Institution: University of Strathclyde

Unit of Assessment: 10 Mathematical Sciences

a. Overview

Organisation and structure: The Department of Mathematics and Statistics was formed in 2009 through the merger of the Departments of Mathematics and of Statistics and Modelling Science (STAMS). The strategic benefits of the merger, in terms of teaching, research, knowledge exchange and administration, were obvious from the start, since there already existed joint degrees, combined administration and research collaborations. The restructuring of research groups and strategy during the merger has led to further success in terms of increased research quality and quantity as well as additional benefits to research staff through associated career enhancement, increased international collaboration and impact, in both an academic and non-academic sense.

Research structure: The Director of Research takes overall charge of strategy, reporting to the Departmental Executive Committee, and convenes the Departmental Research Committee, consisting of all Heads of Research Groups, the Postgraduate Director, the Associate Head of Department in charge of Knowledge Exchange, the Departmental Administrator, a Postgraduate Representative, and the Head of Department. Research strategy and administration are organised through this committee, with input from regular Research Group meetings, and then feeds into the Science Faculty's Research and Knowledge Exchange Committee, on which the Director of Research sits.

Research groups: The merger proved an ideal opportunity to reconsider the research groupings within the Department. Although the five new Research Groups are not restrictive, with many staff being members of more than one Group and conducting cross-cutting research with collaborations across the Department, they each now form coherent research teams with clear strategies and critical mass. The new research groups are:

- Applied Analysis (AA: 4 FTE);
- Continuum Mechanics and Industrial Mathematics (CMIM: 9.2 FTE);
- Numerical Analysis and Scientific Computing (NASC: 9 FTE);
- Population Modelling and Epidemiology (PME: 5.7 FTE);
- Stochastic Analysis (SA: 5 FTE)

b. Research strategy

In RAE2008, the University submitted to the Applied Mathematics and the Statistics UoAs. The strategy for development in each case was to increase the momentum achieved over the previous decade by building on existing research groups through strategic appointments and developing appropriate interdisciplinary research collaborations both within and outside the Faculty of Science and the University. The creation of a unified Department has provided the opportunity to create a joint strategy for research and knowledge exchange and established a good baseline from which to measure success.

Previous strategic research aims and achievements since RAE2008: The vision since 2008 has been for a research-focussed Department with a high level of collegiate collaboration and the ability to jointly tackle real world problems though expertise in research and knowledge exchange, and strong international links. Since 2008, collaboration between researchers from the old Departments/UoAs has increased significantly, with interactions between the five research groups at double previous levels (current funding of collaborative projects is approximately £900k). A unified collegiate atmosphere has been helped by the involvement of staff at all career levels in the strategy-development process, and by the redevelopment of the estate environment, in particular the communal areas. Cross-fertilisation of a more theoretical research base in mathematics and an emphasis on high-impact applied modelling and statistics have now created a merged Department with a greater ability to undertake internationally-leading research and use non-academic links to create significant impact.

A key aim was to maintain the momentum in research that the two Departments had achieved in the previous assessment period. The increase in outputs, from approximately 550 in 2001-2007 to 750 in 2008-2013 is particularly noteworthy and has come about by renewed collaborative activity in more focussed research groups, but also through the strategic hiring of (usually) younger staff as less research-active staff have retired. Consequently, although the number of staff submitted is comparable to that in 2008, there are almost 40% more publications over the REF period and a greater proportion of staff submitted (from 85% in RAE2008 to 100% in REF2014). Details of significant Fellowship success and other indicators of increased research activity given in Section e provide further evidence of the enhanced research capacity of the unit. The increased productivity has, in part, been achieved through strategic appointments of staff with expertise aligned to the central themes of the University's strategic plan and in response to priority themes of EPSRC and the UK and Scottish Governments (see below).

