Institution: University of Surrey

Unit of Assessment: UOA 10 Mathematical Sciences

a. Overview

Mathematics at the University of Surrey has flourished since 2008, further enhancing a history of fundamental, innovative and interdisciplinary research. Since 2008, the principal evolution of research in the Department of Mathematics (DoM) has been in three directions; firstly a significant expansion in interdisciplinary research, secondly an amplification of the area of dynamical systems and PDEs, a traditional strength at Surrey, and thirdly the development of a new research area in string theory and geometry. The headcount in the RAE2008 submission to Applied Mathematics was 22 with 17.42 FTEs and 3 independent researchers. With new appointments in biosystems, dynamical systems, fluids, PDEs and a block of new appointments in Fields, Strings and Geometry, the current REF submission has a headcount of 29 with 28.4 FTEs which includes 3 independent researchers.

In RAE2008, the research groups were (a) Dynamical Systems & Ergodic Theory, (b) Dynamics of Patterns, (c) Geometric Fluid Dynamics, and (d) Geometry and Mechanics. In the intervening period, influenced by strategy, new initiatives, the departure of staff, and the influx of new staff, areas (a) and (b) have been combined to form **Dynamical Systems and PDEs** (DsPDE), a group led by Roberts and Zelik. This area has been amplified by the appointment of a Reader and 3 Lecturers, and the promotion of Zelik to a Readership. Geometric Fluid Dynamics has evolved into **Fluid Mechanics and Meteorology** (FMM), to capture new initiatives in data assimilation, theory of water waves, and ocean wave energy, as well as new directions in geometric fluid dynamics. FMM is led by Roulstone, and has been strengthened by the appointment of 2 new Lecturers. A new initiative, which grew out of existing research, is the formalisation of the area of mathematical biology, life and social science modelling, statistics and pharmacokinetics into a **Biosystems** (BioS) Group. BioS is led by Gourley and Hoyle, both of whom were recently promoted to Professorships, and it was enhanced by the appointment of a new Lecturer. Geometry plays a central role in the research in fluid mechanics and in geometric mechanics, and its underpinning role has been amplified in the new string theory group, named **Fields, Strings & Geometry** (FSG), which takes the use of geometry to new heights. FSG is led by Sfetsos, a newly appointed Professor, and the group has been rapidly grown to critical mass with the appointments of a Reader, an STFC Advanced Fellow, and 4 Lecturers. FSG has already attracted over £1m in outside funding, including an EPSRC Postdoctoral Fellowship, an EPSRC First Grant, an STFC Consolidation grant, and an EU Marie Curie Fellowship.

Interdisciplinary research played an important role in RAE2008, and has developed and expanded in the period. Meteorology has grown with the emergence of the National Centre for Earth Observation (NCEO); Roulstone is the co-theme leader in the area of data assimilation (DA). Astrodynamics has expanded into a European network with AstroNet I & II, both funded by the EU, which were initiated by Roberts in collaboration with the Surrey Space Centre. The area of biological, life and social science modelling has expanded in several directions: the MILES (*Models and Mathematics in Life and Social Sciences*) project, an EPSRC-funded Bridging the Gaps programme, led by Hoyle, the ERIE project (Hoyle, Lloyd & Skeldon) funded by the EPSRC complexity initiative, and pharmacokinetic modelling of drug discovery (Aston & Derks), in collaboration with the pharmaceutical industry (Pfizer, MedImmune). The direction of research into water waves has been enhanced by grants (Leverhulme, EPSRC, Newton Institute) for sloshing and its application to ocean wave energy extraction, led by Bridges and in collaboration with the ocean wave engineering industry (Offshore Wave Energy Ltd, ITPower Ltd).

The DoM arrives at the cusp of the REF period with momentum and a clear future strategy. The research environment is organised into robust research groups with research directions aligned with UK and international priorities, and a multi-faceted dissemination strategy. It has a balance of senior and junior staff with 6 ECRs, 28 current PhD students and a major Doctoral Training Partnership, funding of £110k secured for conferences in 2014, and a portfolio in excess of £3m, funded by major grants from EPSRC, NERC, STFC & EU, with funding out to at least 2018.

b. Research strategy

The overall strategic aim of the DoM is to provide an environment that promotes research of international excellence and impact, that encourages a culture of creativity, enterprise and innovation, fosters the highest achievements, and maximises the application and impact of our intellectual assets. After RAE2008 the DoM set in motion a 3-part 5-year strategy: grow interdisciplinary research, introduce a new research group based on a block of 6 new appointments, and enhance the traditional strength of dynamical systems and PDEs.

