THE ROYAL SOCIETY

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# Hidden wealth: the contribution of science to service sector innovation

Responses to Call for Evidence

Part I

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## Introduction

Sixty-five responses were received for the Call for Evidence. Some of these are provided below, with the others provided in Parts II, III and IV, which are available for download on the Royal Society website. Several organisations/individuals did not wish for their evidence to be published (EDS, Imperial College London, Steve Jewson, University of Sussex, and Willis Re). Please refer to the links on the Royal Society website for copies of the two original Calls for Evidence that were sent out to services organisations and trade bodies (from the private, public or voluntary sector), and to research and academic institutions respectively.

## Responses to Call for Evidence

### Clifford Chance

Amanda Burton, Director of Global Business Services

As a law firm, the majority of our graduates are lawyers. Whilst we do employ accountants and IT staff, these are in support functions. Our areas of innovation tend to come from within the law or in looking at redesigning back office processes. So for example, we are the first law firm to set up a shared service centre in India.

The most important areas of STEM innovation for us would be:

1. Collecting and sharing legal and practice management knowledge, with suitable security boundaries
2. Enabling further improvements to flexible working
3. Improvements in document production, e.g. reliable speech recognition systems
4. Reduced costs of video conferencing

**University of Wolverhampton**

Gerald Bennett, Pro-Vice-Chancellor, Research and External Development

1. Links include:

    - e-Innovation Centre – an incubator facility for 50+ ICT companies, almost exclusively service sector based.
    - Tourism industry developments from Computing & IT.
    - Research Institute for Healthcare Sciences work with the NHS
    - Radio frequency identification work with retail, logistics and even scrap metal sectors
    - Science Consultancy Services in spin-out company in specialising in water quality.

2. Direct and formal in most cases with some indirect via employment of graduates, post-graduates.

3. ICT Companies, NHS, Accountancy Practices, mainly in the West Midlands and growing. Intellectual property arrangements are often problematical and are individually negotiated.

4. Industry-University Consortia, conferences, collaborative research.
   Research is steered to service industry needs just as it is to manufacturing industry needs. As service industries grow and now, to any extent, dominate so their research needs begin to dominate. This, in turn, is shaping the academic curriculum.

5. STEM graduates are highly employable in finance, ICT, logistics etc, etc. There are probably more STEM graduates in Finance and ICT than in manufacturing and research taken together!
   There is much movement from NHS and ICT into HEIs less so from Finance and Financial Services – we can't compete on salaries.
   There is a very high level of co-operation with service sectors on developing graduate/post-graduate STEM skills especially the NHS and the ICT industry.
   There is evidence of specialist STEM skills required in service sectors. However "ordinary" STEM skills are so desirable that service sectors readily employ any STEM graduate.

6. Data – we are working in all the data areas mentioned and many more besides.
   Interfaces – yes, we do work extensively in these areas
   People and skills – we develop entrepreneurially skilled individuals across the University and particularly, in STEM areas through our Institute for Innovation and Enterprise and associated projects across the institution.

7. There are no real barriers to the work of this organisation with service sector companies. Equal treatment for research proposals involving the service sector is desirable. Equality of recognition for the work being carried out in service sectors by STEM researchers/postgraduates etc is needed.

**Brunel University**

3 page response from G Rodgers, Pro-Vice-Chancellor for Research

Brunel University welcomes the initiative of the Royal Society in investigating the nature of the contribution of STEM research, education and training to innovation in the service sector industries.

Our response is organised in three sections

## 1. The nature and extent of links between STEM and the service sectors.

The links between the University's research, knowledge transfer, learning and teaching activities in the STEM disciplines and the service sector are many and various. A number of service sector innovations have been influenced by our research in the STEM disciplines, for instance:

- risk models developed by CARISMA (Centre for the Analysis of Risk and Optimisation Modelling Applications) have been widely used in the financial services sector.
- research by CEBER (Centre for Energy and the Built Environment) on the sustainability of production and consumption, particularly on the transportation and refrigeration of food, has been used by a number of retail companies, including Tesco.
- the research collaboration MATCH, (Multidisciplinary Assessment of Technology Centre for Healthcare), funded by the EPSRC, supports the healthcare technology sector and its user communities by creating methods to assess value from concept through to mature product.

The University has a range of relationships with the service sector industries including a portfolio of contract and collaborative research, consultancy and licensing activities. Indirect activities include the placement of students in this sector, at both undergraduate and postgraduate level, as well as the recruitment of graduates and postgraduates from our Schools of Engineering & Design, Information Systems, Computing & Mathematics and Health Sciences & Social Care.

