Institution: University of Kent

Unit of Assessment: 10 (Mathematical Sciences)

a. Overview

This **unit** consists of two groups, **Mathematics** and **Statistics,** which were returned in 3 separate submissions in the RAE2008 (Applied Mathematics, Pure Mathematics and Statistics). Together with the Centre for Actuarial Science, Risk and Investment (**CASRI**), they form the School of Mathematics, Statistics and Actuarial Science (**SMSAS**). CASRI has a focus on the professional aspects of actuarial science, and has strong links with professional bodies and the financial sector more generally.

The research of the Mathematics Group is centred around three main themes: **Algebra** with a focus on Algebraic Topology, Invariant Theory, Representation Theory, and Quantum Groups; **Analysis** and in particular Functional Analysis; and **Applicable Mathematics** including Integrable Systems and Mathematical Physics. This is a young and growing group with currently 21 staff, comprising 4 professors, 3 readers, 4 senior lecturers, 8 lecturers and 2 Marie Curie Fellows. Much of the research of the Statistics Group falls under one of two broad headings: **Applied Statistics**, with a focus on Statistical Ecology, and biological and financial applications; and **Bayesian Methodology**, particularly Bayesian nonparametrics. Other strong areas of research within the Group include Shape Analysis, Applied Probability and Risk, and Nonparametric Regression. The Statistics group is a well-established group that currently has 13 members, comprising 5 professors, 1 reader, 3 senior lecturers, 3 lecturers and 1 NERC Fellow. **All members of the Mathematics and Statistics groups who are eligible for REF2014 are entered into the REF**.

b. Research strategy

Our strategy has been to expand on our successes in RAE2008 by maintaining our **renowned expertise** in Statistics, while **rejuvenating and widening** our research in Mathematics. Over the period we have seen significant investment and our research active staff have increased by nearly 40% to 33.08 FTE, up from 24 in RAE2008. Our ambition to be recognised as a **centre of excellence** in all our research fields has been supported by the following strategic approach.

1. Sustain our Statistics group. Members: Breuer, Brown, Cole, Griffin, Kolossiatis (ECR), Kong, Kume, Leisen, McCrea (ECR), Morgan, Ridout, X Wang, Zhang. Staff appointments in the Statistics Group since the RAE2008 have been centred on strengthening the **excellent research reputation** of this group. Zhang left to take up a chair at York, but returned in 2010 to a chair at Kent. Kong was appointed in 2009 as an early replacement for the soon-to-retire Brown. Recently, Walker left to take a position at the University of Texas (USA). We were able to replace him with another leading researcher, Leisen, who joined Kent in July 2013 bringing expertise in Bayesian methods, including Bayesian econometrics and nonparametrics. To further strengthen the area Kolossiatis was also appointed, providing additional capacity and quality. This period of stability has allowed the Statistics group to consolidate and secure the reputation of excellence in both methodological and applied Statistics. As noted in the previous RAE, many of the Group work in several areas, but there continues to be a particular focus on Statistical Ecology and Biological Modelling (Cole, Griffin, McCrea, Morgan, Ridout, Zhang), based particularly on the award of a further 5 years funding (2010-2015) by the EPSRC and NERC of the National Centre for Statistical Ecology (NCSE), and also on Bayesian Methods (Brown, Griffin, Kolossiatis, Leisen, X. Wang, Zhang) and, in particular, Bayesian Nonparametrics and Markov chain Monte Carlo and general simulation methods. We have also strengthened Nonparametric Regression with the return of Zhang and the arrival of Kong. Other strong research areas within the Statistics group include: Applied Probability and Risk (Breuer); Shape Analysis (Kume); Econometrics and Finance (Griffin, Kolossiatis, Leisen); and Medical Neuroimaging (Zhang). 22 postgraduate researchers (PGR) have completed a PhD in Statistics since 2008, and the group is currently supervising 17.5 PhD students and 1 postdoctoral research assistant (PDRA).

2. Expand our Applicable Mathematics team. Members: Clarkson, Dunning, Foster (ECR), Hone, Krusch, Loureiro (ECR), Mansfield, JP Wang. In the RAE2008 the Mathematics group submitted 6 people in the Applied Mathematics UoA. The research interests of this Applied Mathematics submission were primarily Integrable Systems and Mathematical Physics. All members submitted in RAE2008 are still at Kent and are all entered into REF2014. This stable core of research active staff has provided a strong base for expansion, attracting 4 postdocs and winning 3 EPSRC grants, for instance. This team is currently supervising 8.5 FTE PGR and 1

PDRA. A new permanent position was opened up in 2012 with the objective of **strengthening and enhancing** the research interests in Integrable Systems. Loureiro's appointment as a lecturer achieved this aim by bringing further expertise in Special Functions and Orthogonal Polynomials, and in particular on the algebraic aspects of the topic. Her appointment is also creating new possibilities for collaborative research between the Applicable Mathematics and Algebra teams through combinatorial aspects of special functions. Additionally, Foster was appointed as a lecturer to bring further numerical analysis expertise to the Mathematical Physics component.

