

Institution: Newcastle University
Unit of Assessment: UoA 10 Mathematical Sciences
<p>1. Unit context and structure, research and impact strategy</p> <p>Overview</p> <p>At Newcastle, research in mathematical sciences falls entirely within the School of Mathematics, Statistics and Physics. Physics was added as recently as 2017, so that most of the current School comes under UoA10. All of the quantitative information in this document refers to the mathematical science research of the School.</p> <p>The School has a broad base of mathematical science research, covering the three major divisions of Pure Mathematics, Applied Mathematics and Statistics. Newcastle submitted to each of the separate mathematics panels in all pre-2014 Research Assessment Exercises. At the 2014 Research Excellence Framework the School was ranked 11th on grade point average and 10th on proportion of 4* research by the combined mathematical sciences UoA10 sub-panel.</p> <p>Since REF2014, the School has made significant progress in line with the overarching strategy to pursue research which is '<i>informed, stimulated and extended through its application in a wide range of scientific disciplines and practical applications</i>'. Specifically:</p> <ul style="list-style-type: none"> - The School has increased its research active FTE in mathematical sciences by over 60%, its grant income by 50% and its postgraduate student numbers by 50%. This has been facilitated by a 50% increase in UG student numbers. - There has been an expansion in the diversity of staff within the School. Of 26 Teaching and Research (T&R) hires, six have been female, raising the proportion of female T&R academics on open-ended contracts from 10% in 2014 to 20% in 2020. Eleven of these hires have been from outside the UK. - The School has expanded its data science activities. Joint with Computing Science, the School runs a Centre for Doctoral Training in Cloud Computing for Big Data. It is linked to the National Centre for Innovation in Data and has formed a close association with the Alan Turing Institute and the Francis Crick Institute. - Cross-disciplinary and intra-disciplinary research has been greatly expanded through close links with the new Physics section incorporated into the School in 2017, through collaborative research between the Pure, Applied and Statistics sections, and through initiatives in Biology and Health including collaborations with the Newcastle Centre for Life and the Newcastle Clinical Trials Unit. - Business and industrial based research has been expanded through the appointment of an academic Director of Business Engagement, the creation of a new unit, NU Solve, that acts as a conduit between the School and the outside world, and the appointment of skilled support staff. During the REF period the School has supported over 100 industrial partners and attracted seven Knowledge Transfer Partnerships. <p>Increasing staff numbers was one of the School's major objectives at the 2014 REF. At that time the School had 33.4 academic FTE across the three mathematical science sections, including four on Teaching and Scholarship (T&S) contracts. There are now (July 2020) 52.3, of whom 3.5 are T&S. Three of the academic staff currently hold five-year research fellowships (Guervilly, NERC Research Fellowship; McFadden, STFC Ernest Rutherford Fellowship; Seifert, Newcastle University Academic Track Fellowship) and will transition to open-ended lectureships at the end of the fellowship period. In addition, the School has gained six</p>

experimental physicists and three observational astronomers (not being returned to UoA10) who complement the applied mathematicians and are establishing links with the statisticians. Other staff on indefinite contracts but not attached to any of the sections include three professional statisticians in NU Solve, three full-time and one part-time teaching colleagues on T&S contracts supporting the School generally, three mathematicians in the E-learning unit (which conducts pedagogical research), two PhD level computer support officers, two computer technicians and a total of 12.7 FTE in School-based professional support staff. Despite the global pandemic, academic staff investment in the School has continued - as of July 2020, two lectureships were in-flight across Applied Mathematics and Statistics (and have subsequently been filled).

Since the 2014 submission, the School's grant income has also increased markedly, from roughly £0.75M to £1.6M per annum. The increase has been in both absolute value and in income per FTE, demonstrating the School's commitment to improving research culture and supporting grant capture.

The School has a tradition of diversity with regard to country of origin, with 30% of the T&R staff in the School from outside the UK at the time of REF2014. However, at that time the School had only 3.6 female T&R members of staff: three academics in Pure and one part-time Principal Research Associate in Statistics. Since then, the School has driven to embed strong Equality, Diversity and Inclusion (EDI) principles in all activities and processes, and of the 26 T&R hires across the School, six have been female and 11 have been from outside the UK.

The Director for Business Engagement (DBE) is a new role as of 2017, whose remit is to increase engagement with external non-academic partners in order to increase the reach and impact of the School's research. In line with the goal from REF2014, the School expanded the former Industrial Statistics Research Unit into a new business engagement unit called NU Solve. The DBE works alongside the manager of NU Solve and the School's Research and Impact Facilitator on two new bodies, the Business Engagement Committee (BEC) and the Business and Engagement Advisory Board (BEAB), the latter of which include various partners from business, industry and government.

Organisation

The School is part of the Faculty of Science, Agriculture and Engineering (SAGe). Following a Faculty reorganisation in 2017, the School of Mathematics and Statistics became the School of Mathematics, Statistics and Physics. The main consequence for the School was the addition of Physics as a fourth research section. Teaching and research in the Pure Mathematics, Applied Mathematics and Statistics sections was essentially unaffected, apart from some changes in management structure.

The School Executive Board (SEB) now consists of nine academic members together with the School Manager and representatives of Finance and of People Services. The academic members are:

- Head of School (HoS)
- Deputy Head of School (DHoS)
- Director of Research and Innovation (DRI),
- Director of Excellence in Learning and Teaching (DELT),
- Director of Postgraduate Studies (DPG)
- Director of Business and Engagement (DBE),
- Director of Mathematics
- Director of Physics
- Director of Statistics

The School's research is further supported by a team of Research Group Leaders (RGLs) and the School Research and Innovation Committee (SRIC). The RGLs are responsible for the research of focussed groups within the School. They have overall holistic pictures of their

groups, they help determine and implement the group strategies within that of the School, and they support their group members individually. SRIC decides broad objectives and strategies and oversees research across the School, including support, training and opportunities for researchers, developing strategic research initiatives, and examining performance and development of the research groups.

Applied Mathematics

Applied Mathematics has 19.7 T&R FTE (20% female). The Section is further divided into four research groups: Geophysical and Astrophysical Fluid Dynamics, Relativity and Cosmology, Quantum Matter, and Mathematical Biology and Archaeology. Some staff members belong to more than one group.