Using the HEFCE HEIF 4 funding the University is intending to increase its capacity for sustainable knowledge transfer activities through a range of initiatives, a number of which will impact on the service sector. Our strategic priorities for knowledge transfer over the period 2008-12 are to:

- Develop a strong culture of engagement and KT capacity
- Diversify and increase our income from sustainable, third stream sources
- Build our profile with our regional, national and international communities
- Enhance our cultural, sports and community outreach activities
- Increase the socio-economic impact of our research and teaching

Central to our strategy for employer engagement is our continued participation in the WestFocus consortium, including the Knowledge Exchange that has supported innovation in London since 2004. WestFocus will continue to provide: a central access point to enterprise for SMEs, staff and students; business creation funds

and expertise; the promotion of student enterprise and employability; enterprise training for staff; and networks between academics and business.

## 2. STEM, people and services sector innovation.

Brunel has a tradition of providing undergraduate degrees with a strong employer focus and with integral work placements. The University had 868 students on work placement in the academic year 2007/8, compared with 846 in the previous year. A number of service sector organisations took students for the first time including Universal Pictures International, Push Group, Burger King, Data Technology plc, Department for Work and Pensions, Stella McCartney, Directory of Social Change, HM Revenue and Customs, News International, Carphone Warehouse, HFC Bank, Mizuho Corporate Bank, National Air Traffic Service, Surrey Police and the Suffolk County Council.

All placement students are visited by staff during the placement, facilitating knowledge transfer between the company and the University, and giving rise consultancy and other end user engagement activities.

All new courses approved at the University are considered by an approval panel. All such panels contain a representative from a relevant employer.

## 3. Enhancing the contribution of STEM to service sector innovation.

Brunel is working in a wide range of research areas which have the potential to underpin innovations in the service sector, including:

- Data Modelling and Visualisation
- Information Systems Evaluation and Integration
- Built Environment and Sustainability
- Human Centred Design
- Intelligent Data Analysis
- People and Interactivity
- Information and Knowledge Management.

The University offers postgraduate programmes in a majority of these areas, contributing to the supply of appropriately qualified individuals.

The University regards the provision of HEIF funds from HEFCE , dedicated to developing capacity in knowledge transfer, as an important innovation to promote links between universities and service sector organisations.

**IBM**

We believe that the term "STEM" in this document is ambiguous since it includes "scientifically trained people" in one context and yet excludes "social science" in another. We infer that you wish to limit the "science" part of STEM to the physical sciences and our response is based on that assumption.

We believe that IBM has a well-deserved global reputation for innovation both in products and in services. These innovations are primarily driven by meeting customer requirements and, in doing so, we use the full range of skills in our workforce, including those trained in disciplines from classics through to nuclear physicists. This diversity is also reflected in the ranks of the senior management in IBM UK.

In our experience, innovation is not the preserve of the STEM community, particularly in services, where economists, for example, help our financial services customers provide innovative offerings to the market. Similarly other 'social' science disciplines input across a range of other issues - from service design to user interfaces. We recruit STEM graduates into a wide range of roles from business consultants through to software developers where they will work alongside non-STEM graduates and, in the course of that work, each will transfer skills to the other. As a result, the employees acquire multi-disciplinary skills and are able to contribute more to the business. It is vital to recognise that the importance of STEM skills goes across our organisational boundaries and is not restricted to the practice of traditional STEM applications.

It is thus our view that greater appreciation of science across the board is highly relevant to innovation in services - but also that the greater breadth and practice of applying STEM disciplines to a wider range of issues than is normally discussed would greatly enhance the applicability of STEM skills to innovation in services. There is also the issue of making the UK Innovation system work in step with the services sectors - issues such as grant timescales, assessment methods and communication channels significantly and adversely affect the true potential of the UK Innovation system.

IBM has a strong university relations program in the UK and elsewhere - and is encouraging universities to provide multi-disciplinary courses at all levels to enable their graduates to be better equipped for the workplace. We are promoting the concept of multi-disciplinary courses in Service Science, Management and Engineering (SSME) to address the challenges arising from services having such a predominant position in national economies. We are working with the universities to determine how best to construct a curriculum and also what are the key problems requiring sustained research. We have been pleased to support a number of the recent proposals for EPSRC-funded Doctoral Training Centres where SSME was included as a primary theme.

A number of market research findings have shown that the predicted major growth service areas in the UK are in finance and communications (including media and telecommunications). IBM already has multi-disciplinary teams working with clients in those industries, turning their requirements into innovative services. These teams will include representatives from our business consultancy, our delivery operations and our software development groups. Where appropriate, IBM UK will call upon resources from other IBM companies and business partners across the globe.

In our experience, the success of a new service will be determined primarily by the acceptability of the human interface of that service - whether it be based on an IT application or a revised person-to-person business process. IBM has a record of innovation in usability and accessibility, where social science skills, for example,

are as important as STEM skills.