3. Develop the emerging Algebra team. Members: Casteels (ECR), Fleischmann, Launois, Paget, Roitzheim (ECR), Rosenkranz, Shank, Towers (ECR), Woodcock. In the RAE2008 the Pure Mathematics panel acknowledged the progress made by the Algebra team at Kent, and in particular the fact that it was now a young coherent research unit. During the REF period the institutional commitment has been **sustained and enhanced** in order to ensure that this team reaches its full potential. So when G. Brown was promoted to a Readership in another institution, he was replaced by Rosenkranz whose expertise in Computer Algebra fits well with Launois' research in Noncommutative Algebra, and also links with that of Mansfield and JP Wang. The domain of expertise of the Algebra team was further enhanced by the appointment in 2012 of Roitzheim, first as an EPSRC Postdoc Research Fellow and then as a lecturer. Her expertise in Algebraic Topology and Category Theory complements the current interests of the Algebra team. Furthermore, our Mathematical Physicists working on Topological Solitons (Foster, Krusch) are also benefiting from her expertise. Recently, Towers was appointed with the aim of supporting the growing research in Quantum Groups and Representation Theory; his research interests lie naturally between those of Launois and Paget. While the team has maintained its long-established leadership position in Invariant Theory (Fleischmann, Shank, Woodcock), this period of growth has allowed the Algebra team to gain a **solid international reputation** in Algebraic Topology (Roitzheim), Representation Theory, Quantum Groups and Total Positivity (Casteels, Launois, Paget, Towers). This is acknowledged by the EPSRC International Review of Mathematical Sciences 2010, and is evidenced by the team's hosting of a 6-month visit of an international leader in Invariant Theory, Broer (University of Montreal), and an International Incoming Marie Curie Fellow (Casteels) working in Quantum Groups, together with the attraction of high-quality PhD students. The Algebra team is currently supervising 5 PhD students and 1 EPSRC PDRA.

4. Create new teams. The strong position of SMSAS during the REF period has led the University to **invest strategically** in the Mathematics Group to create a new Analysis team to provide theoretical support for the Applicable Mathematics team. As a consequence 2 lecturers in Analysis were appointed in 2009: Lemmens and Wood. In order to sustain this new team, an additional position was created in 2012 and was awarded to Constantin, an expert in Functional Analysis. This new Analysis team currently has 4 members, including a Marie Curie Fellow, Professor Naboko, who joined Kent in 2013 for two years. This young and growing team is currently supervising 3 PhD students and 1 EPSRC PDRA. Additionally, SMSAS has created a team in Finance within CASRI with the expectation that this will provide new opportunities for interdisciplinary work with the Statistics Group. For instance, these interactions will be beneficial to hedge fund and asset management companies through the use of complex statistical modelling approaches. To underpin this, we developed a joint MSc programme *Statistics with Finance*, and have built on this with a first joint PhD supervision (the second being due to start in January 2014).

5. Increase the quantity and the quality of our PhD students. Since RAE2008 we have created several MSc courses, including *Mathematics and its Applications* (launched in 2010) and *Statistics with Finance* (launched in 2011) to provide platforms for doctoral studies. As a consequence, PhD students are now recruited at MMath or MSc level. This has had a positive impact on our completion rate which is now much stronger than during the RAE2008 period. During the REF period, an average of 6.5 students have been awarded a PhD per year, up from 1.4 during the RAE2008 period. We are planning for this figure to increase even more when our younger staff obtain supervisory chair status. Our high profile international appointments have enabled us to attract PhD students from many different countries, e.g. France, Germany, Greece, Italy, the Netherlands, Portugal, Romania, Spain, China, Thailand, Canada, Mexico, Ethiopia, Ghana, Iraq and the UK. In addition, the University has recently substantially increased its investment in postgraduate research with the introduction of 100 50th Anniversary Scholarships (per year) and the creation of a dedicated College for postgraduate students. In the last 2 years, SMSAS was awarded 7 such 50th Anniversary PhD studentships, and the financial strength of SMSAS has

allowed it to create the equivalent of 10 3.5-year FTE PhD studentships. In addition, our recent EPSRC awards have led to a significant increase in the EPSRC Doctoral Training Grant, and 8 PhD students were funded by external grants other than the DTG during the REF period. Recently, SMSAS has also started funding undergraduate Summer research (6 projects in the Summer 2013), so that research is embedded at all levels of our School. All of these factors have contributed to the creation of a lively research community that we are planning to expand even further in the next few years.