Interdisciplinary research has flourished at Surrey during the period. Three areas where a critical mass of interdisciplinary activity has been achieved are highlighted below.

Biosystems: one of the biggest surprises of the period was the blossoming and organic growth of BioS, representing biology, pharmacology, life and social sciences, which arose out of existing strengths in dynamical systems, mathematical biology, and pattern formation. It is now a major research area in the DoM. BioS was strengthened by the appointment of Dunlop (modelling of biological systems) to a Lectureship. A key feature of the development was the £3.4m award by EPSRC of the ERIE project, an initiative led by Gilbert (Sociology) with co-investigators (Hoyle, Lloyd & Skeldon) in mathematics. A second independent initiative is the MILES programme, led by Hoyle, including collaboration with Sociology, Computing, Biology, Engineering, Digital Arts, and Physics at Surrey and a range of non-academic endusers. Other directions in BioS include sleep modelling (Derks & Skeldon), in collaboration with the Surrey Sleep Centre, tumour modelling (Lloyd & Skeldon) in collaboration with the Royal Surrey County Hospital, and pharmocokinetic modelling of drug discovery (Aston & Derks). Output highlights include Gourley & Zou (2008) *A mathematical model for the control and eradication of a wood boring beetle infestation,* SIAM J Appl Math (selected for reprint in SIAM Review, 2011); Derks et al (2013) *Stability of stationary fronts in a nonlinear wave equation with spatial inhomogeneity*, J Diff Eqns; and Hoyle & Ezard (2012) *The benefits of maternal effects in novel and in stable environments*, J R Soc Interface. Both the ERIE and pharmacokinetic modelling projects underpinned impact case studies.

Data assimilation and water waves: are two topics which emerged from research in geometric fluid dynamics. This area was strengthened by the appointment of three new Lecturers: Cheng (nonlinear PDEs & fluids), Tronci (geometric mechanics & fluids), and Turner (vortex dynamics & hydrodynamic stability). DA research has expanded with the opening in 2009 of NCEO, a NERC funded centre of excellence with Roulstone the Surrey node leader, supporting a sequence of PhD students and a long-term postdoc. DA is developing in other directions such as carbon cycle modelling (Aston & Skeldon). Prof Peter Clark, who input CFD into the DA initiative, moved to Reading Meteorology in 2012 and a replacement post in Computational DA is planned. The theory of water waves has been enhanced by an EPSRC grant on wave energy extraction (Bridges & Turner), in collaboration with industry, and the funding of a 2014 Newton Institute programme on water waves. Output highlights include Roulstone et al (2009) *A geometric interpretation of coherent structures in Navier-Stokes flows*, Proc Roy Soc London A (a starting point for the Clay Maths 2014 Conference); Hydon & Mansfield (2008) *Difference forms*, Found Comp Math; and Ardakani & Bridges (2011) *Shallow water sloshing in vessels undergoing prescribed rigid body motion in 3D*, J Fluid Mech (2011). Both the DA and ocean wave energy projects underpinned impact case studies.

Astrodynamics:, which emerged from research in geometric mechanics, has expanded into a UK and European network funded by the EU. This theme is led by Roberts in collaboration with the Surrey Space Centre. AstroNet I (2007-2010) was an EU Marie-Curie Research Training Network with the European Space Agency as the principal non-academic partner, and AstroNet II (2011-2014) an EU Marie-Curie Initial Training Network led out of IEEC in Barcelona, with industrial partners Astrium and Thales, and smaller companies Deimos and Clyde Space. This project has provided underpinning research for the next generation of satellite control systems. Output highlights include Roberts et al (2011) *A unification of models of tethered satellites*, SIAM J Applied Dynamical Systems.

New research group: the second strategic aim emerging from RAE2008, where the four research groups were closely linked, was to appoint a new group to broaden our research portfolio, using new faculty-authorised funding. The broad directions under consideration were (a) stochastics, (b) quantumology and (c) geometry. There was an extensive pre-advertisement search and interview process, but it was essential and ultimately profitable. From this process a view emerged that the latter themes could be combined with the creation of a "Fields, Strings & Geometry" group, especially since outstanding candidates could be found. The new group is led by Sfetsos and includes a Reader (Grant), an STFC Advanced Fellow (Gutowski), and four lecturers (McOrist, Pasquetti, Torrielli, Wolf). Output highlights include Sfetsos et al (2009) *The black hole and FRW geometries of non-relativistic gravity*, Phys Lett B (highest cited paper in the submission); Pasquetti et al (2008) *Remodelling the B-model*, Comm Math Phys; and Gutowski & Papadopoulos (2013) *Index theory and dynamical symmetry enhancement of M-horizons*, J High Energy Phys.