In summary, IBM recognises the importance of STEM skills to its UK business but welcomes the stance taken by several UK universities to embrace the multi-disciplinary approach that SSME promotes. We are looking for graduates that have a "T-shaped" skills profile; that is, a depth of knowledge in (at least) one subject area coupled with a breadth of knowledge across several others. This is not unique to IBM but a common view held by many major UK companies.

**IBM (Belgium)**

Education, Learning and Skills for an Innovative Service Economy

Skilled and creative employees are a fundamental factor in the innovation process and a major source of competitive advantage. In the Agricultural Age, land and farm production defined competitive advantage. In the Industrial Age, it was raw materials and manufacturing capability. Today, it is the ability to create and apply intellectual capital based on multidimensional expertise – increasingly in the area of services.
Workforce skills must include both technology and strategic expertise. An understanding of technology – its current capabilities as well as its future potential – is now integral to business decision making. Importantly, these skills are not static, requiring continual refreshing through life-long learning and retraining. Technology and skills in relation to innovation is not an either/or decision. The majority of service firms attach equal importance to investing in new technologies and in skills.

In the past IT services were all about "repair and maintenance." Today, services are about optimizing business. There is a lack of people in Europe with both IT and business skills which understand the new role of IT services and who be interested to work at a European level. This is probably the biggest challenge for Europe: create a mobile workforce which can operate across the cultural and language barriers.

Consequently we need to adapt education and training policies to rapidly changing requirements for new skills and create a new discipline for services sciences. Services science is a multidisciplinary field that seeks to bring together knowledge from diverse areas to improve the service industry's operations, performance, and innovation.
In essence, it represents a melding of technology with an understanding of business processes and organization. It is a shift from a technology-centric view to a holistic view that encompasses both technology and business. Professionals need new skills and education in a variety of fields to yield the best results in service industries. It is critical to develop and foster a broad perspective that includes research from many areas, including economics and law.

You might ask why is IBM so interested in this?

When IBM first started building computers, there were no formal education programmes in computer science. In fact, the term "computer science" didn't even exist. So where were the designers, engineers and the scientists going to come from? The answer was to work closely with universities. IBM's first research lab was at Columbia University in the US, a co-project of the school and IBM. Columbia's first computer science course was co-taught by an IBMer. Today there's no shortage of computer science education.

Now the services industry, especially IT services, is facing the same daunting challenge. There is a dearth of formal programmes to educate the type of employees needed to support the services marketplace. Just as it did 60 years ago, IBM is working with academia to change that. If fact, IBM has drawn up a dedicated academic curriculum in SSME and is using its global research facilities to explore the intricate dynamics of innovation in services.

And today forward-thinking universities are getting in on it. Most notably in North America, Europe, and Australia where already courses are available at graduate and Master levels. Courses running SSME programmes include: the US's Massachusetts Institute of Technology, the University of California, Berkeley

and Carnegie Mellon University; Makerere University, Uganda; Universidad Raimon Llull, Spain; Erasmus University, Rotterdam; Budapest Tech, Hungary; Switzerland's École Polytechnique Fédérale de Lausanne; Italy's Bocconi School of Management, the University of Pavia, Scuola Sant'Anna di Pisa and University of Castelanza; Portugal's Porto University; Germany's Karlruhe University and University of Stuttgart, and the UK's University of Manchester, University of Warwick, University of Cambridge, and the Imperial College of Science, Technology and Medicine in London.

But still the majority of universities are teaching the skills required for the manufacturing era and they need to dramatically evolve to the era of services design and delivery.

We believe strongly that academia needs to consider services as a distinct and legitimate area for research and teaching, and that doing so is part of academia's role in preparing students for the high value jobs of the future, jobs that are out there and available and will be for decades to come.

- Governments, industry and universities together must enable the creation of a new academic discipline on Service Science to bring together ongoing work in computer science, operations research, industrial engineering, business strategy, management sciences, social and cognitive sciences, and legal sciences to develop the skills required in a services-led economy. Also schools should be involved in this process. There will be a change from ICT workers with specialized technical skills towards hybrid professionals with competencies in business or scientific areas beyond traditional ICT who will be able to respond to the challenges of a more dynamic service oriented economy. Well targeted education policies will have a significant positive effect on the competitiveness of the European ICT and knowledge service providers given the sector's dependability on highly skilled workers.

**Legal & General**

Thank you for the opportunity to comment on the Royal Society review. As you may know, I led the study for UK Government on behalf of the Council for Science and Technology on this subject and I append the report to the Prime Minister.

As far as Legal & General is concerned – the direct involvement with academia has historically been extremely low – with academia showing little interest and having little to offer and the company not believing that there was any worthwhile opportunity. This is changing and the company has sought and developed relationships to assist its assessment of risk from geology and flooding in its general insurance business and the impact of health improvements on its life risk exposures.