6. Strong support of ECRs. The University and SMSAS are strongly committed to the support of ECRs, as evidenced by the interdisciplinary ECR Network aimed at encouraging ECRs to meet those in other Schools and share good practice through regular guided workshops. SMSAS was also instrumental in developing Research modules within the University's Postgraduate Certificate in Higher Education (PGCHE). For instance, Clarkson developed and convened 2 modules of the PGCHE: *Effective Research in Higher Education* and *Developing as a Research Degree Supervisor*; and Mansfield has been leading an ECR Network workshop on *Constructing a Realistic Project*. This strong support has helped 6 members of the Mathematics Group to hold EPSRC First Grants during the REF period. For the First Grants of Krusch, Launois, Lemmens and Rosenkranz, the School provided additional funding to extend the PDRA contracts from 14 months (the maximum length possible within capped budgets) to 18 months. In Statistics, McCrea was awarded a NERC Postdoctoral Fellowship in 2012, and 2 ECRs/PDRA were funded by NCSE. As a consequence of these funding awards, Research Assistants and Fellows have been joining Kent, adding to the **vibrant research environment** that has been supported by an increasing number of research events (e.g. Kent Algebra Days series, LMS/EPSRC Summer School in 2010, ISEC 2010, BMC 2012, High Dimensional Inference and Applications 2013).

VISION: Building on our successful period 2008-2013, we will continue to develop our ambitious research strategy for the period 2014-2019, based on the following principles.

i. Sustain our well-established teams in Algebra, Applicable Mathematics and Statistics. The aim over the coming years is to develop the young group of researchers to fulfil their potential and become leading international researchers. Research leadership for the next 5 years will be provided primarily by the 8 professors (Fleischmann in Algebra; Clarkson, Hone, Mansfield in Applicable Mathematics; Griffin, Ridout, Zhang and a chair to be appointed in Statistics) and the Director of Research (Launois) with the foci of research continuing to be in Representation Theory, Invariant Theory, Algebraic Topology, Quantum Groups, Integrable Systems, Mathematical Physics, Biological and Ecological Modelling, and Bayesian Methodology and Computation. Given that the next retirements of senior staff, aside from 3 senior staff, are more than a decade away, we see this as a perfect opportunity to **consolidate and further enhance our international reputation** in these disciplines. Building on the continuing successes of the EPSRC/NERC funded NCSE and the successful series of International Statistical Ecology Conferences that has been established, a major grant application will be made in 2014 for a research council Platform or Programme grant (whichever is deemed the more appropriate) in order to continue and advance the research of the Centre when the current funding ends (2015). Morgan will formally retire at the end of 2013, but will continue to play an active role as co-Director of NCSE until the end of the current grant, including supervision of PhD students and a PDRA. The University and SMSAS are in the process of securing a high-level appointment to replace Morgan: an offer for a **Chair in Statistics** to start in 2014 has just been made. Additionally **2 lectureships in Statistics** are currently advertised with priority given to Statistical Ecology and Statistics with Finance, supporting both our impact and research strategies.

ii. Continue to support our developing teams in Analysis, and interactions between Statistics and Finance. To support the Analysis team, SMSAS will appoint a **lecturer in Geometry and Topology** in 2014. This will develop new possibilities of research, and will establish connections between the Analysis and Algebra teams through research in Algebraic Topology, and also between the Analysis team and our specialists in Topological Solitons. The development of interactions between Statistics and Finance will be led by Griffin. This will be supported by the recently created Kent Centre for Finance with members from the Statistics group, CASRI and the Kent Business School. The new lectureship in Statistics with Finance currently advertised (see above) will bring more expertise in this area.

iii. Develop new themes of research. The financial strength of SMSAS will allow several

additional new appointments in the next few years. In particular, building on the current expertise of the Applicable Mathematics team, the University has agreed for SMSAS to create a Numerical Analysis team. As a consequence, SMSAS will advertise **lectureships in Numerical Analysis** in 2014. This new team will link in with the research of Dunning, Krusch and Mansfield, whose most recent EPSRC-funded projects involve significant amounts of numerical analysis. This planned investment is part of our impact strategy; see Section c of REF3a.

iv. Further expand our number of PhD students. Our medium-term target is to increase our postdoctoral community from around 35 PGR currently to 50. Additional studentships will mainly be funded by SMSAS which is in a strong financial position due in part to the success of its taught postgraduate programmes; however University and externally-funded studentships will also be sought. This will also be possible thanks to the support of the University which is investing £35M in a new building for SMSAS (joint with Kent Business School) for 2016. This new building will give us the needed space to achieve this target (and beyond), and in the interim, temporary facilities have been created to allow for our planned expansion.