Dynamical systems and nonlinear PDEs: have been traditional strengths at Surrey. With the theory of finite-dimensional dynamical systems peaking nationally, and the move of Bruin to Vienna and Melbourne to Warwick, our strategy has been to move the centre of activity towards infinite-dimensional dynamical systems, and combine it with analysis of PDEs, leading to the formation of the DsPDEs Group, led by Roberts and Zelik. This group was enhanced by the promotion of Zelik to Reader, expansion of activity in Geometric Mechanics, and new staff appointments: Grant to Reader (a member of the FSG group, but also working in nonlinear PDEs), and the appointments of Cheng (PDEs, with applications in fluids) and Morris (Dynamical Systems) to Lectureships and Shmerkin (Dynamical Systems) to an Early Career Fellowship. Six new PhD students were recruited, and a series of national PhD schools were organised at Surrey as well as a major ICMS conference in 2011 (co-organised by Bartuccelli & Zelik). The group combines dynamical systems (Hamiltonian dynamics, bifurcation theory, coupled oscillators, ergodic theory, fractal geometry, and geometric mechanics) with nonlinear PDEs (calculus of variations, dissipative PDEs, Navier-Stokes, pattern formation, and numerics). Output highlights include Zelik et al (2013) *Counterexample to regularity of Mane projections in the theory of attractors*, Russian Math Surveys (shows that a well-known conjecture is wrong); Oliver & Wulff (2012) *A-stable Runge-Kutta methods for semilinear evolution equations*, J Functional Analysis; and Hochman & Shmerkin (2012) *Local entropy averages and projections of fractal measures*, Annals of Math.

Although the four research groups follow distinct paths of development, they are not silos, and indeed some of the most active work is between members of different groups. However, the group structure is important for formulating critical mass in an area, a line management structure for annual reviews and a framework for internal review of grant proposals. The research environment is enhanced by a lively visitor and seminar programme: the current seminar programme consists of colloquia on Friday, and four subject specific (group) seminars on Tuesday through Friday. These seminars are supplemented by special programmes, like the "Themed Semester" series, and special lecture series.

Research in the DoM is led by the Director of Research (Bridges), and a Mathematics Research Committee (currently including Gourley, Hoyle, Roulstone, Sfetsos, Wulff, and Chaired by Bridges). This committee provides overall direction for the local research environment, and is integrated into the Faculty research environment, enabling the DoM to take advantage of Faculty-wide research initiatives: shared opportunities for PhD funding, equipment grants, joint projects with the Space Centre, Advanced Technology Institute, Medical Physics Group, Computing, and Astrophysics.

Future strategy

The key issues for the next five years are the gelling and evolution of the four research groups, intradisciplinarity and synergy enhancement between groups, building on interdisciplinary research successes, executing a robust strategy for research funding and PhD students, and networking: national networking to enable timely response to RCUK initiatives, and international networking to advance international excellence, all taking into account University, national, and international priorities, and underpinned by a vigorous equality and diversity strategy.

Currently, the DoM has more than £3m in awards from EPSRC, STFC, NERC, EU and Leverhulme, as well as a funded DTP and a range of small grants, extending out to at least 2018. Crucial to future research funding is diversity. Moreover, with anticipated shrinkage and channelling of RCUK funding, the funding strategy will be increasingly linked to the interdisciplinarity strategy, with enhanced interaction with industry, the Met Office, local hospitals, wave energy and space companies, and the Surrey Research Park.

Interdisciplinary research has been a major growth area since RAE2008. It is expected to unfold, with new initiatives and partners, and supplement RCUK initiatives where industry funding is required for large proposals. “Green mathematics" - mathematics underpinning a sustainable environment - has developed in the period and is expected to be a growth area in the future building on the mathematics of weather, modelling sustainable energy economies, carbon cycle modelling, and ocean wave energy modelling.

The MILES programme has been ground-breaking in its approach to the start-up and development of interdisciplinary projects. With the end of EPSRC funding in 2014, MILES is evolving in two new directions. Firstly, it has become part of the national Bridging the Gaps network, with regular conferences on the advancement of interdisciplinarity. Secondly, MILES will form the core of “Collaboration Surrey”, a University-wide creative programme for interdisciplinary projects, led out of DoM, with internal and external funding of at least £70k out to 2016.

