Institution: University of South Wales

Unit of Assessment: B10

a. Context

The Mathematical Sciences group has an extensive history of engaging in applied and collaborative research. The main impact areas broadly align with our three main research themes: (i) Physical sciences and industrial mathematics; (ii) Biological, health and social sciences; and (iii) Data integrity and combinatorics. In particular, the main impact areas of our research are:

- Economic: job creation and professional training
  - Our researchers developed algorithms ensuring reliable data transfer used in communication systems by the *British Armed Forces* throughout the world, requiring the manufacturing and management of 50,000 radios sets and the training of 75,000 users.
  - Our researchers have provided statistical problems drawn from bioinformatics to help define Europe's first hub-and-spoke super-computing facility *High-Performance Computing Wales* (HPC Wales) generating employment and up-skilling staff.
- National Security: adoption of new technologies
  - Military communication systems used in combat and other situations by the *British Armed Forces* throughout the world rely on algorithms developed by our researchers.
- Health: evaluating cancer treatments
  - Our researchers are analysing patient's long term quality of life following cancer treatment, with potential future impacts on the *Cancer Reform Strategy* in the UK.
- Environment: improving existing technologies
  - Researchers are investigating improved efficiency of steel and coal blast furnaces throughout Europe with *Tata Steel* (and others), reducing carbon and other emissions.
  - Researchers have established the world's largest national DNA database for flora with *National Botanical Gardens of Wales* and *HPC Wales*, aiding environmental surveys.

b. Approach to impact

The UoA's approach to generating impact during the assessment period has been enhanced by the development of three strategies:

(i) Identify and respond to new opportunities, utilising agile working approaches,
(ii) Develop and expand existing successful research teams to widen impact,
(iii) Engage in collaborative projects, working especially with end-users.

These strategies were formed by analysing previously successful collaborative projects led by our researchers (including a project on military communication systems presented as a case study). Much progress has been made by adopting these strategies during the assessment period; indeed nine staff members have used their research expertise to engage with non-academic audiences.

(i) *Identify and respond to new opportunities, utilising agile working approaches*

Local, national and international impact has arisen through the pairing of researchers with industrial and business partners, which has been enhanced through an agile working approach and researcher-focussed support services developed by the University.

Opportunities for new projects have arisen through networks developed by researchers and the University. Researchers, aided by the University's Research and Commercial Services Offices and the Innovation, Commercialisation and External Engagement groups, have formed new partnerships with organisations such as OTSC Ltd, GXS PDQ Ltd, (both **Roach**) National Botanical Gardens Wales (Dr. Tatiana Tatarinova, former full-time staff member, currently HPL) and HPC Wales (Tatarinova & **Wiltshire**). These partnerships have involved the buy-out of staff time (e.g. 12.5% of **Roach**'s time has bought out by a collaborative £1.4M project funded by European Commission Research Fund for Coal and Steel; Proposal No: RFS-PR-11026, EPSS No: 304596), the appointment of research assistants and postgraduate studentships and the adoption of agile working approaches, including taking extended leave.

The Case Study involving HPC Wales (with Tatarinova & **Wiltshire**) is an example of how a new opportunity arose (to define Europe's first hub-and-spoke super-computing facility) and how our

researchers were able to contribute and shape its future using their expertise.
This strategy has also been adopted on an international level. On the request of the Kurdistan Regional Government, Prof. Jamal Ameen (not returned) took extended leave to establish the Kurdistan Regional Statistics Office (http://www.krso.net/) and as its director led numerous surveys and analyses on housing and welfare that impacted on government policy; he was awarded a gold medal from the House of Representatives, Iraqi Federal Government, and a trophy from the World Bank for his active contributions to a five year poverty reduction strategy for Iraq. Indeed, as a consequence of Ameen's work, the Mathematical Science group have recently recruited a number of research students from Kurdistan and Iraq.

(ii) *Develop and expand existing successful research teams to widen impact*
Future impact is being developed through the appointment of new staff to support and expand established research areas along with the engagement of current staff on existing projects.

The UoA's Applied Mathematics submission in RAE 2008 featured work on health statistics; to promote this activity further, an additional staff member with similar research interests (**Farnell**) has been appointed during the assessment period. **Farnell**'s research has included collecting and analysing longitudinal data on the quality of patient life following radiotherapy treatment for cancer with potential impacts on the National Cancer Reform Strategy in the UK.

Augmenting this work in applied statistics, Tatarinova, whose research is in computational biology, was also appointed and through establishing numerous collaborations has made considerable impact, including with **Wiltshire** on HPC Wales (see case study). The potential for further impact has been enhanced through the creation in 2013 of a spin-out company *myregulome.com ltd* that uses intelligent algorithms to analyse genomic databases.

Existing collaborative research teams have also been expanded by engaging current staff; for example, work initiated in 2007 with Chorus Steel (EPSRC CASE/CNA/07/81 "Development of improved mathematical models for Furnace Control and Operation") involving Dr. John Hayward (not returned) has continued with an ongoing related project involving **Roach** (see below).