The Geophysical and Astrophysical Fluid Dynamics (GAFD) group is the largest Applied group, having ten academic faculty (**Bushby, Carr, Fletcher, Guervilly, Rogers, Sarson, Shukurov, Soward, Swailes, Wood**). Since REF2014, the group has added four academic staff (**Carr, Rogers, Swailes, Wood**) along with **Guervilly** who is a NERC research fellow (and proleptic lecturer). The GAFD group is the oldest group in the Applied section with expertise and international reputation dating back to the early 1960s. The research focus of the group is on fluid and gas dynamics across a range of geophysical and astrophysical objects, including the Earth's atmosphere and oceans (**Carr, Soward, Swailes**), planetary atmospheres and interiors (**Guervilly, Rogers, Sarson**), stars (**Rogers, Wood**), galaxies (**Fletcher, Shukurov**) and intergalactic plasmas (**Sarson, Shukurov**). As astrophysical and geophysical plasmas and fluids are affected by magnetism, much of the work revolves around studies of magnetohydrodynamics. The group carries out both analytic work and numerical simulations using high-performance computing with sophisticated numerical codes, developed in-house and as part of larger teams. The group also carries out some laboratory/experimental work, focusing on the dynamics of internal solitary waves and rotating flows.

REF2014 goal: We plan to follow up on our successful investment in the LOFAR radio-telescope project with participation in the €1.5bn Square Kilometre Array.

Multiple members of the group (**Fletcher, Sarson, Shukurov**) have done this, working on comparing simulation results to observations, often in collaboration with observational collaborators in Bonn. The group's connections to observations have recently expanded with the appointments of the observational astronomers Archibald and Harrison as part the growth in physics. Their observations will help guide theory and numerical simulations in the group and vice versa.

The Relativity and Cosmology group has four members (**McFadden, Moss, Rigopoulos, Uhlemann**) and an additional observational cosmologist (physicist Leonard, not returned to UoA10). The group has grown significantly since REF2014, with one member retiring (Toms) but four new members joining (Leonard, **McFadden, Rigopoulos, Uhlemann**) and another Ernest Rutherford Fellow expected to join in March 2021. The group is well placed to make a significant contribution to the theory and observation of the large-scale structure of the universe, by exploiting its membership of the international Euclid and Legacy Survey of Space and Time collaborations and working with the growing number of astronomers who are part of Newcastle Physics. The group is also active in the newly emerging field of analogue gravity, where laboratory systems are used to model phenomena such as the big bang and black holes, in collaboration with the Quantum Matter group.

The Quantum Matter group has eight members (**Baggaley, Barenghi, Billam, Emary, Parker, Proukakis, Sergeev, Wood**) with five members also working within the other groups. Since REF2014 the group has expanded, with five additional academic staff (**Baggaley, Billam, Emary, Sergeev, Wood**). The Quantum Matter group at Newcastle has a long tradition, with studies of quantum fluids (liquid Helium) dating back to the 1970's. The group focuses its studies on theoretical and numerical modelling of quantum properties of matter and light, from the

fundamental to the technological. It studies a range of different research topics associated with quantum gases and fluids, quantum optics and quantum technologies. The group's work is conducted in close collaboration with a large number of key international experimental research groups and centres.

REF2014 goal: We will develop the strength and reputation of our new Joint Quantum Centre.

The group is a founding member of the Joint Quantum Centre (JQC) along with Durham University, which has a number of experimental physicists with overlapping research interests. Many of the School's large grants are held jointly with Durham through the JQC, which hosts at least one international conference a year. There are close connections and collaborations with the BEC Centre at Trento, Italy, and with the National Physical Laboratory within the UK. Moreover, the group is beginning to work closely with experimental condensed matter and atomic-molecular-optical physicists who have been hired within the School as part of the physics growth.

Mathematical Biology and Archaeology is the newest group in the section, although research in these fields (notably mathematical archaeology) dates back to the late 1990s. There are currently seven members (**Baggaley, Emary, Fletcher, Golightly, Gillespie, Parker, Sarson, Shukurov**) all shared with other groups within the section (and in Statistics). The research within the group divides across a number of areas, for example: cooperative animal motion, stem cell growth and motion, ecological networks, biological image analysis and signal processing with applications to ecology. Their inter-disciplinary approach to tree disease propagation has been recognised recently through the 2020 award of a EPSRC New Horizons grant to **Baggaley, Golightly** and **Parker** for their project *Modelling and Inference of UK Tree Pandemics*.

All of these groups will benefit significantly from the expansion of physics and its inclusion in the School. The interaction with experimental physicists, observational astronomers and theoretical physicists of all varieties under the same roof will strengthen the quality and relevance of the work done in the Applied Mathematics section at Newcastle and will also draw in expertise from Statistics for analysis and processing of data.

Pure Mathematics

The Pure Mathematics section has 13.4 T&R FTE (30% female) as of July 2020, with two groups: Algebra and Analysis.

REF2014 goal: In pure mathematics our strategy involves a combination of continued development of core research in algebra and analysis.

There are seven members in the algebra group (**Balagovic, Duncan, Jorgensen, Kolb, Rees, Stewart, Vdovina**). Within algebra, the group has expertise in geometric and combinatorial group theory (**Duncan, Rees, Vdovina**), which is a key area of algebra in the UK. Research focuses on questions of theoretical complexity, decision problems, the study of automorphism groups, surface groups, buildings and knot theory. **Vdovina's** work extends into differential and algebraic geometry as well as the K-theory of C^* -algebras. There are firmly established ties to the School of Computing and to Mathematics and Computing at Durham University through the Northeast Organization of Discrete Structures (NODES) collaboration. The second strong area is representation theory (**Balagovic, Jorgensen, Kolb, Stewart**), which is firmly within the mainstream of pure mathematics. This includes Lie theory, algebraic groups, Kac-Moody algebras, quantum groups, in particular quantum symmetric pairs, Hecke algebras, triangulated categories, in particular cluster categories, and applications to geometry, combinatorics and the representation theory of finite-dimensional algebras. In 2016, with EPSRC support, Jorgensen established the Newcastle Higher Homological Algebra Group, which currently (July 2020) has four members and is the main UK group in this emerging area of mathematics. Since REF2014 the international profile of the group was boosted by two appointments. **Stewart's** appointment

in 2015 added expertise in algebraic groups and modular representation theory while **Balogovic's** appointment in 2016 added expertise on Hecke algebras and Yangians.

Newcastle has since the 1960s established a reputation for research in Analysis. The Analysis group has more than doubled in size since REF2014 and now has eight members: **Dritschel, Kakariadis, Kimsey, Lykova, Seifert, White** along with **Putinar** and **Young** as part-time (20%) senior researchers. **Seifert** holds a Newcastle University Academic Track (NUAcT) Fellowship. The main research topics in analysis are operator theory, operator algebras, complex function theory and the interplay between these areas. This includes C^* -algebras and Banach algebras (**Dritschel, Kakariadis, Lykova, White**), moment problems and connections to real algebraic geometry (**Dritschel, Kimsey, Putinar**), operator semigroups (**Kakariadis, Seifert**) and applications of operator theory to complex analysis (**Dritschel, Lykova, Kimsey, Putinar, Young**). The work of the analysis group has far-reaching applications in chemistry, physics, quantum information and control theory. **Putinar** and **Young** have established links with Engineering. The interface between Analysis and Engineering was further strengthened by the appointments of **Kimsey** and **Seifert**.