v. Sustain our lively research community. While we will continue to seek EPSRC funding, we also plan to explore new funding routes to diversify our portfolio. This has already started with an NERC Fellowship awarded to SMSAS in 2012, and two Marie Curie Fellowships in 2013. The School will also continue to strongly support EPSRC First Grant applications by further extending any PDRA position obtained through this scheme to 2 years (our policy during the REF period was to extend such positions to 18 months). Our ambition is to maintain the vibrant postdoc community that has emerged at Kent in the past few years. This will be achieved through external funding as well as a new scheme of **Research Fellowships in Mathematical Sciences at Kent** which has recently been approved by the University and SMSAS. Under this scheme, SMSAS will award 2 or 3 two-year fellowships each year, thus contributing to sustain our fertile research environment.

c. People, including:

i. Staffing strategy and staff development

Our aim for SMSAS to be recognised internationally as a **centre of excellence** in all our research fields has led us to high profile appointments during the REF period: Constantin, Lemmens, Loureiro, Roitzheim, Rosenkranz, Wood in Mathematics and Kong, Leisen, Zhang in Statistics. In addition, we created strategic lecturing positions with a reduced teaching load of 1 module per year. Currently, Foster, Kolossiatis and Towers are benefiting from these newly created positions. All these appointments have been made to strengthen existing teams/groups and to create new opportunities for research (see Section b). For instance, a new Analysis team was created. These new appointments have also produced additional cross-team collaborations and two recruited staff came with personal fellowships/grants (Constantin, Roitzheim). Our research strategy is presented to the University at an annual planning meeting, where we discuss our future research plans and appointments. Our proactive approach to support our ambitious research strategy has led the University to **invest strategically** in SMSAS for the next few years. In particular, we have recently made an offer for a Chair in Statistics to join Kent in 2014 to further develop our Statistical Ecology activities. Furthermore, we are currently advertising 2 lectureships in Statistics, and the University and SMSAS have approved for SMSAS to create a team in Numerical Analysis, to appoint a lecturer in Geometry and Topology, and to fund 2 or 3 prestigious Research Fellowships in Mathematical Sciences (see Section b for details). As a result of this ambitious but carefully planned period of recruitment we now have a well-balanced unit consisting of 9 professors, 4 readers, 7 senior lecturers, 11 lecturers, 1 NERC fellow and 2 Marie Curie fellows, of whom 7 are ECRs. This large number of ECRs acknowledges the strong support provided by the institution and contributes to our vibrant research community. This is complemented by our larger than ever PhD and postdoctoral community: the unit is currently supervising 35 PhD students and 4 postdocs.

The School workload allocation model (WAM) includes 500 hours for research-active staff to conduct their research. Other research-related activities (supervision, grant applications and management, community contributions, etc.) all add to this substantial baseline time allocation. All staff are encouraged to make academic visits, receive academic visitors, participate in conferences and workshops and present seminars. The School has a dedicated fund to support these activities, and this is complemented by the Sciences Faculty Research Fund. Opportunities for developing and realising new research ideas are provided through Study Leave and Academic Leave of Absence: one term in seven. This has enabled staff to take a total of 24 terms of study leave over the REF period.

Career Development Support: We are committed to developing staff at all levels to ensure that all our members **reach their full potential**. Staff who are appointed on probation take the University's Postgraduate Certificate in Higher Education (PGCHE), which involves undertaking 2 core modules on teaching and 2 optional modules over a 2 year period. Staff who have already completed parts of a similar programme elsewhere, or have previous experience of teaching in Higher Education, can apply for exemption from parts of the PGCHE programme. The optional modules include *Developing as a Researcher in Higher Education* and *Developing as a Research Degree Supervisor*. Staff on probation have a mentor, normally somebody who has recently completed the PGCHE, and a probation supervisor, normally a more senior member of the School. Research assistants may take the PGCHE optional module on *Developing as a Researcher in Higher Education* as a standalone module and, if involved with teaching, may take the two teaching modules which form the Associate Teacher Accreditation Programme. Whilst doing the PGCHE, staff members have significantly reduced teaching loads (50%) and a minimal administrative load. Additionally, ECRs benefit from the institutional ECR network which combines development workshops and social events. The **effectiveness** of this support is evidenced by the large number of EPSRC First Grants obtained by SMSAS during the REF period, and the fact that around 80% of our postdocs have obtained Lectureships/Fellowships afterwards.

All staff members are appraised annually by senior staff, when their research needs and opportunities are discussed in a confidential environment. Staff are encouraged to attend continuous professional development events organised either by the School (e.g. PhD supervision training) or by other institutional providers: Learning and Development (leadership programmes, generic skills, equality and diversity training); the Unit for the Enhancement of Learning and Teaching (accredited academic development programmes and academic CPD, including specific content on researcher career development); the Graduate School (Researcher Development Programme for postgraduate students and postdoctoral researchers) and Research Services (Grants Factory and Early Career Researcher Network). The quality of this support and our commitment to researcher development (in line with the Concordat to Support the Career Development of Researchers) is evidenced by our attainment of the EU HR Excellence in Research award. Academically, the School runs several seminar series as well as a School colloquium. These series give PhD students and postdocs the opportunity to present their work and to practice their communication skills in a supportive environment.

