committee (Hunton), Member of the EPSRC IHES review panel (Dorey), Member of the EPSRC Mathematical Sciences Strategic Advisory Team (Dorey, Hunton), Member of the

European Union Grant Assessment Panels (Piette, Zakrzewski), Member of the Executive Committee of the Society for Imprecise Probability: Theories and Applications (Coolen, Troffaes), Member of the Executive Committee of the Statistical Modeling Society (Einbeck), Member of the International Centre for Mathematical Sciences Programme Committee (Gregory), Member of the IoP Mathematical and Theoretical Physics Group (Taormina), Member of the Leverhulme Senior Fellowship Selection Panel (Ward R), Member of the LMS Prizes Committee (Sutcliffe), Member of the LMS Publications Committee (Hunton), Member of the LMS Research Meetings Committee (Parker, Sutcliffe), Member of the Mathematics Program Curriculum Development Team for the Pan African University (Dorey), Member of the OECD working group developing the Maximum Residue Limit Calculator for harmonised international regulation of agricultural pesticides (Craig), Member of the Particle Physics, Astronomy and Nuclear Physics Committee of STFC (Gregory), Member of the Physics Evaluation Group at the Natural Sciences and Engineering Research Council of Canada (Dorey), Member of the Royal Society of Edinburgh Sectional Committee (Straughan), Member of the Royal Society Newton Fellowships Panel (Parker), Member of the Royal Society Research Grant Scheme Panel (Goldstein), Member of the Royal Society Sectional Committee 1 (Ward R), Member of the Royal Society University Research Fellowships Panel (Gregory), Member of the Science Advisory Committee of the Institute of Physics Publishing (Gregory), Member of the Science Foundation Ireland Panel (Taormina), Member of the Scientific Committee for the Knowledge Transfer Network for Industrial Mathematics (Wooff), Member of the South Moravian Programme Grant Assessment Panel (Piette, Zakrzewski), Panel Leader for the Research Council of Norway Centres of Excellence Scheme (Coolen), Secretary of the C18 Mathematical Physics Commission of the International Union of Pure and Applied Physics (Dorey), Trustee and Member of Council of the LMS (Hunton), Vice-Chair of the IoP Mathematical and Theoretical Physics Group (Dorey).

Between 2008 and 2013, members of the unit on the EPSRC Peer Review College included Chu, Coolen, Dorey, Goldstein, Gregory, Hunton, Ross, Straughan, Sutcliffe, Taormina, Zakrzewski, and Zamaklar.

The following prizes were awarded to members of the Department during the assessment period:
Donald Julius Groen Prize of the Safety and Reliability Group of the Institution of Mechanical Engineers (Goldstein), Mitchell Prize of the International Society for Bayesian Analysis (Goldstein, Vernon), Lester R. Ford Award by the Mathematical Association of America (Ward T). In addition, the following prizes were awarded to students in the Department: Prize for outstanding thesis by the International Society for Bayesian Analysis (Williamson), Silver Young Researcher Awards by the International Journal of Approximate Reasoning (Baker, Crossman, Huntley, Maturi).

Plenary, Keynote and Named Lectures were given by members of the unit at:
The International Conference of Numerical Analysis and Applied Mathematics, Psalidi-Kos, Greece 2008 (Straughan), The Gowland Lecture at the Science and Religion Forum, Liverpool 2008 (Gregory), 28th International Colloquium on Group Theoretical Methods in Physics, Newcastle 2010 (Ward R), LMS Mary Cartwright Lecture, Durham 2010 (Gregory), QMath11 Conference, Hradec Kralove, Czechia 2010 (Post), 19th International Conference on General Relativity and Gravitation, Mexico City, Mexico 2010 (Hubeny), Young Researchers in Mathematics, Cambridge 2010 (Gregory), XVIth European Workshop on String Theory, Madrid, Spain 2010 (Hubeny), Fifth Summer Safety and Reliability Seminars, Gdansk, Poland 2011 (Coolen), Le Congrès National de Mathématiques Appliquées et Industrielles, Guidel, France 2011 (Sutcliffe), The Second International Conference on Numerical Analysis and Optimization, Muscat, Oman 2011 (Straughan), Seventh International Conference on Dependability and Complex Systems, Brunow, Poland 2012 (Coolen), 3rd Symposium on Games and Decisions in Reliability and Risk, Ireland 2013 (Coolen, Wooff).