Increased grant income from a wide funding base was a further aim of the new Department. The value of grants from EPSRC, our major funder, has increased from £3.75M for the period 2001-2008 to almost £5M in 2008-2013 (not including a further £3M in recently announced awards). Furthermore, the funding has been obtained from many Programmes other than the Mathematical Sciences and there has been an increase in much larger and longer grants, which have been strategically targeted. Most notable are the Science & Innovation award on numerical algorithms for parallel computing (with Edinburgh and Heriot-Watt, total of £5M with additional internal investment from the University), and the Platform grant on inverse problems in non-destructive testing (£900k, with Electric Engineering), as well as the TSB Future Cities award (£24M, with Glasgow Council) which will look at network analysis of large data sets. Further notable non-EPSRC funding is highlighted in Section d.
There has also been a significant level of inward investment by the University, which sees the Department playing a key role within the research strategy of the institution. Considerable pump-priming funding has been provided for new collaborations with internal and external groups, with the University continuing to fund the Bridging the Gap scheme (originally established by EPSRC), leadership of which is within the Department.

Strategic appointments to key research areas have been central to consolidating new and existing research groups in the merged Department and we have taken advantage of proleptic appointments to ensure continuity but also to re-align certain groups in new research directions. There has been significant strengthening of all research groups, most notably through:

- new leadership in the Marine Modelling Group with the appointment of Prof. Mike Heath (2009) from the Scottish Government (Marine Scotland Science) to lead the University's role in the Marine Alliance for Science and Technology for Scotland (MASTS) and to provide continuity for the future retirement of Prof. Bill Gurney
- significant investment from the University following the Science & Innovation award, to increase capacity in the Numerical Analysis Group, appointing Drs Victorita Dolean and Natalia Kopteva as Readers (2013)
- University investment in the Stochastic Analysis group to increase research capacity and to develop areas of use to the new MSc in Quantitative Finance, appointing Dr Wei Yang (2013).

The Department also aimed for **increased activity in multidisciplinary areas** particularly through collaborations with industry and Non-Governmental Organisations (NGOs), which is hugely beneficial for research relevance, PG and PDRA training as well as societal and economic impact. Key initiatives have been: engagement with the EPSRC Bridging the Gap project, which was jointly led by the Department and was awarded in 2007, and the co-founding of the Scottish Universities Insight Institute by a member of the Department. The number of non-academic groups collaborating with the unit has doubled in this assessment period, compared to the RAE, with projects funded with a wide range of organisations including Hewlett-Packard, IDEAS, Health Protection Scotland, Veterinary Labs Agency, Marine Scotland, Scottish Government, CRUK, Bioinnovel, Doosan Babcock, Cascade, Oasys, Chemtec, Proctor & Gamble, NAG, Wyeth, Shell, DSTL, Rolls Royce and Simul8 (approx. £2.7M total funding in REF period). Many of these collaborations have been developed through the use of pump-priming funds from a variety of sources (EPSRC, Knowledge Transfer Network (KTN) internships, BTG, and the EPSRC

Knowledge Transfer Account).

We have also achieved our aim of **maintaining a high level of PG students** by accessing wider funding sources and by leveraging through co-funding with industry and NGOs. In particular, the number of CASE awards (either EPSRC Industrial CASE, KTN CASE and, lately, EPSRC DTG provided CASE) has increased from 10 in 2001-2008 to 15 in 2009-2013. The Department now uses around 40% of its DTG allocation to support CASE, or co-funded CASE-like awards.

Infrastructure renewal was also important in the new Department and was achieved very soon after the merger through University investment of over £600K of estates infrastructure funding which increased capacity through a larger footprint and by better utilising space. Further investment from the University and external sources have been used to install a dedicated parallel computer system.