(iii) *Engage in collaborative projects, working especially with end-users*
Collaborative projects have been established or reinforced through the formation of numerous EPSRC Case Studentships and Knowledge Economy Skills Studentships (KESS, European Social Fund awards) which both require inter-disciplinary research teams with an industrial partner. These include projects involving **Roach** with:

- Tata Steel Research, Development and Technology (Development of improved mathematical models for Continuously Operated Steel Reheating Furnaces, Voucher: 10000528),
- GXS PDQ Ltd. (to generate quality rules in the consumer sector, Voucher: 09001375),
- OSTC Ltd. (to construct artificial intelligence decision techniques to generate financial trading rules, Voucher: 11330389).

The first of these projects investigates advanced measurements and dynamic modelling for improved furnace operation and control of different continuous steel reheating furnaces, involving six other institutions and companies across four countries throughout Europe and the impact is set to be both significant and wide-ranging; its aim is to minimise the energy requirements of such furnaces and thereby reduce carbon and other emissions.

Further national and international collaborations and consultancies utilizing staff expertise have arisen. **Farnell** works alongside consultant oncologists from Christy Hospital, Manchester (Dr. S. Davidson, Dr. L. Baraclough, Dr. C. Baker) in their analysis of cancer treatments. **Walker** has close collaborative links with engineers at the University of Strathclyde developing novel ultrasonic transducers. In 2008-2009, Mark Griffiths (not returned) undertook a £20,000 consultancy project for Acumina Ltd, on behalf of the Department of Education, to assess the effectiveness of questions at discriminating between pupils of differing ability in Key Stage 2 Mathematics SAT papers. Since 2011, **Wyburn** and Hayward have liaised with the Office of the Welsh Language Commissioner attempting to develop new policies for securing the future of the Welsh language.

c. Strategy and plans

The Mathematical Sciences group will continue applying the three principle strategies described above. Their implementation overlaps with our staffing strategy (see REF5). Specific activities aimed at developing future impact are described below and an over-arching strategy utilising recent successes and opportunities is also given.

In the Physical Science and Industrial Mathematics theme, to ensure future impact our intention is to develop current collaborations and involve additional researchers with appropriate skill sets by building on our existing successful strategy (e.g. the Tata Steel project series); **Walker**, **Trevelyan** and **Boswell** have a range of expertise in applied mathematics and numerical computation that can contribute to such future projects.

Within the Biological, Health and Social Science theme, future impact is planned by utilizing our speciality in applied statistics. **Farnell's** research in medical statistics, described above, is likely to shape both clinical practice and the national Cancer Reform Strategy. Further work is planned to arise through the development of the *Barcode Wales* project, initiated during the current assessment period by Dr Tatiana Tatarinova and research students. Working with National Botanic Gardens of Wales, the project created a DNA database of the native flora of the nation of Wales enabling environmental surveys to be performed without the reliance on a taxonomic expert but instead applying statistical analyses and algorithms developed during the current assessment period. Central to this approach is the use of facilities offered by HPC Wales and builds on existing expertise reported in a case study below. Related work involving the application of the DNA codes work of **Smith** and **Perkins** to long term storage of vast data archives in DNA (the feasibility of which has recently been demonstrated) is planned to be investigated, engaging both **Hunt** and Dr Sian Jones (not returned).

More generally, we intend to promote collaborative activities with industrial partners by utilising University-wide expertise with regards to Knowledge Transfer Partnerships (KTPs; the Commercial Services Office provides support for such activities) by first appointing a KTP Champion. Facilities offered by HPC Wales (see case study) will be central to this: funds have been committed by HPC Wales and Fujitsu to support such collaborative projects. We will continue supporting existing academic collaborations with a view to generating the wider impact of that research.

New initiatives, such as those arising from Horizon 2020, will be explored in line with the UoA's strategy of responding to new opportunities, with the overall aim of increasing income. The publication of high-quality research will continue with the goal of developing future impact, principally in already established areas using existing staff expertise. Further opportunities to generate impact that have arisen from the merger creating the University of South Wales will be explored; for example, it is proposed to combine **Boswell**'s interest in modelling athletic performance with the expertise in sports physiology of colleagues in the Health and Sports Science Research Centre to influence performance strategies adopted by elite-level sports competitors.

d. Relationship to case studies

1: Developing frequency assignment techniques for British military communication systems

This case study provided the template for strategy (iii) "*Engage in collaborative projects"*. By working closely with BAE Systems and QinetiQ, the mathematical research, overseen by **Smith** and later **Perkins**, was performed in such a manner that the algorithms constructed were immediately translated into military communication systems developed by the industrial partners.

2. Using genomics to shape high performance computing

This case study principally arose through the implementation of strategy (i) "*Identify and respond to new opportunities".* In 2010, HPC Wales, Europe's first super-computing facility based on a hub-and-spoke model, was launched; **Wiltshire** identified this as an opportunity to further mathematical research and industrial collaboration and so took a lead role. Once established, the system required testing with "real-world" problems; Tatarinova seized the opportunity to analyse datasets from genomics and so helped define projects and business partners currently using HPC Wales.