As well as undertaking core research, members of the Pure section have been working with colleagues in other sections of the School in accordance with our 2014 goal:

REF2014 goal: Our aim is to break down traditional fragmentation and increase the prominence of trans-disciplinary research making best use of the modern pure mathematical methodology.

Young and **Henderson** (Statistics), along with Taylor from Engineering at Lancaster University, were awarded £547K in 2015 by EPSRC for a project "Adaptive treatment and robust control", which focused on engineering and statistical aspects of control theory. **Nye** (Statistics) and **White** have collaboratively published on the application of diffusion processes to imaging techniques. **Seifert** collaborates with chemists from Oxford, Reading and Grenoble on properties of metal cyanides. **Kimsey** collaborates with **Emary** (Applied) at the intersection of truncated moment problems and questions from quantum mechanics and quantum information theory.

Kakariadis is working with medical doctors and architects from Giessen, Oslo, Munich, UCL on a project to investigate the appropriateness of antibiotic options and probabilistic hospital protocols. **Vdovina** and **Duncan** have begun a project with the neurology group in the Newcastle Faculty of Medical Sciences, investigating gait as an early indicator of dementia, and **Vdovina** and **Henderson** (Statistics) have an ongoing project on the topological analysis of metric trees, with application to the venous structure in the human eye.

Statistics

The statistics group has 15.7 T&R FTE (10% female): **Avery, Fawcett, Coleman, Gillespie, Golightly, Heaps, Henderson, Matthews, Nye, Oates, Philipson, Pollock, Prangle, Shi, Villa, Wilkinson, Wilson**. It has an established reputation for outstanding research, with expertise across data science, biostatistics, and spatial and environmental statistics and growing links with engineering. There are two broad themes, *Bayesian* techniques and *Biostatistics*, with extensive crossover between them.

Development and application of Bayesian methodology is a recognised area of strength, particularly computational approaches, together with expertise in the construction and analysis of complex hierarchical models (**Fawcett, Gillespie, Golightly, Heaps, Oates, Pollock, Prangle, Villa, Wilkinson, Wilson**). Highlights include stochastic differential equation models, sequential Monte Carlo algorithms, Bayesian solutions for models with intractable likelihood, Bayesian inference for phylogenetic trees, Bayesian analysis of ranked data and prior specification and elicitation. **Prangle** received in 2020 a EPSRC New Horizons award for his project *Learn2Sim: Learning to Steer Computer Simulators*, meaning two of the 50 national New Horizons awards (from 1200 applications) came to Newcastle. Within the group, **Oates, Pollock** and **Villa** are all recent hires. **Oates** brings additional expertise in computational statistics,

inverse problems, probabilistic numerical methods and data-centric engineering. **Pollock** also brings expertise in computational statistics, and in addition cryptography and risk modelling. **Villa** strengthens the group's Bayesian non-parametric research. Group leader Richard Boys sadly died in 2019. His replacement chair, along with an extra lectureship, was advertised in early 2020 but the appointments were deferred as a result of the coronavirus pandemic.

The other main theme for the statistics group is biostatistics, broadly defined (**Avery, Coleman, Henderson, Matthews, Nye, Philipson, Shi**). This includes survival analysis, longitudinal data analysis, clinical trial design, including cross-over trials and cluster-randomised trials, modelling and inference for stochastic systems biology, phylogenetics, modelling in non-metric spaces, functional data analysis and Gaussian process regression, genomics and meta-genomics.

Philipson's appointment in 2020 adds to the group's expertise in inference under missing data and joint modelling of longitudinal and event time data, including computational aspects.

Matthews is currently seconded 60% time to the Faculty of Medical Statistics, where he works closely with Professor James Wason and his biostatistical research group, primarily on design of clinical trials.

REF2014 goal: Our strategy for statistics involves concentrating on the established strength and standing of statistical bioinformatics research at Newcastle and collaborating with computing colleagues on methodology for the analysis of big data.

Since 2014 the group has continued to study Bayesian inference for systems biology. Examples include **Oates'** work on graphical models in molecular systems biology and in RNA editing, and the **Golightly** and **Gillespie** stochastic kinetic modelling approaches. The focus of applications has moved in part towards data centric engineering, where biological systems are viewed through engineering methods. In particular, through the £5.5M EPSRC grant *A New Frontier in Design: The Simulation of Open Engineered Biological Systems*, **Wilkinson** has collaborated with colleagues in Engineering on the application of statistical emulation of complex models to enable the engineering of new functionalities in natural or synthetic organisms.

Research in data science has expanded over the REF period, often in collaboration with Computing Science at Newcastle. In 2014, joint with Computing, the Statistics group obtained an EPSRC Centre for Doctoral Training in Cloud Computing for Big Data, with **Wilkinson** as co-Director. The CDT has enrolled approximately 10 students a year since 2014 and is continuing, with Cohort 7 joining in autumn 2020. Each student is jointly supervised by Computing and Statistics, and a wide range of joint projects have resulted from the collaboration, including applications of Bayesian statistical methods to very large sets of streaming data, originating for instance in the Urban Observatory in Newcastle. The group have close ties to the Newcastle-based National Innovation Centre for Data (NICD), which employs several statistics PhD graduates.

Four colleagues currently have fellowships from the Alan Turing Institute. **Wilkinson** is ATI strategic theme lead for molecular medicine, a 20%-time funded role which includes developing a formal relationship between the Turing and the Francis Crick Institute. He also heads a £358K project on streaming and real time monitoring and forecasting (45% time). **Oates** received a 100% ATI Fellowship as group leader for data-centric engineering, now co-funded by Lloyd's Register Foundation. **Pollock** is a Turing Fellow (30% time) in the Defence and Security Programme and is leader of the statistical secret sharing project on the statistical use of cryptographic techniques for the purposes of inferential privacy. **Shi** (10% time) is part of the ATI programme on Health and Medical Sciences. The four fellowships have been supported by five PDRA positions, two PhD studentships and one research support engineer.

REF2014 goal for Statistics: an increased contribution to research activities elsewhere in the University

Other than the 2020 hires, every member of the Statistics section now has ongoing collaborative research projects with colleagues elsewhere in the University. Examples include **Fawcett's** work with engineering on the placement of speed cameras, which underpins an impact case study, **Shi's** involvement in the Limbs Alive project on the rehabilitation of stroke patients, and **Heaps, Wilkinson, and Wilson's** roles as CIs on the £1.5M NERC-funded project *Flood Prepared*. The group are members of the £2M cross-faculty *Spatial Analytics and Modelling* programme, joint with Geography, Planning and Geomatics, which has funded one Chair of Statistics, two PDRA positions and one PhD student within the School.