The future strategy for PhD students is twofold: robustification of the funding strategy, and attraction of quality candidates. For the former, the strategy is to introduce a Surrey Mathematics Doctoral Training Centre (SM-DTC), with internal core funding, and partnering with consortia of peer institutions to manage funding and prepare for RCUK multi-partner initiatives. The SM-DTC will also manage the current and future connections with other DTCs in the University (EU Marie-Curie PhD training in space, EngD programme in sustainable energy, ERIE PhD students, NERC PhD students). A major new development is the NERC award in November 2013 of a Doctoral Training Partnership (DTP) between Reading and Surrey, with the Surrey component led by Roulstone, in the area of “SCENARIO: *SCience of the Environment: Natural and Anthropogenic pRocesses, Impacts and Opportunities*”. This DTP funds 60 PhD students over the next five years. The strategy for recruitment of PhD students is multi-fold: target MMath and MSc students, expand the summer UG research programme (EPSRC Summer bursaries, Nuffield grants, internal scholarships), the IMA national UG research conference (at Surrey in Feb 2014), the MMath seminar during semester, and invite UGs to research events such as colloquia. The target steady-state PhD population is 30+ PhD students; currently the PhD population is 28 (5 of which are co-supervised with other disciplines).

The primary pathway for dissemination will continue to be publication, taking into account the vast new range of pre-publication (ArXiv, etc), publication (ejournals), and post-publication (blogs, etc) venues. Publication will be enhanced by the new green-gold open access (OA) pathways, which is a high priority for the University, with some DoM publications being gold OA and all DoM publications currently being green OA. Publication quality will be enhanced through the range of international research partnerships. A research blog, on the DoM webpage, reports on research highlights.

Conference organisation facilitates the showcasing of research and demonstrates a leadership role in the conference theme. Over £110k has been secured for conferences to be organised by Surrey staff in 2014 (FSG conference at Surrey, ClayMath Conference, Newton Institute Programme, SIAM Nonlinear Waves, IMA UG Research Conference).

In addition to gelling and evolving the research groups, primary new initiatives are proposed at the interface between groups: (a) stochastics, linking with dynamical systems and PDEs, and with applications in biology; (b) pure geometry, with applications in string theory, mechanics and fluids; (c) mathematics underpinning data assimilation; and (d) mathematics in life and social sciences. All four directions have significant momentum already.

c. People, including:

i. Staffing strategy and staff development: Academic Staff are the lifeblood of the Department. Appointing, mentoring, developing, training, managing, appraising, funding, promoting and providing sabbaticals are all instrumental to a productive staff environment.

Appointments follow research directions which are determined by strategic deliberation. Once a research area is targeted for appointment, the appropriate balance of junior and senior positions are decided. Mature research areas are driven by new lectureship appointments, new research areas are driven by professorial appointments. The DoM has received strong Faculty support for both sustaining mature areas and new initiatives. The new appointments during the period were based on excellent qualifications, experience and resonance. Sfetsos (Professor), formerly of the University of Patras, has an h-index of 34+ and was recently chosen as one of three candidates in Greece to receive a national excellence award. Grant (Reader) was recently awarded a Habilitation at the University of Vienna. Of the Lecturers: Cheng was a Hildebrandt Assistant Professor at Michigan and a postdoc at Arizona State, Dunlop was a postdoc at Oxford (EPSRC) and held a BIOMS Postdoctoral Fellowship at Heidelberg, McOrist was a postdoc at Cambridge (EPSRC Personal Fellowship), Morris was a postdoc at Warwick (EPSRC) and Roma II, Pasquetti was a postdoc at Neuchatel, CERN, Imperial, and Queen Mary (Marie-Curie Fellow), Torrielli was a postdoc at York, Utrecht, MIT, Humboldt and Padova, Tronci was a postdoc at EPFL, Turner was a postdoc at Exeter (EPSRC) and Brighton (EPSRC), and Wolf was a postdoc at Imperial and Cambridge (STFC Postdoctoral Fellow). Of the independent researchers, Gutowski was formerly a postdoc at Queen Mary, Oxford, Cambridge, and KCL; Regelskis was a Postdoc at York (EPSRC); and Shmerkin was a postdoc at Jyaskyla (Finland) and Manchester (EPSRC).

Mentoring is a key part of the startup process for new appointments. New Professors are given a startup fund (including internally funded postdocs, internally funded PhD studentships, appended lectureships, high performance computers, and discretionary research funds). New lecturers are given light administrative and teaching loads, offered support for recruitment of PhD students and RAs, given funding priority for conference attendance, and encouraged in new research directions. Evidence of this is the promotions of Gourley and Hoyle to Professor and Zelik to Reader (all three having initially been appointed as Lecturers). The DoM plans to appoint Gutowski to an academic post when his fellowship ends.

