Institution: Aberystwyth University

Unit of Assessment: 10 (Mathematical Sciences)

a. Context

The impact generated by our research in the **Mathematical modelling of Structures, Solids and Fluids** and **Quantum Structures, Information and Control** occurs in the following areas:

- **Economic impacts**: for example, mathematical modelling of crack propagation is giving a Polish SME a new business activity in hydraulic fracture, and methods of simulating foam dynamics are transmitted to multinational companies for the purposes of staff training.
- **Impacts on public policy and services**: for example, a US government laboratory is using our theory of quantum feedback control to design quantum devices for communications, giving them a security advantage.
- **Impacts on society, culture and creativity**: for example we target schools, science fairs and festivals for young people with research talks, and, in particular, have a significant effect on the Welsh landscape in the stimulation of the general public and school children's understanding of mathematics through an annual presence at national eisteddfods.
- **Health impacts**: a research collaboration with a Swiss hospital has led to a software analysis tool for minimally-invasive diagnosis of osteo-arthritis.

The main users of mathematics research from the Department of Mathematics and Physics (DMAP) are therefore research labs, SMEs, multinational companies, medical doctors, the public and schoolchildren.

b. Approach to impact

Mathematics research at AU has a long history of work with industry and of public engagement. This is now being formalised through nominated "champions" within DMAP for outreach and third mission, overseen by the DMAP research committee (RC). Impact is now discussed and recorded at individual biannual research monitoring meetings with the HoD and the DMAP Director of Research, and staff are encouraged to put themselves forward for policy-forming committees (e.g. Mishuris on hmc^2) to stimulate impact on public policy development and delivery. Through the DMAP Research and Impact Fund we support travel that aims to generate research impact, for example visits to companies and trade fairs.

Assistance in generating impact-related activities is provided by AU's Research Office, particularly in preparing "Pathways to Impact" documents. Research of commercial value is negotiated through AU's Commercialisation and Consultancy Services, recently brought under the aegis of the Research Office to provide a more coherent service. DMAP is also in a position to draw on AU's Research Fund, which provides selective support for strategic, non-recurrent, research initiatives, and the Wales European Collaboration Fund, for developing European Consortia with industry, as Mishuris did when preparing the *Industry-Academia Partnerships and Pathways projects* Hydrofrac and PARM-2. In addition, AU has recently appointed Professors of Public Engagement in Science and Engagement with the Public Imagination, and the Department is developing close working links with these professors to further enhance research-related impact on society, for example an up-coming event on Pythagoras (on 5/12/13).

Economic impacts: Using research secondments, DMAP is able to apply its research to problems of industrial interest wherever possible. Examples include Mishuris' work with the Polish SME EuroTech that is developing software for accurate modelling of hydraulic fracture: staff and PhD students are seconded to EuroTech to ensure that the modelling is relevant, while EuroTech staff are seconded to AU for training; Wrobel also came to AU from Eurotech on a Marie-Curie fellowship. In 2013 we hosted the first six months of a 2 year researcher secondment from Enginsoft (Italy) on software development for the company. In this way companies, including EuroTech, are changing the way in which they concentrate their business as our research gives them a lead in new markets, while a secondary **impact on practitioners** arises through the training and consequent changes in professional standards.

DMAP staff contribute their research interests to AU's Directory of Expertise and this, combined with attendance at conferences and networking events and membership of learned societies,

provides routes to the provision of consultancy services. AU provide an incentive for this form of impact by returning consultancy fees to staff through discretionary codes. Examples of consultancy that have arisen from our mathematics research during the census period include advice to large multinationals such as Biocompatibles and Unilever on modelling foams and foam flows. Cox was also Aberystwyth PI on the strategic Procter and Gamble-EPSRC project to develop numerical simulations of foam rheology. Gough's work on quantum feedback control is being taken up by a US government laboratory to design quantum devices for communications, giving them a security advantage and hence our research is having an **impact on public policy and services**.

Health impacts: An extension of these approaches to impact is evident in Mishuris' development of a medical research strand in mathematical modelling. He is on the board of the Health Modelling Centre Cymru and (with Argatov) has successfully devised a new indentation test for the minimally-invasive diagnosis of osteo-arthritis, based on a mathematical model of a viscoelastic cartilage layer. Through the further collaboration with clinicians in Switzerland, this research promises to have a tangible impact on the enhancement of public health and the practices of health professionals.

Impacts on society, culture and creativity: we are aware of the need to educate the general public and school children about what mathematics is and the variety and uses of University research mathematics. In this work we attempt to negate the "bad press" that mathematics receives as being abstract, useless, and difficult, and in so doing we hope to encourage an increase in numbers of students enrolling in Mathematics courses, and therefore in providing graduates with skills that are useful to British society and, in particular, industry.