Promotion: The University has a promotions process which recognises and rewards all aspects of academic excellence. Professors in the SMSAS, in particular those who have been members of the University Promotion Committee, **mentor** those who are applying for promotion. Furthermore, the University holds workshops for individuals who are preparing their cases for promotion. This **excellent support** combined with the strong career development support offered by the School and the University (see above) has led a number of our more junior staff to develop cases for promotion. Since the RAE 2008, within the unit, Hone, Griffin and Ridout have been promoted to Professor, Launois and JP Wang to Reader, and Cole, Dunning, Kume, Lemmens and Rosenkranz have been promoted to Senior Lectureships.

International staff appointments: Our growing international reputation has led to an increase in our international appointments: 3 (out of 11) RA/Fellows and 6 (out of 12) academic staff. For instance, 3 of the recent academic staff appointments in Mathematics are international: Constantin (Austria), Loureiro (Portugal) and Rosenkranz (Austria). The most recent appointments in Statistics are also international: Kolossiatis (Cyprus), Kong (The Netherlands), Leisen (Spain). Furthermore, SMSAS is currently hosting 2 Incoming Marie Curie Fellows originally from North America (Casteels) and Russia (Naboko). During the REF period, SMSAS had several long-term (more than 6 months) international visitors: Viallefont (France, 2008), von Hardenberg (Italy, 2009/2010), Broer (Canada, 2010), Zullo (Italy, 2012/2013). Launois and Shank also hosted 2-month internships for 2 master students from ENS Cachan (France). This growing international dimension has greatly increased the diversity, vibrancy and quality of our research environment.

Personal Research Fellowships: SMSAS attracts highly regarded researchers. Of the unit's 34 members, 3 hold personal fellowships: McCrea holds a NERC Postdoctoral Fellowship to support her work in Statistical Ecology (2012-2015), and Casteels and Naboko are holding Marie Curie International Incoming Fellowships (2013-2015). In addition, Roitzheim held an EPSRC Postdoc Research Fellowship (08/2012-01/2013).

Equality and Diversity: The University's HR strategy and policies support the research

environment through the effective recruitment, selection and induction of staff, good employment practices, including a mediation scheme and work/life balance initiatives. Specifically in terms of equality and diversity the School is involved in various internal and external networks related to equality strands (age, disability, gender reassignment, marriage/partnership, political opinion, pregnancy maternity/paternity, race, religion, sex and sexual orientation) and is particularly proactive on the gender front, taking a leading role in the University Athena SWAN activities. The School has an Athena SWAN committee which is preparing an application for an award, to be submitted as soon as the University has obtained its Athena SWAN award. The School is a Supporter of the London Mathematical Society's Good Practice Scheme and participated in the Good Practice Scheme benchmarking exercise in 2012. Our unit of assessment has 11 women members (1 Professor, 1 Reader, 2 Senior Lecturers, 6 Lecturers, an NERC Fellow), and 2 PDRAs. Clarkson has been a member of the LMS Women in Mathematics Committee since 2007, is **the chair of the steering committee for the LMS Good Practice Scheme** and has given presentations at its workshops. In March 2013, Paget organised an Athena SWAN Colloquium with high profile women speakers in Mathematics, Statistics and Actuarial Science.

ii. Research students

There has been substantial growth in both the number and quality of doctoral students during the REF period. The School has recruited 47 doctoral students and several MSc/MPhil students, with the annual intake double that of the RAE2008 average. The aim for the next REF period is to expand the doctoral headcount to 50, compared to around 35 currently, and to develop more junior staff as new supervisors. The **growth** has been supported by increased external funding from EPSRC projects and CASE studentships, significant increase in the EPSRC Doctoral Training Grant, and NCSE studentships. There has also been a substantial investment in studentships by the University (e.g. 50th Anniversary Scholarships), and the School. All studentships are offered for a minimum period of 3.5 years with the School providing the additional funds to extend all 3-year awards. Stringent recruitment and selection procedures ensure that the School only recruits the best qualified candidates and does so transparently and equitably. Almost all students hold an undergraduate masters qualification or MSc at first/distinction level. The home/EU/international split is roughly 40/30/30%, and 43% of current PGRs are female. Recruitment is supported by the central European and International Offices.

Training: Each student has a primary and secondary supervisor. Junior members of staff take the PGCHE module *Developing as a Research Degree Supervisor* and gain experience of the supervision process through working with a more experienced colleague. The Statistics Group collaborates with the Durrell Institute of Conservation and Ecology (DICE) (part of the School of Anthropology and Conservation) and its partners in the NCSE to train and supervise research students. Strong research interactions between the students and postdoctoral researchers are encouraged, and all researchers have been recently housed together in a new building. PGRs and PDRAs have a representative in all school committees.