Sabbaticals are actively promoted in the DoM. Staff can apply for a sabbatical at any time, particularly when there is resonance with an external event. The rule of thumb is half a year sabbatical for each 5 years in post. Indeed, since 2008 almost all existing staff (excluding new appointments) had a sabbatical of 6 months or more. Staff are also encouraged to apply for externally funded fellowships (fellowship awards are reported in Section e below).

Development and training for all staff are managed centrally by the Staff Development Department which works alongside HR to enable appointments, organise general induction events for new staff, and implement a comprehensive staff development programme. Staff Development Policy ensures that all employees have equal access to appropriate training and development in line with an assessment of their development needs and the Equal Opportunities Policy.

Equality and diversity: the University recognises the benefits of a diverse community and aims to ensure that it can fully harness the talents, creativity and skills that people bring, and maintain its continuing commitment to equality and diversity across the broader community. As a public body, the University is committed to meeting its legislative responsibilities under the requirements of the Equality Act 2010. The DoM was actively engaged in the University's successful bid for an Athena SWAN Bronze Award in April 2013. Furthermore, the University is committed to ensuring that effective and targeted equality and diversity training is undertaken by all staff. A flexible working policy has been implemented and promoted across the University. The gender split for the 29 REF-submitted staff is 6 female and 23 male.

Postdocs: at the postdoctoral level, DoM takes pride in its track record of hiring RAs capable of independent research. RAs are nurtured to the extent that is necessary, with a wide range of ECR training integrated with staff development for junior academic staff, and input from the Careers Service, Staff Development, and Research & Enterprise Support. First destinations of recent RAs include Lectureships at St Andrews, Coventry, Nottingham, Heriot-Watt, Southampton, Surrey and Lund (Sweden), and Postdocs at Nottingham, TU Denmark, and TU Vienna.

ii. Research students: The PGR environment in the DoM is overseen by the Director of PGR (DPGR). The DPGR (Derks) is responsible for recruitment, admissions, research training, transferable skills training, progress monitoring, PhD confirmation examination, fundraising, and the overall welfare of students within the DoM. The DPGR sits on the Faculty PGR committee, and that committee in turn answers to the University Research Degrees Committee. Responsibility for monitoring research degree quality and completion rests with the latter Committee, chaired by the Deputy VC (Research and Innovation), which reports to Senate.

The DoM recruits PGRs through DoM and Faculty PGR Days, project-specific adverts on jobs.ac.uk and findaphd.com and the DoM website, internal targeting of excellent students and word of mouth. Application and admission of research students are subject to the University's Equality and Diversity Policy, the associated Code of Practice for Students and the University Student Disability Policy. Prospective students are interviewed prior to admission, with the use of video-link for overseas applicants.

With the ever-changing funding environment, a key role of the DPGR is to ensure a balanced portfolio of funding. The DoM has been very successful in this area with principal funding from EPSRC (DTG, Faculty DTC, CASE awards, Industrial Doctoral Centre CEES (EngD in sustainable energy)), and NERC (NCEO, DTP). Other funding sources include EU Marie-Curie, University Research Scholarships (URS), Overseas Research Scholarships (ORS, formerly national, now Faculty funded), overseas students with scholarships, and internally funded PhD studentships, often linked with ORS awards or large EPSRC grants.

Research students receive subject specific and generic training. For subject specific training, students are sent on the intensive one-week courses organised by LMS & EPSRC, the MAGIC courses via video link, as well as internal training courses organised during the period (e.g. 2 PDE training courses and a dynamical systems training course were held at Surrey). The DoM is currently re-introducing an MSc in Mathematics, which will provide a conduit for new PhD students, a programme for training current PhD students, and a forum for sharing staff expertise.

The Department has one of the highest PhD completion rates in the University, with almost all students finishing within four years. Since 2008, 27 students have completed of which 23 had their Principal Supervisor in mathematics and 4 had their Principal Supervisor in another discipline. First destination of the 27 completions: 12 (44%) obtained Postdoc positions (Bristol, Bar Ilan, Reading, Dundee, Surrey (x2), UC Dublin, TU Denmark (x2), Imperial, London (LSHTM), British Antarctic Survey), 8 (30%) obtained positions in industry (BMT Argoss, Mott McDonald, Mathworks, National Grid, NATS, SSTL, Finance sector, R&D), 4 (15%) went into teaching, 1 was placed in a Government Research Lab, and the other 2 are currently looking for postdoc positions. Career development and job searching is assisted by the University's Careers Office.

