Institution: University of Birmingham

Unit of Assessment: Mathematical Sciences

a. Context

The School of Mathematics at the University of Birmingham is located in the College of Engineering and Physical Sciences. Within the School there are three main discipline groupings, namely, the Pure Mathematics Group, the Applied Mathematics Group and the Optimization and Statistics Group. Each of the three main discipline groups is subdivided into less formal Research Groups. The research activity within the School takes place within the Research Groups, across the interfaces of the Research Groups and through collaborations within the University, with other worldwide academic institutions and with industrial, commercial and scientific companies in the private and public sectors. Specifically, the School adopts two fundamental pathways to achieving impact. The first pathway encourages direct involvement with industrial and commercial users though the establishment of relationships with relevant companies and bodies via direct funding contracts. The mechanisms for establishing contacts are detailed below in sections (b) and (c). Specific partnership projects that have been successfully developed within the School have led to directly funded high quality research with, for example, Statoil AS, Schlumberger PLC, Birmingham Women's Hospital, Airbus (UK), Boeing Company (USA), Malvern Instruments, NAU, European Space Agency, Astrium Ltd – Satellites and Intelligent Energy. The majority of these projects are related to staff in the Applied Mathematics and Optimization and Statistics Groups. The second pathway encourages joint work with other Schools and disciplines within the University (and at other institutions) on projects designed for industrial or commercial impact. Specific examples of such projects are those established with the Railway Research Institute and GCHQ, together with the development of computer algebra software (for both commercial and non-commercial use) via the GAP and NAG projects, and collaboration with the School of Computer Science in developing combinatorial and graph theoretic approaches to analysing and predicting internet vulnerability to failures and the spread of viruses, and collaborative work with the School of Medicine on statistical aspects of clinical trials. These examples are principally related to members of staff in the Pure Mathematics (combinatorics and algebra) and Optimization and Statistics Groups (medical statistics).

b. Approach to impact

The approach to establishing suitably directed impact for the research activities within the School of Mathematics operates on three integrated levels, associated with University support, College support and School support.

The University provides an overarching strategy and leadership for impact via the University Research and Knowledge Transfer Committee, in association with the University's Research and Commercial Services structure. This has three principle activities, each identifying and supporting specific areas for impact:

(i) Commercial partnerships are led by the University owned company Alta Innovations, which provides detailed support to researchers across the University who are engaged, or seeking engagement, with industrial, commercial and scientific partners in the private sector. This support includes market research, commercialisation of research, locating suitable industrial partners, establishing and negotiating appropriate financial support for joint ventures, establishing consultancy agreements and contracts, and filing patent applications. Within the School of Mathematics, contracts have been established with, for example, Statoil AS and Schlumberger PLC.

(ii) Strategic Research Partnerships is a service which provides support in the development, and preparation for submission, of large scale multi-disciplinary projects, and thereafter in the management of such projects. This includes the development and maintenance of industrial and commercial partnerships. Interdisciplinary projects with the School of Mathematics, the School of Medicine and Birmingham Women's Hospital have been established in this way.

(iii) The Birmingham Research Park provides purpose built accommodation to private sector organisations seeking to establish direct contact with research activities throughout the University, in terms of research, development and training.

At the College level, impact related aspects of the research activities within the associated Schools is developed and monitored by the College Research and Knowledge Transfer Board. This Board interfaces with the University Research and Knowledge Transfer Committee, develops impact strategy within the College, and provides support for the associated Schools through Business Development Managers. The role of Business Development Managers is to provide and implement a strategic overview for impact and Knowledge Transfer within the College and liaise with the University's Research and Commercial Services, on the part of specific staff or staff groupings within the College, who are engaged in partnerships with industrial, commercial and scientific companies in the private sector. Within the School, research projects have been established with, for example, Malvern Instruments, Paratec Ltd, Intelligent Energy and Statoil AS, via this mechanism.

At the School level, activity related to knowledge transfer and impact is led by the School Director of Research. The School Director of Research is a member of the College Research and Knowledge Transfer Board, providing a direct interface for the School with College strategy, activities, initiatives and support in this area. The strategy for, and support of, knowledge transfer and impact within the School is established through the School Management Committee, of which the School Director of Research is a member.

The three tier structure described above, in relation to knowledge transfer and impact policy and procedure within the University, is effective in allowing for the free flow of strategic objectives, tactical choices, initiatives and opportunities. It provides dedicated support and expertise, from the University to the individual within the School, and from the School to the University, via the interface of the College.

c. Strategy and plans

The specific strategy for developing impact from the research activities within the School is directed towards establishing concrete contacts with research and development activities in industrial, commercial and scientific companies, mainly in the private sector, and encouraging collaborations with other disciplines on projects designed to have commercial or industrial impact. Such contacts are initially developed in two ways; either through renewed personal interactions with longstanding contacts or through leads established with the support of the College and University structures described above.

Initial contacts are developed through an exchange of research seminars, taking place both in the School, and at the industrial partners or collaborators research centres, which provides an excellent forum for open discussion and debate on impact related problems for all School members (including Postdoctoral Fellows and PhD Students) and industrial partners. This generally leads to the identification of specific problems of fundamental importance for the industrial partner, and which are of significant depth and generality to require substantial mathematical development. The focus on problem development is directed to establishing a set of concrete and well-defined problems, the resolution of which will lead to high quality research (which is publishable, when contractual necessities allow, in high ranking journals) and which will make substantial impact on the requirements of the industrial partner.