The institutional-level Graduate School leads and champions the strategic development of provision for graduate education and research at Kent. Development opportunities include formal research training, career development elements and structured supervision by a supervisory team. Students attend at least 100 hours of assessed taught courses to broaden their subject knowledge. Options are chosen from courses provided through membership of two EPSRC taught course centres, the **Academy for PhD Training** in Statistics and the **London Taught Course Centre** for PhD students in the Mathematical Sciences, and three Masters: *Mathematics and its Applications*, *Statistics* and *Statistics with Finance*. During 2008-2013 our unit members ran 10-12 courses on research-led advanced topics at the two EPSRC centres, many of which took place at the University of Kent. The MSc in *Statistics* has been financially supported by EPSRC up to and including the 2012/3 academic year. PGRs reflect annually on their existing skills and training needs as part of the University's Researcher Development Assessment. The School provides training in subject-specific transferable skills, and an **extensive range of workshops** are offered by the Graduate School. Together, the training comprehensively covers all areas of the Vitae Researcher Development Framework. PGRs have the opportunity to teach, for which they are trained and paid, and run the central Maths and Stats Clinics (open to all Kent undergraduates), which allow the PGRs to develop their communication, support, teaching and mentoring skills. PGRs attend the weekly seminars organised by their research group, and organise their own

weekly seminar programme, which also hosts external student speakers. Statistics students also attend the East Kent Royal Statistical Society local meetings, which are held at the University. There are several informal discussion groups per year on topics of special interest and the School provides funding for students to attend research schools. Formal training also included an LMS/EPSRC short course on *Classical and Quantum Integrable Systems* held at Kent in 2010. Throughout the REF period, there have been over 400 seminars on a wide range of topics.

Progress monitoring: The progression monitoring and supervisory system, overseen by the School Director of Graduate Studies, is designed to ensure that our researchers receive all the guidance and support they require throughout the course of their PhDs. Supervisors meet with their PhD students weekly/fortnightly and a formal supervisory record is maintained. PGR progress is reviewed by a panel of experienced supervisors at five key points during the PhD. For each progression interview, students write progress reports (including a literature review in year 1) and give a presentation. This stringent monitoring has improved completion rates, and 93% of the PGRs who started in 2007 and 2008 submitted within four years.

Achievements: During the REF period, our research students have (co-)authored over 66 peer-reviewed publications. The International Society for Bayesian Analysis awarded Martinez-Ovando the **2012 Savage Award** for the best thesis in Bayesian Statistics (Theory and Methods). The School provides funding for research students to attend and present research at national and international conferences. In many instances, students also obtained a travel award from the organizers in recognition of poster abstracts, and have won prizes for best student talks. PGR graduates have started careers in banking, actuarial work, defence, teaching and consultancy, and obtained research positions at, for example, the European Central Bank, Central Mexico Bank, Pfizer and Cumbria Biodiversity Data Centre. About a third of the PGR graduates have gone on to pursue academic careers in the UK or abroad.

d. Income, infrastructure and facilities

The REF period has been very fruitful for our unit in terms of research income, infrastructure and facilities. We have **increased** our EPSRC funding and we have **diversified** our funding portfolio by winning 2 Marie Curie Fellowships and an NERC Fellowship. We have also continued to attract CASE studentships and won our first KTP award (joint project with KROHNE Ltd which led to our Calibration impact case study). This project was awarded the highest grade of "Outstanding" (top 10%) by the KTP Grading Panel. Our strong academic (and financial) performance has enabled the School to lever additional University funding to achieve our strategic aims. This has included increasing the staffing base to 33.08, up from 24 FTE in RAE2008, and the investment of £35M in a new purpose-built building, due for completion in 2016. In the interim, temporary facilities have been provided to ensure that the planned growth is not constrained in the coming years.

Income: The University's dedicated research support office provides advice and training in identifying funding opportunities, developing, costing, negotiating and managing research grants, and more broadly in supporting the University's research culture. This includes facilitating interdisciplinary research, through regular 'PVC Lunchtime Seminars' and internal funding to support the development of large, complex and interdisciplinary projects; an ECR Network; and the award winning 'Grants Factory' programme, in which staff who have been involved with Research Councils and major charities provide advice to those with less experience. The School plays an active role in this programme as, for instance, Clarkson and Mansfield have been involved in the delivery of some of these workshops. All of these initiatives are supported by a comprehensive information service, utilising traditional and new media, such as surgeries in Schools, visits, newsletters, email updates, Twitter, and a popular blog, 'Fundermentals'. At the school level, Clarkson, Fleischmann, Hone and Morgan have been members of several EPSRC panels, and Mansfield was a member of the **EPSRC Strategic Advisory Team**. These experienced members help more junior staff in the development of grant proposals and most proposals, including all large grants and all Research Council applications, go through the University's Peer Review system before submission.