At the University level, the Researcher Development Programme (RDP) is the primary source of research and transferable skills training. The RDP content is fully in line with the Vitae Researcher Development Framework (RDF) which incorporates the precepts of the Concordat to Support the Career Development of Researchers. The University undertook, in 2011, an institution-wide gap analysis and developed an action plan, on which further investment was based. PGRs present at the University-wide spring PGR Conference. The Researcher Development Team provides training in poster and oral presentation, and presenting to a diverse audience. PGR progress monitoring includes a 6-month (faculty) report and an annual (university) report. There is a Confirmation process after 12-18 months, which is independent from and additional to the monitoring processes outlined above and is the main formal assessment for PGRs in order to continue to a PhD.

d. Income, infrastructure and facilities

The Department occupies the entire fourth floor of the Thomas Telford Building, with some spillover of interdisciplinary positions located in other departments. In 2012 a University training room was taken over and converted to a PhD room, and 6 new staff offices were created.

The Department has a state of the art computing environment, with a PC-Linux machine on every desk for staff members, RAs and postgraduates, supplemented by laptops or tablets where appropriate. It also owns three multi-processor servers for CPU-intensive numerical computations, and access is available to the Faculty High Performance Computing facilities. Support is provided for all IT by a team of specialists (Faculty Computing Service). Smart whiteboards are now mounted in the main mathematics seminar room and the main tutorial room, and DoM has access to a range of shared video link setups. A recent expansion of the computer environment was facilitated by a faculty-wide EPSRC small equipment grant in 2012.

At the University level, a £13.2m library extension opened in 2011, followed by redevelopment of research space for archives and special collections in 2012. The top floor of the library has been refurbished for PGR use only, in response to feedback from the PGR survey (PRES). The electronic journals portfolio has been massively expanded during the period and now almost all mathematics journals of interest are available electronically, as well as over 300,000 e-books, 140 databases and digitised e-theses, all accessible on and off campus. New Surrey theses will routinely become available online via “Surrey Research Insight” (SRI) and the ProQuest database. SRI enhances the visibility and accessibility of research outputs, thus increasing the likelihood of citations. Significant quantities of digital backfiles of journals have also been acquired to provide a broad and deep research collection. The University has an open access (OA) strategy, informed by recent RCUK Policy developments, with gold OA in operation, funded by the University, starting in Spring 2013. Green OA has been in operation for many years, facilitated by the SRI repository.

Research income

Since the last RAE, the funding strategy has been to diversify, strengthen internal procedures for proposals, and make new appointments that are both excellent and contribute to building critical mass. At the beginning of the period the grant portfolio stood at about £1,080k with awards from NIH (Hydon, £212k), EPSRC (Roulstone, Wulff £328k), other RCUK (Aston £125k), NSF (Beck, $108k), EU (Roberts, €254k), and small grants (Leverhulme, LMS, Travel, etc) totaling £131k.

During the period there was a dramatic increase in funding from a multitude of sources. Grants that were awarded and completed during the period amounted to £1,322k, and grants awarded during the period but continuing past 2013 amount to £3,032k, plus the NERC DTP awarded in November 2013. A summary of the grants follows.

EPSRC: total in excess of £2,800k, with a major complexity grant (ERIE: Hoyle, Lloyd, Skeldon £1,240k), ergodic theory (Melbourne £298k), wave energy (Bridges £292k), MILES (Hoyle £259k), Biosystems: TRANSGEN (Hoyle, £231k). First grants: Lloyd £101k, Torrielli £97k, Personal Fellowship: Regelskis £221k, CASE and small grants: £96k.

EU: total in excess of €865k, including Astronet I and II (The Astrodynamics Network) which started in 2007 and runs to 2015, with partners in Finland, France, Germany, Italy, Poland, Spain, Turkey and the UK, and collaboration with the European Space Agency (the total award for I & II was €6.2m with the contribution to DoM €522k); Marie-Curie fellowship (Sfetsos €295k) and the BREUDS Network Grant (Roberts, Morris €50k). In addition to the €865k, an ERC Fellowship with value in excess of €1m was awarded to Melbourne, and subsequently taken up at Warwick.

Leverhulme: total in excess of £210k, with four Fellowships (Bridges, Hoyle, Roulstone, Wulff) £136k, an ECR Fellow (Shmerkin) £56k, and a Visiting Professorship (Aaronson) £23k.