Future strategic aims: The aims since the formation of the Department have largely been met. However, having devised a more focussed research strategy, secured an influx of energetic new researchers and vastly improved our infrastructure, we now have the platform to build on this success and achieve more during the next few years. There are various mechanisms, either existing or imminent, that will ensure our growth in research capacity are stimulated by both internal and external influences and illustrate the expanding range of opportunities that we are now capable of embracing. There are four key thematic areas where the majority of our research staff will make significant contributions:

- *Marine ecosystems and climate change:* This is an area of growing global importance and Strathclyde's contributions will build on unique capabilities in the Department, with collaboration from the Scottish Government, the fishing industry and other universities in Europe. Funding worth over £10M from EU and NERC is pending.
- *From nano to macroscale fluid dynamics:* This theme will be supported by BTG funding and a new internally funded theme in the Technology and Innovation Centre. It will benefit from our international networks of collaborations and build on recent involvement in programmes such as the INI Programme in the Mathematics of Liquid Crystals (co-organised by the Department) and the INI programme on Mathematical Modelling and Analysis of Complex Fluids and Active Media in Evolving Domains.
- *Continuous Manufacturing & Crystallisation:* The Department is part of the recently awarded EPSRC grant "Intelligent Decision Support and Control Technologies for Continuous Manufacturing of Pharmaceuticals and Fine Chemicals" (£2.5M) which will be a major initiative within the Department, linked to £28M of funding in this topic and the wider research objectives of the Technology and Innovation Centre.
- *Smart Cities:* a new and extremely exciting collaboration involving the Numerical Analysis and Scientific Computing group has developed over the last year, which has led to the successful Glasgow bid for the TSB Future Cities Demonstrator programme (£24M). The award will include UoA 10 researchers in network science, epidemiology and experimental design, and involve a large number of researchers from industry and NGOs. The use of network analysis research will be key to understanding the large amount of data which aims to be exploited.

The University's £89M Technology and Innovation Centre (TIC) provides perhaps the most significant opportunity to add impetus to our expanding research portfolio. The TIC is a definitive statement of how Strathclyde intends to undertake research and engage with research partners. The new building, to be completed in 2014, will support colocation of academic and industrial research groups, and provide high quality public and exhibition space. The TIC research themes have been mapped onto the Department's research structure and links have been developed in several key areas:

- *Advanced Engineering & Manufacturing:* strategic input is being given through involvement with members in the Continuum Mechanics and Industrial Mathematics group, particularly the topics of materials modelling and inverse problems. This is building on existing collaborations with Mechanical Engineering (joint project in nano-filtration) and with the Centre for Ultrasonic Engineering, where there are numerous industry links and large research projects (e.g. an EPSRC platform grant - £1M for 2008-2012 and £2.5M for 2013-

2018)

- *Continuous Manufacturing & Crystallisation:* existing funded interaction between the Department of Chemical and Process Engineering and the Applied Analysis group will be enhanced, particularly in the area of coagulation and fragmentation, where the group have many years of expertise.
- *Health Technologies:* a member of the Population Modelling and Epidemiology group is currently on this theme's steering committee and interaction between a number of Departments (Bioengineering and SIPBS) will continue and will benefit from input from new groups in public health and drug discovery.
- *Sensors & Asset Management:* will extend existing links with researchers in the Continuum Mechanics and Industrial Mathematics group.

Monitoring and achievement of aims: The attainment of success in these developing areas of research will be monitored by the Director of Research and the Research Committee, reporting to the Departmental Executive Committee and thus to Faculty and University management who provide oversight of strategy. The University-wide annual Research Audit will provide the mechanism to assess and adjust aims when appropriate. Optimisation of the use of resources including staff time will further ensure that there is appropriate focus on the research initiatives. For example, we will develop classes and degree structures which allow staff to undertake the majority of their teaching and administration duties in a single semester, optimising time for research.

c. People, including:

i. Staffing strategy and staff development

Relationship of staffing strategy to University strategy: Strathclyde intends to be one of the leading international technological Universities in the world. As part of its strategy, the University insists that each staffing request contains a comprehensive description of the strategic research need for the post, at Department, Faculty and University level, with potential engagement in cross-disciplinary activities, e.g. the TIC initiative, which is of particular importance. Our Department has benefited greatly from such an approach and positions in mathematics and statistics are advertised widely and produce applications from all around the world. We always shortlist and offer positions to the best candidates regardless of origin and, due to the quality of applicants, have never had problems obtaining visas. Currently 13 out of the 35 submitted staff (by headcount) originate from outside the UK. During the REF period we have attracted five top class researchers to the department and two other posts are currently advertised.

