Institution: University of Chester

Unit of Assessment: 10: Mathematical Sciences

a. Context

The research of the Unit is undertaken by the Mathematics Research Group whose research focus has been on analysis and simulation of solutions to functional differential equations. These problems may be characterised by the need to model evolutionary problems, systems with delay or feedback, and systems where memory effects are significant. Solutions to these systems exhibit varying degrees of sensitivity to parameters and perturbations, and stochastic variants of deterministic models are sometimes used to reflect uncertainties. The main applications areas for these equations arise in engineering (for example, in modelling of materials, especially polymers), in environmental sciences (such as modelling the effect of pollution in a river) and in the bio- and bio-medical sciences, such as in modelling the ageing processes in human tissue and the immune response to an infection. The main impacts of the work are through the use of models to replace experiments, which can save time and money, bringing products to market more rapidly, at lower cost and with greater levels of confidence and rigour, and the ability to make more rapid advances in medical treatment for diseases while using fewer animal or human subjects in experiments. Financial modellers use similar types of equations in models and there has been recent interaction with users from this area to develop further joint working for the future. A key strategic development at the University has been the acquisition of the former Shell Thornton Research Centre which will become the University's new science and engineering campus and host a major new science park. The Mathematics Research Group plans to develop strong collaborations with engineering and technology researchers and will provide R&D support to local and regional businesses through the science park.

b. Approach to impact

Application of the results of research undertaken by the Mathematics Research Group has always been at the heart of the Group's activities. Recognising that mathematics research usually has an indirect, rather than direct impact, there has therefore been a considerable focus on engaging with scientists from areas which themselves interact directly with users. These interactions and insights have driven the areas of research activity and helped prioritise research questions for the Group's work as well as expanding the capacity of a small group to conduct high quality research with impact.

Through the Chester-based Leverhulme International Network on stochastic problems with delays, there have been interactions with financial modellers and with those working on medical modelling.

Through continuing joint work with Bocharov (currently based in Moscow; he was a member of the Chester academic staff between 2002 and 2004 and has been supported in his work at Chester by a Leverhulme Visiting Professor award and a Santander Universities-funded International Research Excellence Award) and his co-workers and with immunologist colleagues from the Chester Biological Sciences Department there have been opportunities to understand and contribute to work on immunological modelling and a potential future reduction in animal experimentation.

Through joint work with Freed (formerly at NASA Materials Branch) and others there has been an opportunity to contribute to greater understanding of soft human tissue through the development of reliable solvers for differential equations of fractional order.

The fundamental approach of the Mathematics Research Group is to interact early with people who already understand the needs of the applications area. The aim is to ensure that the needs of the application area are translated through this collaboration into clear and achievable mathematical objectives and research questions. Having formulated the research questions, the strategy is to work on the mathematical project but keep the lines of communication with users open via the translator to test new insights against reality. The final stage in the process is to communicate and

disseminate results both in the mathematical literature and translated into a form that will be useful to the users. A feedback mechanism is then employed by listening continuously to the users to see how they interpret and use the results. This feedback mechanism provides one basis for subsequent mathematical objective-setting.

This strategy demonstrates that answering questions that are of relevance to users has been at the heart of the research Group's activities for many years. One of the impact case studies presented reflects the long-term nature of the follow-through of work in immunology. Another example of the Group's work (based on interactions with Freed) can trace how the desire by heart surgeons in the US to gain a better understanding of soft tissue dynamics led to the need for more reliable and efficient solvers for fractional differential equations. A report for a US clinic (based on the solvers developed jointly in Chester and Germany) was written to explain the new insights into soft tissue dynamics. Subsequently, some of the medical scientists who commissioned the report have developed a new type of heart valve that is almost ready for adoption in Europe following clinical trials.

Within the wider institution, impact is rewarded through being one of the criteria considered explicitly in applications for promotion to Professor or Reader. The annual Performance and Development Review (PDR) process also explores impact in terms of opportunities for commercialisation of research, and public engagement activities and opportunities. The University's Research and Knowledge Transfer Office monitors all funded projects closely, and one aspect of this monitoring is a report on impact activities. Where appropriate, this can lead to a cross-referral to the University's Knowledge Transfer grant schemes which can pump-prime commercialisation of research outcomes.

Moving forwards, the acquisition of the Shell Thornton site as a science park and science and engineering campus provides the Mathematics Research Group with an excellent opportunity to develop its applied research portfolio. The University is establishing a strategic working group (chaired by Ford) to identify strategic collaborations and research objectives for the extensive range of potential industrial applications.

c. Strategy and plans

The University's commitment to the development of future impact from research undertaken now is underpinned by an expectation that a minimum of 20% of the QR income from the RAE2008 exercise is deployed in impact-generating activities. This is an institutional policy that has been embraced by the Mathematics Research Group which has used the funding to support further joint work with the collaborators described in Section b. In addition, funding has been sought through the University's International Research Excellence Awards to develop further impact through collaboration. For research outcomes that are close to the marketplace and closest to commercial exploitation, the University operates a system of Knowledge Transfer grants, funded using HEIF income, to pump prime the commercialisation of research. To date, Mathematics has not been in a position to commercialise outcomes directly and has sought to generate indirect impacts through interactions with other applied scientists as described in Section b. We anticipate that this will continue, and be strengthened further through the recent acquisition of the Thornton Science Park by the University, and the development of a Science and Engineering Faculty at the site provides new opportunities for collaboration in the engineering sciences and for commercialisation of research in applied mathematics in the future.

d. Relationship to case studies

The first case study presented exemplifies how interactions between the Group and Bocharov and his external co-workers have led to applied mathematics research that has generated impact in medicine. The interactions helped to stimulate the research questions, and the outcomes of the research have been published both in mathematics journals and in appropriate user-oriented outputs and have influenced the users in the ways described in the case studies to affect clinical research currently being undertaken. The second case study presented relates to the work of Ford

as an Expert to the European Commission. The nature, relevance and quality of the advice he is able to provide is influenced by the approach to impact described in Section b, but there is no direct link. In Section b, an example of work with Freed, which has not formed the basis of a case study, provides further evidence of how the approaches from Section c have been effective.