NERC: total in excess of £540k, awarded as the DoM part of the NCEO grant, funding the data assimilation project at Surrey (RA and Investigator time), with additional funding for a sequence of

PhD students. The DTP, funded in Nov 2013, joint with Reading, which funds 60 studentships, will bring in additional income of the order of £1m. The NERC activity is led by Roulstone.

STFC: total in excess of £595k, including an STFC Advanced Fellowship (Gutowski £326K), and an STFC consolidation grant (Sfetsos £271k).

Other (Conference, Travel, Network, LMS): in excess of £200k has been awarded in the area of ambience grants. Awards for conferences: Clay ($30k, McOrist, Roulstone, Wolf), ICMS (£20k, Bartuccelli, Zelik), Surrey/EPSRC/FSG (£31.6k, Torrielli & Regelskis), Newton (£58k, Bridges), LMS (£3.4k, McOrist & Wolf), as well as in kind funding for conferences at AIM (Derks), SIAM NW14 (Bridges), BANFF (Bridges). In addition to AstroNet, network grants have been awarded to support PANDA, LDSG, UGPN, Santandar, FAPESP, and BREUDS (Section e). A range of travel grants, conference grants, LMS grants and summer project (Nuffield, EPSRC) grants have been awarded.

e. Collaboration or contribution to the discipline or research base

Networks, clusters and collaborations

National networking is important for grant applications and PhD recruitment, and international networking is important for maintaining international excellence in publications. Surrey DoM has excelled at both. At the national level staff have collaborations (joint grant or published paper) with researchers at 33 UK universities: Bath, Birmingham, Brighton, Bristol, Cambridge, City, Coventry, Dundee, East Anglia, Edinburgh, Exeter, Heriot-Watt, Imperial, Keele, Kent, KCL, Leeds, Liverpool, Manchester, Nottingham, Oxford, Plymouth, Queen Mary, Reading, Sheffield, Southampton, Strathclyde, Sussex, St Andrews, Swansea, UCL, Warwick, and York. At the international level staff have collaborations with researchers in 28 different countries (with the number of universities in parentheses): Argentina (1), Australia (1), Austria (2), Belgium (2), Brazil (12), Canada (8), China (1), Czech Republic (1), Denmark (1), Finland (3), France (11), Germany (15), Greece (3), Ireland (3), Italy (6), Israel (2), Korea (1), Lebanon(1), Netherlands (6), Poland (5), Portugal (5), Romania (1), Russia (2), Spain (6), Sweden (3), Switzerland (5), Turkey (3), and USA (28).

Many of these national and international collaborations have been formalised. The University has created the University Global Partnership Network (UGPN) which formally links Surrey with North Carolina State University and the University of Sao Paulo in Brazil. The network provides seed money for collaborations, and the DoM currently has 4 funded projects ongoing in this network. At the Department level, there have been long standing international, national and local networks, and they have grown during the period. NCEO is a national network, which began in 2008, linking Reading, Leeds, Oxford, Warwick and Surrey. AstroNet has been running since 2002, and includes a range of UK and EU partners. BREUDS: a Brazilian-EU Partnership in Dynamical Systems, runs from 2013-2016, funded by an EU IRSES grant, and links Surrey with universities in Brazil, Europe and the UK. SPADE-ACE (Structure preserving algorithms for differential equations), was an international network (2007-2011), funded by the Norwegian Research Council, with the Surrey node led by Hydon. The DoM is a member of four national LMS funded networks: PANDA (Patterns, Nonlinear Dynamics and Applications), LDSG (London Dynamical Systems Group) which have been running for several years, and two new networks: the Southeast Math Physics Network (led by Torrielli), and a Geometric Mechanics Network linking Brunel, Imperial and Surrey (led by Tronci). In addition, DoM has membership in or links with CliMathNet, London String Theory Triangle, TRANSGEN, national Bridging the Gaps, and the AHVLA (Animal Health and Veterinary Laboratories Agency) in Surrey.

Fellowships

Thirteen personal fellowships have been awarded: Leverhulme ECR Fellowship: Shmerkin (2011-2013); Leverhulme Visiting Professorship: Aaronson (2011-12); STFC Advanced Fellowship: Gutowski (2011-2016); EPSRC Postdoctoral Fellowship: Regelskis (2013-2016); NSF Postdoctoral Fellowship: Beck (2006-2009); VINNMER Marie Curie (Sweden) Fellowship: Maad-Sasane (2011-14) (hosted at Surrey); EU Marie-Curie Fellowship: O'Colgain (2013-2016); Noether Fellowship (Perimeter Institute, Canada): Pasquetti (2014). Leverhulme Personal Fellowships: Wulff (2007-8),

Roberts (2007-8), Roulstone (2008-9), Hoyle (2009-10), Bridges (2009-11).