Collaborations between the sections within the School have already been described with regard to Pure Mathematics and Statistics. There are also fruitful collaborations between Applied Mathematics and Statistics. **Golightly** (Statistics), along with **Baggaley, Sarson and Shukurov** (Applied), developed Bayesian methods to study the spread of Neolithic populations, and is now working with **Baggaley and Parker** (Applied) on the EPSRC New Horizons project to model tree disease spread mentioned above. **Henderson** (Statistics) and **Bushby, Fletcher and Shukurov** (Applied) obtained a £200K Leverhulme Research Project grant to study topological methods for turbulent flows within the interstellar medium, which has been supplemented by three PhD studentships. With the recent recruitment to the School of three observational astronomers, this collaborative research strand is expected to expand significantly.

Strategic Research Objectives

Newcastle University has a strong and balanced portfolio in the mathematical sciences and its long-standing philosophy has been to develop complementary areas of expertise that allow inter-sectional research relationships to flourish alongside core disciplinary research. As demonstrated by the School's recent award of two highly competitive New Horizons Grants, its approach of interconnecting fundamental research teams puts it in a good position to capitalise on this investment. This is one of the many strands of income that will be used to support the growth of disciplinary activity.

At the discipline level, the School has identified areas of strategic importance to consolidate and expand. The Pure Mathematics section will continue to prioritise the core mathematical disciplines of algebra and analysis, bringing together the existing expertise in operator algebras, non-commutative complex analysis and (combinatorial/geometric/quantum) group theory around a common theme of non-commutative geometry, and strengthening its activity in operator theory to complement to recently-appointed NUAfT fellow **Seifert**. Within the Applied Mathematics section, a key strategic priority will be the expansion of the Mathematical Biology and Archaeology group, building on the 2021 appointment of biological fluid dynamicist Croze, and promoting further collaboration with the Newcastle Centre for Life and the Faculty of Medical Sciences. Collaborations between the Applied Mathematics section and the new Physics section are already fruitful and will be grown further in the coming years. For example, the Joint Quantum Centre now has an experimental arm being led by the School, and the Relativity and Cosmology group have joined with Physics as contributors to a successful, multi-institution, interdisciplinary research bid from UKRI (Quantum Simulators for Fundamental Physics). The Statistics group aims to further develop its expertise in statistical data science. Areas of research to be strengthened include statistical theory for machine learning and artificial intelligence. Existing ties with the School of Computing via the CDT in Cloud Computing for Big Data and the jointly run MSc in Data Science will help support these developments. The group will capitalise on data science funding opportunities, for example from the Alan Turing Institute, and expand its collaborations with other scientists within the University and with industry, to generate further impact from its data science research.

To further extend the influence on its research, the School will align itself more closely with the strengths of Newcastle University to facilitate more impactful research opportunities. The

University has defined five pillars of strength (ageing and health, data, energy, cities, and culture and the creative arts). The School will leverage internal investment, for example, the NUAcT fellowships, to create bridges between fundamental mathematical research and the more applied areas of strength across the institution.

Soliciting collaboration from external partners is another strategic priority that is targeted at growing research impact. This will be driven through the School's recently-formed NU Solve unit, which provides the front-door for both internal and external collaborative projects that have a business and engagement element to them. NU Solve will facilitate the establishment of new projects, offer project management and enhance impact across all the School's main areas of research. Traditionally, the industrial business engagement of the School has been through the discipline of statistics. The School is seeking more opportunities for directly impactful research of its Pure, Applied and Physics colleagues.

The School has had enormous success with its recent equality, diversity and inclusivity initiatives, evidenced with the measurable impact on the EDI profile of its academics and its Athena Swan Bronze Award. However, it is recognised that continued evolution is the only way to drive sustainable change. A core component of this activity is the School's commitment to redefining its research culture. The School will undergo a full review of its research processes. This will encompass its attitudes, protocols, professional support, and recognition and reward systems. The programme will engender greater inclusivity by altering how researchers view the efforts and contributions of peer researchers, postgraduate and postdoctoral researchers and support staff. Good mentorship will be championed as key to promoting an inclusive research environment. Since its reintroduction at Newcastle University in 2015, the Physics discipline has used the opportunity of nascency to grow its research base with equality, diversity and inclusivity at its core. This good practice has been adopted across the School and over the coming REF cycle it will reap the benefits of recognising the strength of diversity in perspective and approach.

2. People

Staffing

Since REF2014 the School has:

- **Increased T&R staff from 29.4 to 48.8 FTE, excluding Physics.**
- **Embedded best EDI practice into its policies and procedures, including recruitment and promotion, leading to an increase in female T&R FTE from 3.6 to 9.6.**
- **Increased impact activity including appointing a Director of Business and Engagement and including impact activities into the workload allocation model.**
- **Opened a centre for Doctoral Training in Cloud Computing for Big Data, jointly with Computing Science.**
- **Increased PhD student numbers from 41 to 81.**

The School endeavours to appoint the very best researchers across the three main areas of Pure Mathematics, Applied Mathematics and Statistics. It supports the existence of a community of scientists working together and promotes the development of individual strengths through supervision, mentoring and a well-structured career path.

Equality, Diversity and Inclusion

Since 2014 EDI has been a major focus of the School, prompting numerous initiatives to improve diversity and also to promote more collegiality and an improved working environment for

all staff. The School holds Athena SWAN bronze and will apply for silver at the next round. The many initiatives fall under three broad categories: *Recruitment*, *Improving Workplace Culture* and *Improving the Pipeline*.

Recruitment:

In line with the School's EDI policy, academic posts are advertised for three months and recruitment panels include at least one female member of T&R staff. In 2018/19 the School piloted a recruitment approach from consultancy company Diversity by Design (DbD) in an Applied Mathematics search. The process was almost entirely blind with members of the selection panel not seeing CVs, and with the standard interview replaced by practical assessments of on-the-job activities, such as a tutorial with students. Around the same time the School ran a more familiar process for a Physics post, but in addition to a research talk all short-listed candidates were asked to present a five-minute EDI talk which was considered an essential criterion in selection. Both processes led to diverse short-lists but it was felt that the "blind" process could not be used for strategic recruitment and could not scale to larger recruitment cycles (when hiring several candidates at once).

Learning from this, the recruitment procedure of the School now includes a standard interview and presentations on each of research, teaching and EDI. It is expected that a small-group tutorial role-playing exercise with students will also be implemented once in-person recruitment resumes. The goal of the new recruitment methods is not only to increase diversity but to acknowledge the multi-faceted nature of the academic role and to evaluate candidates on their ability to contribute to all aspects of that role.