Career development support: After appointment staff are assisted in career development through a coordinated mix of Departmental subject-specific mentoring and access to extensive University resources. For **Early Career** (PGR/PDRA/ECR) researchers, the Department support is provided through the Research Groups and is used to assist in familiarisation with University structures, external funding strategies and links to knowledge exchange. Advantage is also taken of Strathclyde's Researcher Development Programme (RDP) which is delivered by Faculties, Professional Services and external partners. The RDP provides a range of opportunities in career management and skills development, and is mapped to the UK's Researcher Development Framework and Statement (RDF/S). The Department has had direct input into tailoring such programmes and one of our research staff has previously been seconded to the RDP during development of the programme of activities. **Examples** of the success of this approach include the mentoring of a research fellow (Kavanagh) in the PME group which has led to her developing an independent line of research, establishing links to researchers in the biomedical sciences in Strathclyde through the Bridging the Gap scheme, using internal funding to assist in the organisation of meetings such as the Young Statisticians Meeting (Chair), and recently being awarded funding from industry to support her research. Another example is a member of the CMIM group (Walker) who received similar mentoring and also engaged at a University level with the RDP, eventually becoming a Faculty coordinator assisting in the design of future programmes. These schemes allowed him to find a wider audience for his industrially relevant research and recently helped him secure a permanent academic position.

Mid-Career researcher development is organised through the University's Mentoring@Strathclyde and the Strathclyde Researcher Career Pathway – a mentoring scheme and analysis tool to support researchers identify their development needs. At the Departmental level Mid-Career researchers are encouraged to be involved in all aspects of academe, including participation in both the Research and Executive Committees. An **example** of this approach has been the development of a member of the NASC group (Ramage) who has become an integral part of the Department (Chairing the Academic Committee and a member of the Executive Committee and Faculty Academic Committee) while maintaining her research profile through mini-sabbatical (half year) breaks. The flexibility in allocating teaching and administration has allowed her to continue research and gain an awareness of University systems at all levels, which has positively impacted on the development of research projects (gaining University funding for PGs and IP support for industrial projects) and more generally supporting her career progression (promotion to Reader in 2010).

The "**Established Academics**" programme has been developed for mid to late career academics and includes workshops on research leadership and maximising effective knowledge exchange. Established academics take positions of leadership within the Department, i.e. as senior managers and convenors of major committees, but also provide mentoring within each research group. Many of our established academics take advantage of focussed University schemes to enhance research, either leadership courses when research groupings expand or funding scheme assistance. For **example**, Higham has taken advantage of schemes based around supporting bids to EU and large UK funding schemes, including applications to FP7 and EPSRC. In particular, large cross-Faculty, interdisciplinary bids such as the Future Cities bid and the proposal for an EPSRC CDT in Mathematics Inspired by Data Sources have benefited enormously from guidance and coordination at the University level. This mentoring and support has allowed his personal and group research to excel, for instance resulting in his recent award of the Royal Society Leverhulme Trust Senior Research Fellowship.

As part of the development of all staff we encourage applications for **personal research fellowships** to assist in the consolidation of existing research and formation of new research themes and international collaborations. During the REF period, formal personal research fellowships have been awarded to our staff by the Royal Society, Leverhulme, OCCAM, Health Protection Scotland and the RCUK Discipline Hopping scheme. In addition, the Department also runs full- and mini-sabbatical schemes, offering year, half-year or term-long periods free from administration and teaching to concentrate on research. The sabbaticals are awarded through an annual call for short proposals and funded by the Department. In the term-long sabbatical scheme, non-research duties are re-scheduled to be concentrated in a shorter period of the year, and this scheme has been particularly successful in allowing staff to write papers and grant proposals.

Implementation of the Concordat to Support the Career Development of Researchers: Implementation of the Concordat and the schemes mentioned above have meant that the University achieved the EU HR Excellence Award in September 2011. The University's action plan for researcher development details current and planned actions, and is available on the University website.