Editorial representation

Eight members of the department serve on editorial boards: (a) Hydon: LMS J Computation & Mathematics; (b) Derks: J Geom Mech; (c) Roberts: J Geom Mech, J Nonl Sci; (d) Wulff: SIAM J Applied Dyn Sys; (e) Gourley: Math Biosciences & Eng; (f) Zelik: Asymptotic Analysis; (g) Roulstone: Quart J Royal Met Soc (Chief Editor until Oct 2008); and (h) Bridges: Dynamical Systems (till Jan 2014). Roulstone's book, co-authored with Norbury (Oxford), *Invisible in the Storm: The Role of Mathematics in Understanding Weather*, was published by Princeton University Press in 2013, and is receiving excellent reviews, including an article in Scientific American.

Peer Review

Staff have been active in reviewing proposals, RCUK College membership and on Mathematics Prioritisation panels (MPPs): (a) Derks (member of MPP, Dec 2012), (b) Hoyle (member of MPP, March 2011, member of the EPSRC CDT Panel in October 2013), (c) Roberts (member of MPP, July 2012, Chair of MPP, Sept 2012), (d) Skeldon (member of MPP for Postdoctoral Fellowships, 2008). Prize committees: Bridges was Chair of the prize committee for the 2012 and 2014 SIAM Kruskal Prize, and a member of the committee for the Lighthill-Thwaites Prize (BAMC 2011).

Roles in Professional Bodies

Roulstone is a Member of the LMS Programme Committee; Sfetsos is a CERN Scientific Associate (4-6 weeks each summer); Bridges was vice chair of the SIAM activity group on Nonlinear Waves (2010-2012) and principal negotiator for bringing SIAM Nonlinear Waves 2014 to the UK. Membership in professional societies: LMS (14 members); Royal Meteorological Society (1); IMA (2); AMS (1); SIAM (3); Moscow Math Soc (1); EMS (1); Europ Society for Evolutionary Biology (1).

Visiting Professors

The DoM has a range of visiting professors. They are appointed by a University committee, based on an assessment involving international referees. The current appointees are (a) Jon Aaronson (Tel Aviv) and Matt Nicol (Houston) in ergodic theory; (b) Guido Gentile (Roma III) and Georg Gottwald (Sydney) in dynamical systems; (c) Vakhtang Putkaradze (Alberta) in geometric mechanics; (d) Alexander Timokha (NUST, Norway) in fluid dynamics; and (e) three former Met Office researchers: Sid Clough, Andrew Lorenc (FRMetS), and Andrew White (FRMetS).

Conference organisation

Members of the Department have been active in organising conferences around the world (either as an organiser or on the organising committee): ICMS 2010 (Bartuccelli & Zelik); BAMC 2011 minisym (Hoyle); LMS Durham 2011 (Roulstone); Oberwolfach 2012 (Roulstone); SIAM 2010 (Derks); SIAM 2012 minisym (Bridges); AIM 2012 (Derks); AstroNet 2008-13 (Roberts); AMS 2012 minisym (Cheng); BANFF 2012 (Bridges); OxPDEs at Surrey & IAS 2010 (Bevan & Lloyd); SMUK at Surrey 2013 (McOrist & Wolf); Surrey IAS 2013 (Aston); LMS at Surrey 2008 (Bridges & Lloyd); Leverhulme Lectures at Surrey 2012 (Zweimuller); IMA Minnesota 2013 (Lloyd).

Invited talks

Since 2008, the number of talks at conferences and universities worldwide is measured in the hundreds, including talks at such venues as the Newton Institute, AMS & SIAM Conferences, MSRI Berkeley, Oberwolfach, IMA Minnesota, BANFF, OxPDES, BAMC, Durham LMS, EuroStrings, and Shanghai JTU. Highlights include: Bevan (SIAM 2013), Cheng (AMS 2012), Bartuccelli (Warwick PDEs 2010), Derks (SIAM 2010), Dunlop (German Physical Society Summer School 2012), Gutowski (BMC-BAMC 2010), Hoyle (BAMC 2012), Hydon (Banff 2010), Lloyd (SIAM 2012), McOrist (Banff 2012), Pasquetti (String-Math 2012), Roulstone (OxPDEs 2012), Sfetsos (Iberian Strings 2011), Torrielli (String-Math 2012), Wolf (Durham 2013), Wulff (TU Denmark Summer School 2011), Zelik (Shilnikov Conf 2013), Bridges (BAMC 2011 Plenary Lecture).