The School's recruitment procedures are considered best practice within the SAgE Faculty and are being rolled out to other Schools. The emphasis on contributions to EDI and workplace culture have been implemented in the University-wide NUAcT fellowship scheme.

Improving workplace culture:

In 2016 the School implemented maternity policies that were considered best practice within the Faculty. The policy stipulated reduced workload for a year upon return from maternity, increased travel budget, no new assigned courses and no large administrative roles. Extended paternity leave is allowed and has been taken up on two occasions. The School also implemented a "Carers Fund" to support additional childcare costs associated with work travel or after-hours work events. All School meetings, including seminars, now occur within core hours (09.30-16.00).

Improving the pipeline:

The percentage of female seminar speakers is carefully monitored and has increased from 10-20% (depending on section) to 30-40% over the last four years. In addition, the School has implemented a "Restart Fellowship" which part-funds a PhD student or PDRA returning to academia after a career break. So far this fellowship has been used to support two individuals to pursue PhD study, and hence a research/academic career, following extensive periods of caring responsibilities. The School has a dedicated EDI budget of £15,000 per year to support EDI activities, such as supporting female visitors to the School, networking events for PhD students and PDRAs, and staff attending and/or hosting EDI training and workshops. The School organises and hosts the annual WISDOM (Women in Science doing Outstanding Mathematics) conference, which showcases mathematics to school girls through positive women role models.

Staff Recruitment

The recruitment strategy in Mathematical Sciences has been to increase all three sections to maintain and build critical mass in research areas and forge links between different groups, as described in Section 1.

As of July 2020 the School has 57.8 T&R FTE, of which 48.8 are based in the three UoA10 mathematical sections, the remainder being six experimental physicists and three observational astronomers. At REF2014, the School had 29.4 FTE of mathematical T&R staff.

The School aims to maintain a balance of staff across different career stages. Of those submitting to UoA10, 18 are Lecturers (22% female), 22 are Senior Lecturers or Readers (18% female) and 13 are Professors (15% female). Five of the new appointments during the REF period were proleptic, to provide continuity in anticipation of pending retirements.

Staff Development and Support

All new members of staff are part of a research group headed by a Research Group Leader (RGL). Each new member of staff is also given a separate mentor. After induction into the School, new members of staff meet regularly with their RGL to discuss and review goals, objectives and development opportunities. New staff have a probationary period of two years, managed by the RGL in consultation with the Head of School. After successful completion of probation there is an annual Performance and Development Review (PDR), described below.

The School has an established workload allocation model. Early career researchers in their first academic position receive as standard a 25% workload reduction in their first year, which is incrementally reduced over the first four years. More experienced early career researchers receive a smaller initial workload reduction. Workloads are formally allocated by the Head of School, in consultation with the Deputy Head of School, Director of Excellence in Learning and Teaching, the Director of Mathematics/Statistics /Physics as appropriate and the relevant research group leader. The model includes core research time for all T&R staff which is supplemented with credit for PDRA and PhD supervisions, grant submission and capture, impact activities and editorial and other research-related external roles.

Computing support is provided by two Computing Officers, who are PhD mathematicians with hardware and software experience, and two computing technicians. Every member of staff is given £1500 per annum for travel and other research related costs, on top of any funding included in research awards. In addition, the subject Directors each hold a budget of approximately £30,000 per annum that can be used for strategic research objectives. Examples have included hosting research workshops, additional travel for staff or PhD students, hosting external visitors and purchasing computing equipment. Early career staff and research students are given priority in requests for funds.

The University offers a large selection of training and development opportunities for all staff. The most popular within the School are: "Leadership Development Programme"; "Research Supervision" and "Readiness for Fellowship". Staff have taken advantage of these programmes, with 34% of School academic staff and 38% of PDRAs having participated in the last five years.

Training opportunities and their efficacy are discussed during the annual PDR, which is mandatory for all staff. The purpose of the PDR is to review the previous year's performance, outline personal development plans, including training needs, and agree objectives and identify priorities going forward. The School provides compulsory PDR training for reviewers in the form of a small workshop and online training is also available. PDRs are generally done by the RGL, except for the professoriate and members of the School Executive Board, who are reviewed by the Head of School. The School has 100% PDR compliance.

The School has a sabbatical policy to ensure that members of staff can take a semester without teaching and administrative duties approximately every 5-6 years. Sabbatical applications are discussed annually by a subset of the School Executive Board. Sabbatical requests can also include travel funds in addition to the normal entitlement. Currently all T&R staff who have been in the School more than five years have had a sabbatical within the REF period.

There are two University-wide annual promotion rounds: one for Professors and Readers and one for other academic promotions. In the past, promotions within the School started with self-identification, informed by PDR discussions. The Head of School (HoS) would write a confirmation letter and then cases would be received and decided by the Faculty Promotions Committee (in the case of L/SL) and additionally, by the University Promotions Committee (in the case of Reader/Professor). Besides discussions with the HoS there was very little support for developing a candidate's case for promotion. This could cause problems because candidates could be unsure whether they met the promotion criteria, which are extensive and generic. Additionally, there is known gender-bias in self-identification. To address these issues, in 2018, the School introduced a Promotions Advisory Group (PAG), with membership chosen to ensure diversity in grade, gender and section. The membership of the PAG reflects all aspects of academic contracts, in particular the Director of Excellence in Learning and Teaching to support T&S staff and the Deputy Head of School who has an EDI remit. Members of the group also mentor candidates, helping them to develop their applications over an appropriate time frame, usually one to three years in advance. Staff may still put themselves forward for promotion under the previous route.

Support for PDRAs

Supporting PDRAs is a high priority for the School, especially as a large drop of people (particularly females) in the academic pipeline occurs between the PDRA phase and permanent contract positions. The School, Faculty and University are committed to the principles and responsibilities described in the revised (2019) *Concordat to Support the Career Development of Researchers* and to the University's own *Code of Good Practice in Research*. PDRAs are fully integrated into the School's research groups, share the same facilities and have access to the same support as other staff. PDRA office accommodation is embedded in the School alongside that for T&R and T&S staff. PDRAs have a formal induction programme and annual PDRs. PDRAs can choose to have their PDR with their supervisor or with another member of staff.

The School places particular emphasis for PDRAs on **career development**, on **networking**, and on **building experience**.

Responsibility for supporting the **career development** of PDRAs lies with the RGL, who works in conjunction with the main supervisor. The *Career Pathways Framework* is designed to assist PDRAs in planning their career development activities to support their future career aspirations. It is used to promote best use of induction, PDR, mentoring and career advice procedures and to encourage participation in developmental activities provided by the Faculty and University to support researchers. Popular programmes for the School's PDRAs include: the *Principal Investigator Development Programme* for aspiring PIs; workshops on *Learning, Teaching and Assessment* and on *Personal Impact*. There is also a *Transitions Programme* to support career moves to outside academia.