Equalities and diversity: The University uses Equality Impact Assessment (EIA) as a systematic and evidence based process which verifies that the University's policies and practices are not discriminatory. The University achieved the Athena SWAN Bronze Award in August 2011 and the Department has already formulated an equality action plan and is applying for an individual Bronze Award.

Visiting scholars: The Department also benefits from a network of Visting Professors who are full members of the Department and form close and long-standing collaborations with specific research groups. They regularly visit the Department, often for extended periods (i.e. Gartland for three months in 2013) and also assist in other ways, e.g. providing an international perspective in preparations for REF2014. These visiting scholars come from across five continents and in some cases have helped develop larger research and teaching links, e.g. with the African Institute for Mathematical Sciences and the Science Without Borders Scheme with Brazil. Visiting Professors during the REF period were: Professor Jacek Banasiak (Kwazulu-Natal), Professor Sheila M Bird

(Cambridge, MRC Biostatistics), Professor Hermann Brunner (Hong Kong), Professor Jose Cuminato (São Paulo), Professor Iain Duff (Harwell), Professor Eugene Gartland (Kent State), Professor Rainer Picard (TU Dresden), Dr Keith Vass (Dundee), and Professor Jay Walton (Texas A&M).

Visiting Professors have enabled our researchers to attain a wider, international, reach and to enhance the quality and impact of our research. For **example**, Prof. Duff's role as project leader in the Parallel Algorithms Group at CERFACS in Toulouse has meant that links to Strathclyde have developed, leading to joint publications and sabbatical visits in both directions. Prof. Cuminato's links to our Department and his position as Head of Department in São Paulo, as well as his leading role in strategy development in the area, assisted in the award of Santander Fellowships to the University, which the Department has already started to exploit further, with bilateral exchanges held in 2013.

Mechanisms to maintain standards of research quality and integrity: The Department is assisted by the University's Professional Services to measure our performance against leading institutions, including compliance (as measured by audit) with relevant standards including QAA Code of Practice for Postgraduate Research Degree Programmes, European Charter for Researchers and Code for Researchers, UK Concordat and the UK Researcher Development Framework. Within the Department we use these measures and evidence of quality and impact of research through Annual Review, and have set targets, in particular for PGR and ECR staff, which aim to develop additional skills. As evidence for this success, in 2011 and 2012, Strathclyde was shortlisted for a Times Higher Education Award for 'Outstanding Support for Early Career Researchers' and Strathclyde is the current THE University of the Year for 2012.

ii. Research students

In the Department, most **decisions on allocation of studentships** are made through Departmental ranking of proposals from staff sent to a strategic University panel process which allocates EPSRC DTG and University Scholarship funds. The ranking criteria are based on: the quality of research and training; alignment with strategic themes; potential to deliver impact (as per EPSRC objectives); quality of student; supervisor completion rate; multidisciplinarity (i.e. co-supervision with other Departments); collaborative links with industry/business or international researchers; co-funding from external sources; and pump-priming of new research areas and for new staff. Funding decisions are given as early as possible in order to secure the best students and recruitment is coordinated centrally in order to develop a cohort-centred ethos, reinforced through subsequent training. This approach has also resulted in an increase in PGR students who have originated from outside the UK, to a current level of 50% of students. The University is keen to see a continuation of the high level of CASE awards within the Department (approximately 40% of our DTG grant allocation).