As part of our research strategy for the period 2008-2013 we strongly supported junior staff applying for an EPSRC First Grant by providing school funds to extend the PDRA position from 14 months to 18. We have now gone one step further by extending any such position to 24 months. As a consequence of this **excellent research support**, our number of prestigious awards has increased dramatically. During the REF period, we held 6 EPSRC First Grants (G. Brown - former member-, Dunning, Krusch, Launois, Lemmens, Rosenkranz), 5 EPSRC Standard Grants (2 for

Griffin, 2 for Mansfield, 1 for JP Wang), a CASE studentship (Morgan & Ridout) and Roitzheim joined Kent with her EPSRC Postdoc Research Fellowship. Morgan & Ridout were Co-Investigators on the BBSRC-funded project *Modelling prion dynamics in the living yeast cell*, which supported a 3-year PDRA in our School, and McCrea won an NERC Postdoctoral Fellowship (2012-2015). The NCSE, funded first by an EPSRC grant (2005-2010), was awarded an NERC/EPSRC grant for the period 2010-2015. We also obtained our first Knowledge Transfer Partnership Award from the Technology Strategy Board (2011-2013); this led to our Calibration impact case study. The unit has received a greater proportion of EU funding than previously under the Framework Programme 7: Launois held a Marie Curie Reintegration Grant (2007-2010), Naboko and Wood obtained an EU Marie-Curie Fellowship in 2012 for the project *Spectral analysis of non-selfadjoint and selfadjoint operators - new methods and applications*, and Casteels and Launois won another Marie Curie Fellowship in 2013 for the project *Representation theory of quantum algebras and their semi-classical limits*. SMSAS has also obtained funding from the British Council (Launois), the Institute of Physics (Dunning), Royal Society (Clarkson, Dunning, Fleischmann, Hone, Krusch, Morgan, Shank), the London Mathematical Society (Clarkson, Dunning, Fleischmann, Hone, Lemmens, Paget, Rosenkranz, Shank, JP Wang, Zhang) and Pond Conservation: The Water Habitats Trust (Morgan & Ridout).

Infrastructure and Facilities: Building on this success, the University has made a strategic investment in a **new academic building** to house SMSAS from 2016 onwards. This major investment of £35M is in response to increases in numbers of staff, research students and taught students in recent years, and planned future growth. In the interim, the University has allocated temporary facilities for SMSAS to implement its ambitious research strategy by continuing its expansion in numbers of PGRs, postdocs and staff. The School's library budget has grown substantially during the REF period, from £77K in 2008/9 to £117K in 2012/3. The electronic database components and general web-based resources are vital for timely research for both staff and research students. The School has also increased its administrative support by creating 4 **new positions**: research support officer, admission officer, placement officer and outreach officer.

Consultancies and professional services: Academic staff are actively encouraged to develop external activities on the basis of their research expertise (see REF3a for further details). These have arisen from two main sources: the STATDESK which provides a platform for interdisciplinary work (see below for more details) and our strong link with financial organisations through CASRI. For instance, this has led to a project funded by a financial organisation, KPMG, on positive definite matrices that involved staff from Mathematics, Statistics and CASRI. Other examples of consultancy include **classified work** and a project funded by the Department for Environment, Food and Rural Affairs (DEFRA) through David Rogers Associates, Aquatic Biological Consultants, on the control of crayfish plague in England and Wales.

e. Collaboration or contribution to the discipline or research base

Research Collaborations: During the REF period, our staff have written articles with researchers from all over the world. Our School has many strong collaborations in place. For example, the NCSE was originally a joint research project involving Kent, St Andrews and Cambridge; the current grant involves seven collaborating universities. Griffin's current EPSRC grant involves Kent, Cambridge, Warwick and the Royal Observatory, Edinburgh. Other examples of joint grants held during the REF period include an EPSRC grant with the University of Leeds and a British Council grant with the University of Porto, Portugal. The School has also been actively involved with various networks, learned societies and international agencies (see examples below).