The School has developed an annual careers and **networking** event for PDRAs and PhD students jointly with the Department of Mathematical Sciences at Durham University. Beginning in September 2018, workshops are arranged by PDRAs and PhD students with guidance from academics and professionals from both universities, and address challenges such as applying for jobs, fellowship opportunities and grant proposal writing. Alongside this, the workshops highlight the importance of managing mental health and promote EDI in the workplace. Feedback has been uniformly very good.

PDRAs can gain **teaching experience** by request, either through full or partial lecture courses (where appropriate), by taking tutorials or lab classes, or by supervising or co-supervising undergraduate projects. Such teaching or teaching support is not obligatory and formally requires the supervisor's agreement (which has never been withheld). The School now also offers the opportunity for PDRAs to gain **management experience**. PDRAs recently indicated that they wanted to be involved more formally in the School decision process. The School has thus created a School PDRA committee (School funds provided when necessary), which will

identify and bring forward issues associated with their career needs. The committee chair is a permanent member of the School Research and Innovation Committee (SRIC), which ensures that a clear line of communication is established with the School management.

PhD Students

The number of PhD students in the School in Mathematical Sciences has almost tripled since REF2014, from around 30 in 2014 to over 80 in 2020. As well as an increase in absolute numbers, the PhD population has also increased relative to the number of staff, from 0.8 to 1.2 PhD students per staff FTE. The School views the current level as close to optimal. On-time submission rate for the School's PhD students has been over 90% during the REF period, and is routinely one of the highest across all Schools in the University.

Part of the increase in PhD numbers has resulted from the award in 2014 of EPSRC funding for a Centre for Doctoral Training (CDT) in Cloud Computing for Big Data, which is run jointly with Computing Science; while the last EPSRC-funded entry cohort has passed, new cohorts are being supported through industrial sponsorship and internal investment. The CDT has so far recruited seven cohorts of eight to ten students. The programme covers four years, with the first year designed to give advanced training in cloud computing and data analytics, followed by three years of in-depth PhD study. The CDT includes a placement scheme via one of the industrial partners, who also provide external PhD advisors and work with the students on applied academic collaborations. About half of the CDT students have main supervisors in the School, from either the Statistics or Applied Mathematics sections.

The School typically receives three studentships per year from the Faculty EPSRC DTP allocation and one from STFC. These are usually awarded strategically, and with priority to early career researchers. Other internally allocated studentships (usually 3-4 per year) are School-funded and are used strategically to support research need. The School is also successful in attracting self-funded and externally-sponsored PhD students, and PhD students from NERC and EPSRC CDTs across the university around inter-disciplinary modelling projects.

Support for PhD Students

All PhD students have two named supervisors. Since REF 2014 the School has appointed a personal tutor for PGR students for pastoral care beyond their supervisory team. Students are expected to meet their supervisors at least weekly. Day-to-day management of PhD matters is the responsibility of the Director of Postgraduate Studies, the four (including Physics) section PhD Selectors and the personal tutor for PhD students. Gender representation is always ensured on the team so that students are able to speak to a female member of staff if they so wish.

The School has a variety of activities to support the academic progression of its PhD students. PhD students have access to the same computing facilities and support as academic staff and PDRAs. Each PhD student has a travel allocation of £1500 and can request additional funds from budgets held by the subject Directors. The additional funds are usually used to allow PhD students to present at international conferences during their final year. All PhD students give at least one internal seminar per year, either in the regular section-specific internal seminar programmes or at annual section-specific PhD conferences.

All PhD students are given the opportunity to undertake paid marking and demonstrating for our undergraduate programmes. They are also given the opportunity (at their request) to do more substantial teaching, such as covering tutorials and problem classes, under close support from an academic mentor. The School encourages and supports such students to undertake the experiential route to accreditation with the Higher Education Academy at D1/Associate Fellow level.

PhD students are given opportunities to be involved in **outreach activities** through University open days and the School's active outreach programmes with local schools, supported by Faculty training workshops on science communication. The School has also encouraged PhD students, and provided financial support, to participate in national outreach and engagement competitions; one successful example is PhD student Laura Wadkin who won the silver medals in the 2017 STEM for Britain competition at the Houses of Parliament and the Smith Institute's 2020 TakeAIM competition. In recent years the School have also part-funded several 3-month placements of PhD students within external companies and organisations (see below).

PhD students undertake 100 credits of **academic and skills training** in their first two years. Statistics PhD students additionally attend the residential Academy for PhD Training in Statistics (APTS) courses, choosing up to four courses depending on PhD topic and prior experience, and are also encouraged to attend the annual Research Students Conference in Probability and Statistics. Pure and Applied PhD students access the virtual postgraduate lecture programme provided via the School's membership of the MAGIC consortium. Generic skills training is provided by the Faculty through its Postgraduate Researcher Development Programme, which makes available a wide range of workshops on transferrable skills, such as scientific writing, entrepreneurship, employability and presentation skills. Faculty-wide PhD induction and networking events are also organised through this programme.

Satisfactory completion of training credits is required for progression into the subsequent year. Each student has an independent progression panel of two named academic staff, who review project plans, annual progression reports and supervisor feedback. Since 2018 the School has implemented annual interviews of PhD students by the progression panel, which are required to be completed before the student can progress.

Forward Staffing Strategy

The School's forward staffing strategy is aligned with its research strategy and is composed of four key strands.

Academic profile and pipeline:

The School will maintain a balanced demographic of research leadership and early career researchers. As staff retire or leave, appointments to the key research areas will be at junior level. Staff will typically reach senior levels through internal promotion, reflecting the School's positive staff development and support policies. In line with institutional ambitions for research activity, the School will strategically grow research staffing at all levels through initiatives such as the NUAAct fellowship scheme, which will appoint 80 outstanding early career researchers over the next four years. The School will pay close attention to succession planning and to preparation of colleagues for leadership roles.

Diversity and inclusivity:

Promoting a diverse and inclusive community will remain a key focus, targeting a representative profile across all protected characteristics. The School will continue its successful practices around recruitment, promoting visibly diverse leadership, and running regular EDI training and community-building activities. Culture and practices will continually be assessed and challenged, led through the School EDI committee and following the School and institutional Athena Swan, Race Equality Charter and Stonewall action plans.

Balanced research capability:

The School will maintain a healthy and sustainable base of curiosity-led disciplinary research while also building activity and innovation at the interface with other disciplines and external stakeholders. The latter will lead to greater prominence of mathematical sciences in institutional efforts towards societal and economic challenges around energy, environmental sustainability, cyber security, food and health.