Training provision: In the last five years, our **researcher development strategy** has undergone a significant step change, with the introduction of taught courses from the Scottish Mathematical Sciences Training Centre (SMSTC) coordinated with the Strathclyde Researcher Development Programme (RDP) and organised through the "PG Portal", a web-based environment for PGR training. Activities are coordinated at the Department level by the PG Director and student training now forms an integrated credit-bearing course, tailored to a student's needs and compliant with the University's requirement that PG students undertake 60 credits of training during a PhD degree. A second arm of RDP is focussed on a broader **training for a range of career paths**, bringing together the larger, University-level PGR cohort. Highlights include: the "Enterprise Academy", to develop enterprise, communication and business plans; "Becoming an Engaging Researcher", involving broadcast media and community engagement; "University Research Day", with PGR involvement at leadership level and, by 2015, all PGRs will also be offered an international secondment. At a subject-specific level, The Department aims to produce PGR students with a **broad mathematical education** and a deep knowledge of their speciality, with training requirements agreed at the start of a student's degree, in consultation with the supervisor, PG Director and student. The number and timing of training courses (e.g. streams in the SMSTC training course) is weighed against previous qualifications to develop a portfolio of training, centred

on the student's needs, to complement the research. The main training is usually through SMSTC, or courses offered by the Royal Statistical Society (RSS) and the International Centre for Mathematical Sciences (ICMS). The SMSTC, for example, provides a high-quality broad training in mathematical sciences with additional support through local tutorials. Attendance and presentation at conferences, and visits to collaborators, also play a vital part in PGR training and financial support is always provided, often through the use of Industrial Placement schemes. PGRs also assist in the organisation of conferences, i.e. the Young Statisticians' Meeting and the Society for Industrial and Applied Mathematics (SIAM) PG Chapter meetings and attend weekly Departmental and group seminars. PGRs are also given the opportunity to contribute to teaching, with training available from Department, University and ICMS. ICMS training is particularly successful and includes specific skills training on "How to manage your supervisor", Unix, LaTeX, bibliographic databases, mathematical software, writing papers and reports. PGRs now have an unprecedented level of transferrable skills, credit-bearing professional research qualifications, a greater understanding of the wider impact of their research, and an ability to collaborate in all environments. Workshops in career development, with speakers from business are provided and EPSRC and non-EPSRC students are also funded to attend GRADschools.

The Department also values its **joint research training** with other departments which includes: the new (starting in 2013) MSc in Financial Mathematics used to train PGRs in the Department during their first year; and joint PGR projects with other Departments (e.g. Chemical and Process Engineering, Biomedical Engineering, Chemistry and Physics) which include training in non-mathematical subjects from centres such as the Medical Devices DTC at Strathclyde.

Monitoring of training: Monitoring is coordinated by the PG Director through an online database. All PGRs have at least two supervisors and are mentored by an independent staff member. Progress is recorded every 3 months in year 1 and every 6 months thereafter, supplemented by regular assessments of research and training. At the end of year 1, a research report enables the Department to decide on progression and during the 2nd year PGRs present their research to peers, write an updated research report and sit a "mini-viva". At the end of 3rd year a draft thesis or a thesis plan with attached papers is required. At each of these assessments the PG Director reports to the Departmental Research Committee which allows progression or, if necessary, organises remedial action or transfer to a Masters level course. These strategies are employed to ensure the students' training is completed to a satisfactory level and that the training programme is matched to the individual's needs. At all times the training programme is flexible and may be adapted to suit changes in needs and research direction. This coordinated approach to PG student research and training has meant that completion rates have increased from 80% in 2009 to 90% in 2013.

Postgraduate environment: The Department provides excellent accommodation and equipment with a mix of larger offices in early years to develop the cohort and smaller (2 PGRs) offices in later years for intense research and writing-up. PGR students are viewed as an integral part of the Department and are involved at all levels, including PGR representation on the Departmental Research Committee.

d. Income, infrastructure and facilities

As highlighted above, our **research funding portfolio** has increased significantly. The department has been part of consortia that have been successful in winning large grants from EPSRC (the Science & Innovation Award (£4.5M with Heriot-Watt and Edinburgh); Continuous Manufacturing of Pharmaceuticals and Fine Chemicals (£2.5M)), and large non-EPSRC grants (from the EU FP7 BASIN programme (13.3M Euros) and Materials World Network ($3.5million)). Additional notable non-EPSRC funding won by the department since RAE2008 has come from: European Commission FP7 (£1,408K); NERC (£641K); Health Protection Agency (£590K); Fisheries Research Service (£398K); Leverhulme Trust (£240K); Chief Scientist's Office (£234K); and MRC (£200K). These grants have resulted in high quality research outputs which are included in the REF submission from staff in the NASC, CMIM and PME research groups.
During the formation of the merged Department the University invested £600k in **infrastructure** to