Interdisciplinary research: One of the strengths of SMSAS is its interdisciplinary nature that provides a fertile environment to develop applicable and/or interdisciplinary research programmes. In particular, the School is very strong in both applied statistics research and methodological developments. Applied work is particularly focused on biological and ecological modelling, neuroimaging, and time series and finance, and we have good links internally with the School of Biosciences and the Durrell Institute of Conservation Ecology and the very recently launched Kent Centre for Finance. Another tool we have that helps to initiate interdisciplinary collaborations is the **STATDESK**, a long-running University-funded system through which staff and research students from any part of the University can seek statistical advice on their research projects. This has led to 4 joint publications in subject-matter journals during the REF period. In the Mathematics Group, several current projects are interdisciplinary in nature. For instance, a current **EPSRC-funded** project led by Rosenkranz is studying symbolic solution methods for linear boundary problems,

including potential applications in actuarial science (renewal risk models with tax payments).
Influence: SMSAS has always supported the development of industrial links, for instance through **CASE studentships**. Our most recent studentship, with the Centre for Environment, Fisheries & Aquaculture Science involved statistical modelling of benthic data. While contacts with industrial partners were mostly informal in the past, SMSAS has been working with the Kent Innovation and Enterprise unit (KIE) of the University to establish more formal and strategic collaborations. For instance, our Calibration impact case study describes an industrial collaboration with KROHNE Ltd, based in Northamptonshire. This built on initial links with the company that were established by X Wang. Support for building this into a more formal collaboration, funded through a **Knowledge Transfer Partnership** (KTP), was provided by KIE. Another example of current collaboration is a joint project with GlaxoSmithKline on design for Drug Discovery (see REF3a).

Leadership roles: Members of staff in SMSAS are actively encouraged to develop external academic leadership roles. To facilitate this, travel funding and time allocations are made, where necessary, to enable such activities. **1) Fellowships:** Marie Curie Incoming Fellowships (Casteels, Naboko), NERC Postdoctoral Fellowship (McCrea), EPSRC Postdoc Research Fellowship (Roitzheim). **2) Examples of journal editorships:** Mansfield: LMS Journal of Computation and Mathematics; Ridout: Journal of the Royal Statistical Society, Series C, Applied Statistics (2009-2012). **3) Examples of Editorial Board Memberships:** Brown: Chemometrics and Intelligent Laboratory Systems (1997-2009). Clarkson: European Journal of Applied Mathematics; Quarterly Journal of Mechanics and Applied Mathematics; Studies in Applied Mathematics; Symmetry, Integrability and Geometry: Methods and Applications. Coordinating Editor for Proceedings of the American Mathematical Society (2007-2011). Griffin: Statistics and Computing, Bayesian Analysis and STAT. Hone: Journal of Nonlinear Mathematical Physics. Lemmens: Linear Algebra and Its Applications. Mansfield: Foundations of Computational Mathematics. JP Wang: LMS Journal of Computation and Mathematics. Zhang: Journal of the Royal Statistical Society, Series C, Applied Statistics (2007-10). **4) Example of prizes and awards:** McCrea: 2011 Young Biometrician Award sponsored jointly by the British and Irish Region of the International Biometric Society and the Fisher Memorial Trust. **5) Examples of invited lectures to major international conferences:** During the REF period, our members have been invited to present their research findings all over the world, and in particular in some of the most prestigious centres/conference series, including (but not limited to): Banff, CIRM (Luminy), IBC, ICMS, ISBA, ISI, MSRI, Newton Institute, Oberwolfach. **6) Conferences organised/co-organised:** Our staff have organised conferences both at Kent and elsewhere, in particular at prestigious mathematical centres such as CIRM (Lemmens), ICMS (Clarkson), Newton Institute (Clarkson, Hone), Oberwolfach (Launois), and in prestigious Statistical Conference series such as ERCIMs 2011 and 2012 (Griffin, session organiser); International Biometric Conferences 2008, 2010 and 2012 (Morgan, session organiser); 58th Session of ISI (Morgan, session organiser); ISEC 2010 (Morgan, chair of scientific program committee). Examples of events organised at Kent include: **British Mathematical Colloquium 2012** (Fleischmann, Shank), Kent Algebra Days series (Launois, Paget, Towers), High-dimensional Inference with Applications in 2013 (Zhang). **7) Examples of participation in research projects/networks:** Clarkson: co-author of the **NIST Digital Library of Mathematical Functions**. Cole: Environmental Statistics Section of the Royal Statistical Society (Secretary 2011-12, Chair 2013-). Launois: member of the steering committee of the EPSRC-funded Anglo-Franco-German Representation Theory Network (2012-2015). **8) Examples of membership of learned societies/consultative roles:** Clarkson: member of the LMS Women in Mathematics committee (2007-); member of the LMS Good Practice Scheme's steering committee; member of the HoDoMS steering committee, since 2012. Mansfield: member of the **EPSRC Mathematics Programme Strategic Advisory Team** (2009-2012); elected member of the LMS Council (2012-); and member of the Institute of Mathematics and its Applications Research Committee, since 2012. Morgan: Fellow of the Learned Society of Wales, elected in 2012/13. Clarkson, Fleischmann, Hone, Morgan: members of various EPSRC panels.

In **summary**, increased investment in academic staff and infrastructure have enabled us to improve the quality of our research and the research environment while expanding the reach of our expertise.