Freedom and opportunity to succeed:

Tailored staff development will be provided in coordination with the NU Organisational Development Unit and the NU Academies (spanning Skills, Policy, Global Challenges and Enterprise) and mentorship. Support mechanisms will include protected research workload, impact sabbaticals and seed-corn funding. The ethos of driving research success through support and opportunity will extend to undergraduate research students and postgraduate researchers, fostering the source of the researcher pipeline.

3. Income, infrastructure and facilities

Infrastructure and Facilities

The School of Mathematics, Statistics and Physics moved to the refurbished Herschel Building in 2007. Since then, there has been continuous investment in infrastructure to improve usage, increase office space to accommodate higher staff numbers and to improve social interaction space. The School has also acquired most of the annex of the building to accommodate the increased number of staff and research students and to house the new Physics section. All staff on full time indefinite contracts have individual offices.

Computing facilities have grown to fulfil the needs of the research groups. Members of the UoA make extensive use of the School's computing network and support provided by two PhD-level Computing Officers and two computer technicians. The Computing Officers provide help with software development as well as with hardware and have expertise in the use of most of the important mathematical packages and languages. In 2014 the School invested £180k on an in-house high performance computing system of 532 cores. This has now been incorporated into a Faculty facility of 1604 cores. The School has a target priority of 35% in the Faculty system and an historical record of 75% of usage. In 2018 the University invested in Rocket, a high performance computer with more than 5000 cores of varying architecture and memory. Mathematicians from the UoA have used a large fraction of this resource since its commissioning. To date 91% of the system's use has been from the Science Agriculture and Engineering Faculty, of which the School has been responsible for 23%. Having access to high capacity computing facilities has enhanced the School's research and allowed postgraduate and postdoctoral students to gain experience in the use of high performance systems without having to compete for national facilities.

Research Income

Research grant income for the UoA has increased from around £0.75M per year in new awards at the beginning of the REF period to around £1.6M at the end. The increase has been per capita as well as in total value: the table below shows research spend (external funder) per T&R FTE for the calendar years during the REF period for which data are available.

Year	2014	2015	2016	2017	2018	2019
T&R FTE	29.4	34.4	39.6	43.6	46.1	45.6
Spend £K	710	898	960	1084	1460	1481
Spend/FTE £k	20.6	22.7	22.0	23.5	32.0	31.8

This has resulted in an increase in national mathematical sciences market share from approximately 1% in 2014/15 to 1.4% currently. The increase follows the introduction of new School incentives to write more grant applications, including workload credit for grant writing and providing School-funded supporting PhD studentships for successful grants of a significant amount. The School has also provided regular grant writing workshops, proposal clubs and research away days focussing on specific topics.

As well as focused research in the mathematical sciences, the School encourages interdisciplinary collaborations and has contributed co-investigators to multiple research projects

throughout the University and beyond. Some significant examples include **Matthews'** role as CI on a £2.19M MRC project on the enhancement of health and wellbeing in later life, based in the Faculty of Medical Sciences, and **Wilson** helping attract £1.77M in EPSRC funding for the National Centre for Energy Systems Integration. Along with **Heaps** and **Wilkinson**, **Wilson** is also CI on the £1.49M NERC Flood Prepared project, working on methods for forecasting rainfall events. **Wilkinson** has many further collaborations outside the School, including leadership roles in a £5.52M EPSRC project on scalable simulation of open biological systems and a £1.97M EPSRC project on protection of roads and railways from landslides and floods, both of which are based in the School of Engineering. He is also CI and active in the £3.71M EPSRC funded Digital Economy Research Centre, based in the School of Computing and involving over 20 external project partners.

4. Collaboration and contribution to the research base, economy and society

Research Collaborations and Networks

Members of the UoA have collaborations with leading research groups throughout the UK and abroad. Of the 53 headcount of people returned to UoA10, 51 have published journal articles during the REF period with co-authors employed at universities outside the UK, and 44 have published journal articles with co-authors from non-Newcastle UK universities. The overseas collaborations span a total of 41 different countries.

Examples of the international links includes **Rogers'** collaborations with NASA, which has had £500K in funding, and long-term collaborations with Trento (**Barengi, Proukakis**), the Max Planck Institute, Bonn (**Fletcher, Shukurov**), and San Diego (**Lykova, Young**), each with at least one publication per year. In the UK, there are recent links with the Alan Turing Institute (**Heaps, Oates, Pollock, Shi, Wilkinson, Wilson**). There is also a broad range of collaborations with Durham University, including but not limited to the previously described Joint Quantum Centre.

UoA10 colleagues have given more than 500 invited international conference presentations and over 300 external seminars during the REF period. The UoA has hosted more than 60 international visitors in mathematics and statistics and sent visitors to more than 50 international institutions.

Colleagues have been involved in the organisation of over 80 conferences since 2014. These include several regular series. The *British Mathematical Colloquium* (BMC) is the main annual conference on mathematics in the UK, and having joined the BMC Scientific Committee in 2013, **Rees** will chair the committee 2020-2023. The *International Workshop on Operator Theory and its Applications* is the main international workshop on operator theory, and **Dritschel** and **Young** have been members of the Steering Committee since 2012. **Coleman** is active in organising the annual *European Network for Business and Industrial Statistics* conference.

Members of the UoA have also co-organised multiple workshops, several of which took place in Newcastle, including the LMS Northern Regional Meeting and Workshop on Higher Homological Algebra (2019), the Newcastle Complex Geometry Workshop (2018), the Workshop on Pseudo-Reductive Groups and Related Topics (2017), the Workshop on Non-Equilibrium Phenomena in Superfluids and Coherent Quantum Systems (2019).

Colleagues in the UoA contribute to several networks of northern British universities: **Kakariadis** is the secretary of The North British Functional Analysis Seminar. **Duncan** and **Rees** are the primary organisers of The North British Geometric Group Theory Seminar, and **Balogovic, Kolb**, and **Jorgensen** are members of the network Algebra and Representation Theory in the North. **Heaps, Wilson** and **Phillipson** are respectively, current Chair, Secretary and Treasurer of the RSS North Eastern Local Group and **McFadden** is School representative for the LMS funded North British Mathematical Physics Seminar.

All sections of the School maintain active seminar programmes. It is School policy that each seminar series should have at least 30% speakers who are female or belong to underrepresented groups. Many seminar speakers are international. To promote the research environment, international speakers are normally invited to stay for a few days when they visit the School.

Sustainability of the Discipline

Several members of the Pure Mathematics Section have been active in the London Mathematical Society: **Jorgensen** was a member of Publications Committee (2011-17), **Rees** was a member of the Nominating Committee (2015-18) and the Presidential Search Committee (2016 and 2018), and **Vdovina** was a member of Council (2015-19) and is currently a member of the Research Grants Committee and the Lectures and Meetings Committee (2016-21). Within the Royal Statistical Society, **Henderson** was a member of Council (2016-19) and Chair of Discussion Meeting Committee (2016-19), a role subsequently taken by **Coleman** (2020-2023), who is also current Chair of Quality Improvement Section (2019-2021) and Chair of Obituaries Commissioning Panel (2019-2021). **Wilkinson** joined the RSS Academic Affairs Advisory Group in 2020, **Oates** is a member of the Computational Statistics and Machine Learning Section committee and **Heaps** is a former member of the Environmental Statistics Section committee. **Parker** is an elected member of the Computational Physics Group of the Institute of Physics and **Rogers** is on the DiRAC supercomputing panel.