refurbish the whole Department. Extra space was given to an expanding PG cohort and larger collaboration areas (seminar rooms and social space) have been developed. The co-location of all secretarial support staff from the previous two Departments into a dedicated administration centre has particularly benefited the merged Department. Further investment has derived from co-funding of the new High-Performance Computing **facilities**, initiated through the Science & Innovation Award.

As well as computational facilities, the Department uses its intellectual expertise through **consultancies and professional services** for many non-academic groups. For example, consultancies and advice has been provided to: the European Food Standard Agency for flu risk; Scottish Food Standards Agency for Wild Game Risk Assessment; as an Expert Witness for the Vale of Leven Inquiry; Health Protection Scotland Advice on Legionella Outbreaks; and surveillance planning during the G8 summit and Olympics. Industrial consultancy has been provided to: BluTest; IDEAS; Zinktech; OncImmune; NHS Greater Glasgow and Clyde; CPS Research.

e. Collaboration or contribution to the discipline or research base

The Department contributes to the national and international research base across a wide range of activities. Collaborations across the world have always been a part of the research activity of the Department; some of the strongest and longest-lasting relationships have led to the Visiting Professorships mentioned above. Members of the Department take roles of responsibility at a local level (i.e. Chair of the Edinburgh Mathematics Society, Branch Chair of IMA), at the national level (members of committees of the Council for Mathematical Sciences, EPSRC SAT/panels, DEFRA, LMS) and the international level (SIAM council member, prioritisation panels of EU and foreign research councils). Further details of such roles and other activities are given below.

On a purely academic level, staff in the Department have active **academic research collaborations** around the world, which have led to publications (many of which are included as REF outputs), grants and non-academic impact with staff in KwaZulu-Natal, Pavia, Oxford, Princeton, Madrid, Beijing Normal, Virginia Tech, Donghua, LNCC, GMU, Limerick, TU Darmstadt, Chubu, Sao Paulo, Maribor, Texas A&M, Vienna, Shanghai, Newfoundland, Sydney, Kent State, George Mason, Vienna University of Technology, École Normale Supérieure, Concepcion, and Alberta. Staff have formed a considerable network of researchers, including those initiated within the REF period, such as the Materials World Network, and organisation of the INI Programme on the Mathematics of Liquid Crystals.

The Department contains world-renowned researchers (e.g. Estrada, Higham, Mao, Osipov, Stewart, Wilson) as well as internationally leading research groups (e.g. in Numerical Analysis, Liquid Crystal Theory, Public Health, Marine Science) and there has naturally been national and international recognition. Notable **Fellowships, awards and prizes** include: Royal Society Leverhulme Trust Senior Research Fellowship (Higham); Leverhulme Fellowships (Wilson, Barrenechea and Ospinov); Fellow of the International Academy of Mathematical Chemistry (Estrada); two Royal Society Wolfson Research Merit Award (Higham and Estrada); German Science Foundation Merkator Guest Professor Award (Osipov); and RCUK Discipline Hopping Fellowship (Mottram).

As a Department which prides itself on the application of its research to create impact, there has always been considerable collaboration with industry, business and non-governmental organisations. These links have grown stronger in the REF period (e.g. Health Protection Scotland and Veterinary Laboratories Agency links are now 15 years old, while Hewlett-Packard have funded projects over the last 12 years). The number of **industrial collaborations** has more than doubled (in number and funding value) in this assessment period, compared to the RAE period. Recent funded project have been with Hewlett-Packard, IDEAS, Health Protection Scotland, Veterinary Labs Agency, Marine Scotland, Scottish Government, CRUK, Bioinnovel, Doosan Babcock, Cascade, Oasys, Chemtec, Proctor & Gamble, NAG, Wyeth, Shell, DSTL, Epiconcept, Rolls Royce, Weidlinger Associates, BP and Simul8. Many of these collaborations have been