Outreach activities are recorded on a continuous basis within DMAP, through the university's Current Research Information System (PURE), and since 2012 staff have been encouraged to use questionnaires following activities with school children; our relationships with teachers in local schools allow us to acquire feedback on the activities as a whole, and this provides one of our case studies. We recognise the value of training in outreach skills: DMAP has run annual seminars for staff on outreach with IoP-HESTEM and AU's Centre for Widening Participation.

Staff regularly provide information to the media on their research and its relevance to current topics of interest. In particular, a strong relationship exists with the BBC in Wales, and staff have appeared on BBC Radio Wales (weather forecast error) and BBC Radio Cymru (foam rheology).

A significant goal is to provide educational research material to Welsh schools, particularly in mid and north Wales, where there is no other University Mathematics provision. Coordinated by the Aberystwyth Mathematics Club (www.aber.ac.uk/en/imaps/maths-club/), our schools and colleges lecture programme introduces various aspects of our research in short, accessible, presentations. We have cultivated contacts with most local secondary schools. Topics include an introduction to foam research and minimisation, and weather-forecasting and error measurement, both of which are given in Welsh and English. These talks have also been presented further afield, including the West Midlands, which provides the catchment for many of our own undergraduate students, and even in Rseszow, Poland. We also work closely with the *Wales Institute of Mathematical and Computational Sciences* (WIMCS) to deliver this goal.

DMAP takes great pride in our Welsh medium outreach, both in radio broadcasts and working with young people. In addition to schools talks, we have an annual presence at both the Gwyddonle (the science tent at the Urdd National Eisteddfod, aimed at young adults) and the National Eisteddfod (for all ages). These two events attract several thousand people every year, and these people have seen, for example, demonstrations on optimisation using soap bubbles, and given feedback through questionnaires.

c. Strategy and plans

Research-led outreach and third-mission activities are each championed by a member of the academic staff, whose experience provides a source of advice for staff preparing projects for funding and undertaking preliminary discussions with businesses and public bodies.

Over the last few years, RC has rationalized DMAP's mathematics research groups into just two broad areas to allow us to build critical mass in these fields. In recruiting staff to these groups, we raise the issue of research impact as an interview criterion. Although there is overlap between the research groups, by concentrating our effort in this way, we expect to be able to guide research projects, based upon our current experience, towards those that should have greater impact. In particular, Mishuris' experience with SMEs and FP7 funding is informing our developing impact strategy. Monitoring is also key to success and rewards for staff, and we are using AU's PURE database to record impact activity for discussion in biannual individual research monitoring interviews. The RC controls a Research and Impact Fund which, in addition to AU funds, supports travel for collaboration and to generate impact. Providing feedback on draft applications on how individual staff could use the fund keeps them aware of the impact agenda. Discussions about impact are a standing item on the agenda of the Research Committee and the results of these discussions are passed on to research groups.

Commercial work is coordinated by AU's Commercialisation and Consultancy Services (CCS), including Non-Disclosure Agreements (NDAs) for preliminary discussions. Regular meetings between the CCS Technology Transfer Team and DMAP staff are organised to identify research with commercial potential, and a new initiative is for a member of staff from CCS to spend time in DMAP on a monthly basis.

In the future, DMAP seeks to use AU expertise across different disciplines to further train staff in using their research beyond academia, and to then reward staff who seek to do this through the introduction of a resource allocation matrix. We will continue to fund exploratory projects that may lead to research impact, and will require that research proposals include a clear impact strategy, which will monitored by RC.

We will enhance our public engagement activities, for example by working with AU's Centre for Widening Participation and Social Inclusion and HE-STEM in Wales. Pan-Wales partnerships such as WIMCS and RIVIC provide a way to do this, and by being part of these larger initiatives we can often make a more significant contribution. Collaborative research, either within Wales or beyond, is also facilitating new contacts with industry, and will enable us to contribute to projects for which Aberystwyth would otherwise not have sufficient breadth of expertise.

We will also train the next generation of researchers – graduate students – in public speaking, public engagement, and the importance of impact in research. The compulsory first year research skills module in Public Engagement And Impact offered by the university has just been updated to achieve this.

d. Relationship to case studies

During the census period a total of five case studies have been drafted. Two cases are submitted to illustrate the impact of mathematics research in two of the four primary impact type categories set out in part **a**.

DMAP's success in generating funds from EU FP7 Marie Curie IAPP projects is a measure of the esteem with which our mathematical modelling is viewed by industry across Europe. The projects HYDROFRAC, PARM-2 and INTERCER, in which the mathematical modelling group is involved, all have industrial partners, emphasising our recognition of the importance of industrial input to research projects. These projects are leading to new software, new materials, and new processes, and hence economic impact. The case study "**Improved parametric resonance of a vibrating screen**" is an example of this.

We also play a leading role in offering outreach and public engagement activities in Wales, in both Welsh and English-medium. Working with the physicists in DMAP, we have engaged with the annual Welsh national eisteddfods for adults and young people, and are part of an increasing science presence at what have traditionally been arts events. This activity is seen and appreciated by thousands of people, as described in the case study "**Optimal geometry of soap films**".