Research panel and college memberships include STFC (**Bushby, Rogers**) and EPSRC (**Barengi, Duncan, Henderson, Jorgensen, Kakaridis, Lykova, Rees, Vdovina**). **Wilkinson** is a core member of the BBSRC Strategy Advisory Panel on Transformative Technologies. **Henderson** joined the Scientific Steering Committee of the Isaac Newton Institute in 2019. **Putinar** was a referee for the 2015 Heidelberg Laureate Forum. **Balagovic** is a member of the steering committee for the EPSRC-funded *Anglo-Franco-German Network in Representation Theory and its Applications* and is a 2020 US National Science Foundation panel member. Multiple UoA colleagues have assisted non-UK funders in evaluating proposals

School staff also contribute to the dissemination of research. **Shukurov** is current Editor of *Geophysical and Astrophysical Fluid Dynamics*, **Putinar** is Editor in Chief of both *Mathematical Reports* and *Revue Roumaine de Mathematiques Pures et Appliquees*. **Jorgensen** and **White** were the main editors of the *Bulletin of the London Mathematical Society* from 2014 to 2019. **Henderson** was the Assistant Editor of *Biometrika* from 2012 to 2017 and since 2015 has been a series editor for the *Chapman & Hall/CRC Monographs on Statistics and Applied Probability*. Until his death March 2019, **Boys** was Joint Editor of the *Journal of the Royal Statistical Society Series C*. Eleven UoA colleagues are currently on advisory boards or associate editors of academic journals.

Outreach Activities

Members of the UoA contribute significantly to outreach, having participated in nearly 50 activities at schools and museums. **Fletcher** was awarded a Great North Museum Fellowship for Public engagement and has hosted lectures, planetarium activities and school visits there. The Applied Mathematics section have contributed to many local events to popularise science, including STEMfest2019, Palace of Science, Bitesize Uni and Pint of Science. They also contributed to a series of videos which forms part of an exhibition on 'Space' at the Centre for Life Museum, Newcastle. On a wider context, the School has organised a number of EDI-themed events at Newcastle with external speakers, including the successful annual WISDOM meeting that promotes women in mathematics. **Rogers** was an invited speaker for a Gender Equality meeting at Aarhus University, Denmark (2019).

Other Esteem Indicators

Several members of the UoA have been recognised by prestigious appointments or prizes. **Soward** is a Fellow of the Royal Society, **Barenghi** is a Fellow of the American Physics Society. **Matthews** was President of the British & Irish Region of the International Biometric Society, 2014-2016. **Coleman** has an Honorary Membership of the European Network for Business and Industrial Statistics. **Kimsey** was awarded the WK Clifford Prize in 2017 and **Oates** was jointly awarded the RSS Research Prize, also in 2017. **Oates, Shi, Pollock** and **Wilkinson** are Fellows of the Alan Turing Institute. **Shukurov** is a Visiting Professor at Pune and, until his death in 2019, **Boys** was Adjunct Professor at Queensland University of Technology. **Billam** and **Proukakis** have been recognized as outstanding referees by the APS journals. **Rogers** has had two covers of Nature Astronomy.

Contributions to the Economy and Society

At REF 2014, two of the School's strategic objectives were:

To reward research with potential impact, by paying close attention to the exploitation of the research results, and by keeping a careful track of research results that could be used in a non-academic context; and

To improve the integration of research between the Industrial Statistics Research Unit (ISRU) and academic staff in the School of Mathematics & Statistics.

Significant reorganisation and investment has taken place in order to meet these objectives.

The Director of Business Engagement (DBE) is a new post, with responsibility for implementing the School's strategy on Engagement & Place, which includes the impact agenda. In particular, the DBE's role is to identify specific actions that are required to deliver effective engagement activity with both internal and external stakeholders. The DBE chairs the Business and Engagement Committee (BEC) which has the role of developing and maintaining internal and external links in support of School and institutional objectives. Specifically, the BEC works to grow business, industry and policy facing research collaborations, to maximise the impact of the School's research and to increase engagement of undergraduate and postgraduate students with business, industry and government.

The Business and Engagement Advisory Board (BEAB) contains external partners from business, industry and governmental agencies, including for example the National Innovation Centre for Data, National Nuclear Laboratory and National Audit Office. The BEAB is chaired by an external member and the board provides an external perspective of School business and engagement activity. The BEAB offers guidance and recommendations with regard to the development and implementation of School policies.

In addition, the School's Industrial Statistics Research Unit has been reviewed and consequently reconfigured, rebranded and renamed NU Solve. The remit has been widened to incorporate mathematics and physics alongside statistics. NU Solve acts as a conduit between the School and the outside world. It provides support and facilitation for academics across the School to engage more widely with non-academic partners and other Schools in the University with a view to improving the impact of the School's academic research.

Since 2014, NU Solve has supported around 100 companies, including Shell, GlaxoSmithKline, the Met Office, Sellafeld, Proctor and Gamble, the Centre for Process Innovation, Sanofi, Pfizer, Northern Gas Networks, Draegar, the National Audit Office and Care Quality Commission.

The School has a good track record with Knowledge Transfer Partnerships (KTPs) and NU Solve has been instrumental in maintaining this high standard. For the present REF cycle, **Coleman** has brought seven KTPs to the School. In addition to partnering with external companies, interdisciplinary work has also been carried out with the School of Computing and

the Business School. KTPs have been carried out primarily by members of the Statistics section. Moving forward, the School aims to involve its other sections in KTP activities.

An important component of NU Solve work is to engage with students to increase the number of placements and internships. Since REF2014, NU Solve has implemented 5-6 week summer undergraduate placement projects and 3 month PhD internships with industrial partners in the UK and abroad, including the Newcastle United Foundation, Nissan, Northern Gas Networks, Smartodds, Akzo Nobel, Shell Amsterdam, Planung Transport Verkehr and Northumberland County Council. The School strategy is to increase the number of placements so as to provide its partners with the skilled graduates they require and further the opportunities for collaborative projects.

The growth of NU Solve and the BEC will continue to be supported through a School allocated budget, which has been increased from £31.5K in 2018/19 to £81K in 2020/21. The short-term budget allocation for Business and Engagement activity is anticipated to yield longer term financial return on investment and better opportunities for staff and students across the whole school.