developed through the use of pump-priming funds from a variety of sources (EPSRC, KTN internships, Bridging the Gap, Knowledge Transfer Account). **NGO research collaborations** have traditionally been a strong point of the Department's interdisciplinary research, and the area where we have had the most impact in a non-academic sense. The large research groups in marine modelling and epidemiology have always had links with Marine Scotland (as well as European equivalents) and Health Protection Scotland, NHS, Vets Labs Agency and the Chief Scientist's Office in Scotland. Over the REF period funding from these organisations totals over £2M. Other smaller funded collaborations exist with the National Institute for Health Research, the European Centre for Disease Control, DEFRA, the International Prevention Research Institute, and NC3R. The REF period has also seen an increase in interdisciplinary research. While we have historically had strength in areas such as those mentioned above in population modeling and epidemiology, and links to physics and chemistry in the material science areas, further collaborations have been started, largely funded through University initiatives. In particular, collaborations with staff in the departments of Chemical and Process Engineering, Mechanical Engineering, Biomedical Engineering, Economics, History, and Electronic and Electrical Engineering have now grown to much larger and more significant research projects during the REF period.

Staff in the Department have also contributed to the wider discipline base through **national or international advisory board membership** and **leadership roles in Research Councils, learned societies or professional bodies**, as members of: a Canadian Government Review panel; Defra's Tuberculosis Vaccines Programme Advisory Group; Technical Science Board of GalvMed Global Alliance; Marine Scotland Scientific Advisory Board; Defra Data Group for TB Vaccination Trial in Badgers (Chair); Programme Advisory Group of the UK NERC Ocean Acidification Programme; the National Review of Climate Impacts on Fish (lead author); Scottish Infection Research Network Management Committee; International Breast Cancer Group Ethics Committee; International Breast Cancer Group Data Safety Monitoring Committee; and the Department of Health SPI-Modelling Committee. Staff have been members and Chair of Research Council Prioritisation Panels as well as a member of the Council for Mathematical Sciences, the EPSRC Strategic Advisory Team for Materials, the EPSRC working group on the "people pipeline", and the London Mathematical Society Research Policy Committee. Half of the staff are members of the EPSRC College and/or part of the peer review systems for other research funders, such as ESF, ESRC, MRC, NERC, EMS, LMS and SIAM.
Staff have also also served as President of the Edinburgh Mathematical Society and President of the Society of Veterinary Epidemiology and Preventive Medicine.

Staff have recently **organised many international conferences**, one of which is the renowned Biennial Numerical Analysis Conference which has now permanently transferred from Dundee to Strathclyde; others include EUROMECH 497 (2009) in Edinburgh, MAIA: Multivariate Approximation and Interpolation with Applications (2010), ICMS workshop on Differential Geometry and Continuum Mechanics (2013), as well as an organiser of the INI Programme Mathematics of Liquid Crystals (2013).

During the REF period, staff have served on the **editorial boards** of over 40 journals, including being the Editor-in-Chief of the Journal of Complex Networks (Estrada), Executive Editor of Journal of Biological Systems (Greenhalgh), Convener of Editorial Board of Proceedings of the Edinburgh Mathematical Society (Grinfeld), Section Editor for Survey and Review section of SIAM Review (Higham), Chief Editor of British Journal of Mathematics and Computer Science (Mao), Joint Editor-in-Chief of Journal of Engineering Mathematics (Wilson), Subject Editor, Journal of Animal Ecology (Gurney), Executive Editor of Proceedings of the Royal Society of Edinburgh, Section A: Mathematics (Higham).

All of these activities are evidence of a vibrant research Department which has grown in strength over the REF period, contributing impact across academic and non-academic arenas at a Scottish, UK, EU and international level. We intend to build on our successes and play an increasingly important role at the heart of a bold, imaginative and innovative University for the 21st Century.