At this stage a specified programme of work can be formulated into a well-defined project, the nature of which depends upon the detailed requirements of the industrial partner. This may lead the project to involve support for PhD students(via the EPSRC CASE Studentship scheme or through direct industrial funding), Post Doctoral Fellows or Consultancy Agreements. Such details are negotiated between the University and the industrial partner via Alta Innovations (referred to in (b)). With a suitable programme and contract in place, the partnership and the associated research activity are able to grow organically, with interactive seminars, discussion sessions and workshops supporting the underpinning research activities, and ensuring continued close contact with the requirements of the industrial partner. In general, when appropriate, a workshop is held at,

or near, the completion of the project. The focus of this workshop is to ensure optimum integration of the research activities and conclusions into the advancements of the original problem presented by the industrial partner, to broaden the base of the impact wherever possible, and to set a platform for the discussion of future developments and partnerships.

The above detailed strategy for establishing, maintaining and developing partnerships with industry is leading to significant advancements for industrial partners, together with the publication of associated papers in high quality journals. This interactive mechanism is generating research which has focused impact on the activities of the industrial partner, whilst encouraging the flow of high quality industrially significant problems into the School. It is proving very effective in engaging academic staff, Postdoctoral Fellows and PhD students with industrially motivated mathematical problems of significant impact. For example: The impact case studies described by Needham involve partnerships with the Norwegian State Oil Company Statoil AS and the oilfield consultancy company Schlumberger PLC. In contrast, the second case study described by Kocvara involves the development of high level optimization software for the well-established Numerical Algorithms Group Ltd (NAG).The case study described by Petrovskaya relates to aircraft design, and has led to significant advances in computational aerodynamic capacity for the Boeing Company. Aircraft design is also the theme of a successful partnership with Stephen and the US Air Office of Scientific Research. The case study described by Smith with the Birmingham Women's Hospital is related to human biology and medicine, in particular with reference to human reproductive physiology, and has led directly to a new imaging methodology, and a new resulting device OptoSplit III, which has been commercialised by CAIRN Research Ltd. In contrast projects established by Gurney relate to the technology of fuel cell stacks and systems, in partnership with Intelligent Energy, and supported through the University Knowledge Transfer Scheme, whilst projects established by Uddin address detailed aspects of nano-sizing in systems, in partnership with Paratec Ltd and Malvern Instruments. Also a very recent collaborative research project has been established with LAM Research AG (Austria) in relation to aspects of theoretical and computational bubble dynamics in drug delivery systems. This collaboration was an outcome of the Bubble Dynamics Workshop held in the School in April 2012, and the Ensor Review Meeting on the following day, which attracted 20-25 industrial representatives from the UK, Germany, Austria, USA and Singapore

In addition to the above strategic approach, the School has established joint appointments in medical statistics with the School of Medicine, with the aim of strengthening the ongoing research in applied medical statistics. The research activities in this area have direct implications and impact on current and ongoing assessment and trials for medical treatment strategies, and form a complimentary approach to the research activities in the recently established Mathematical Biology and Medicine group within the School of Mathematics. It is further proposed, and at an advanced stage of planning within the University, to establish a Centre for Biostatistics, which will span the School of Mathematics, the School of Health and Population Sciences and the School of Cancer Sciences. This will bring under one leadership the collective expertise within the University associated with the application of statistics to biomedical issues of high significance. The design of this focusing and streamlining is targeted to facilitate and significantly enhance the current and future impact of the vital research in this area.

A further strand of activity which is being developed by the School is in the area of outreach to the local community in the West Midlands area. This has involved the establishment of the annual lecture series 'Birmingham Popular Maths Lectures' aimed at engaging the general public with mathematical problems and development. These lectures are attracting audiences of up to 200 people on a regular basis. In addition to this, the School also organizes Mathematical Masterclasses in local schools aimed at 16-18 year olds.

The strategy described above, relating to the generation of impact associated with research activities within the School, will be developed further by establishing more direct and proactive links from the School with the College Research and Knowledge Transfer team, to enable contact to be made with potential industrial and commercial users at the earliest opportunity, and to explore fully the continued development of specific ongoing projects. Within the School it is intended to

encourage staff to engage in high quality research, with strong impact, through establishing allowance mechanisms which reduce responsibilities in other areas in relation to impact activity and success. Further significant opportunities for the establishment of high impact research activities are anticipated through the strengthening of links with the School of Materials Science within the College, and the forthcoming development of a Bioinformatics initiative within the University.

The success of the above School strategy for developing industrially linked high quality research projects, which deliver significant impact to the industrial partner, is exemplified in the five detailed impact case studies. These case studies also illustrate the breadth of the impact which research partnerships established by the School have made.

d. Relationship to case studies

The relationship of the five submitted case studies to the approach to impact and impact strategy within the School has been outlined and described in sections (b) and (c). In particular, the five submitted case studies relate to partnerships with industry and commerce which have been established within the framework of the following pattern:

- Initial contact between the relevant person in the School and the industrial/commercial partner.
- Preliminary seminars given by the industrial/commercial partner in the School, aiming to broaden the scope of the partnership, whilst fixing ideas on specific projects, objectives and participants.
- Establishment of contracts and programmes of work, with the industrial/commercial partner and the University. This is facilitated either through College Research and Knowledge Transfer Support or Alta Innovations.
- Intensive work programmes involving visits and presentations by both partners, and leading to the production of detailed reports to the industrial/commercial partners.
- Focused workshop to disseminate the outcomes of the project and discuss further and future developments, together with any implementation issues relating to the project.
- The preparation and submission of high quality research papers jointly with the industrial/commercial partners, relating to generic aspects of the project, where this is in accord with contract.