Legal & General has three main businesses in the UK – risk, savings and investment management. The mathematical modelling, risk assessment and underwriting, asset / liability structuring with the interplay of derivatives is, to my technological eye, demanding of some of the finest STEM minds both inside and outside the company. The actuarial profession has, of course, applied stochastic and statistical techniques to historical data and projected forward on this basis. I am certain that we should be applying more science in understanding and modelling risk [ every element ], in deriving better models and achieving better correlations. The operations, both with customers and internally, has been increasingly automated as the full potential of expert systems and artificial intelligence, coupled with straight through processing, is exploited. Innovation is a continuous activity – products, service, systems, and is as intensive as any I have experienced in manufacturing industry.

**Oxford-Man Institute**

In September 2007 the Oxford-Man Institute of Quantitative Finance was established as an interdisciplinary research centre in the University of Oxford. Man Group plc provide three forms of support to the Institute:

- A research grant to the Institute for £10.45M to cover the Institute's core costs for its first 5 years
- Permanently endowed a new Chair at Oxford (cost £3.3M) called the Man Professor of Quantitative Finance
- Co-located with the Institute their own Research Lab which provides Practitioners' insights for researchers and students at the Institute

The Institute's remit is to be academically outstanding, developing into the leading centre in our field. We conduct curiosity driven research for the public domain. We draw scientists and students from throughout the University to spend part of their week at the Institute as well as having our own full time staff. Currently we have faculty members from the following University Departments: Computing Science, Economics, Engineering, Law, Mathematics, Said Business School and Statistics. 70% of our faculty and students are members of the Maths and Physical Life Sciences Division of the University.

The physical co-location of an industrial research lab with a university research centre has been a boon to both parties. We share a common room, research lab members come to our university seminars. It means that long term relationships are established between lab members and academics which has lead to the involvement of various researchers in joint projects with colleagues from the Lab. Further, our researchers and students gain significantly by having easy access to industrial insight. In addition Lab members and colleagues from Man Group can apply to audit courses in the University.

This physical co-location is unique in our field, although there are currently many rumours of other leading universities trying to copy it.

Man Group and academics at Oxford worked very hard at the start of our joint discussions about setting up the Oxford-Man Institute to iron out potential challenges associated with co-location. From a university viewpoint the crucial element was academic freedom to set the research agenda, being able to pursue truth without fear or favour and to publish the results. We were fortunate that many colleagues at Man Group had first hand experience of carrying out research at universities and understood and actively supported the importance of this.

In turn the Institute is running a strong conflicts of interest process which means colleagues promptly reveal to the Institute's Director when they are working as a consultant to other financial companies. Further, co-location has meant the Institute runs a tighter form of security on its front desk than is familiar in some areas of the University.

Currently around a third of the Research Lab members regularly publish articles in the academic literature for the public good. Some of these active researchers have been offered associate membership of the Institute and can submit their work to be published under the Institute's affiliation. An independent Editorial Board has been established to check that such publications are not made for the commercial benefit of Man Group.

Finally, although the research grant from Man Group covered five years, it is the publically expressed hope of both sides that Man Group will continue their active involvement in the development of the Institute beyond that time. Our collaborative agreement anticipates this and has put in place a timetable and process for renewal.

Background: Man Group plc

Man Group describes itself as "Man Group plc is a leading global provider of alternative investment products and solutions for private and institutional investors worldwide, designed to deliver absolute returns with low correlation to equity and bond market benchmarks. Man has a 20-year track record in this field supported by strong product development and structuring skills, and an extensive investor service and global distribution network.

The Group employs 1,600 people in 13 countries, with key centres in London and Pfäffikon (Switzerland), and offices in Chicago, Dubai, Hong Kong, Montevideo, Nassau, New York, Singapore, Sydney, Tokyo and Toronto. Man Group plc is listed on the London Stock Exchange (EMG) and is a constituent of the FTSE 100 Index."

On 27th June 2008 Man Group's market capitalisation was £10.477B, which made it the 31st highest valued UK based company.

Background: Oxford University and Finance Research

The Oxford-Man Institute is the physical home for interdisciplinary research at Oxford in quantitative finance. We have Departmental strengths too.

The Mathematics Institute has the Nomura Centre for Mathematical Finance, which supports a couple of post-docs and students and runs an annual invited lecture. Their Mathematical and Computational Group is strong and works with the Institute. It has many links with a variety of financial firms.

The Said Business School has a Finance group, which has strengths particularly in corporate finance.

The financial research and teaching in the university is coordinated through our virtual umbrella organisation called the Oxford Financial Research Centre. This has some modest financial support from Credit Suisse.

**Retail Research Group at Surrey University**

2. Direct and formal.
Relationships that have been in place for a number of years have recently become more formal via ESRC/AIM Business Engagement project (and subsequently Forum) on Retail which took place in 2008, also subsequent award of £1.5m from ESRC over five years for business engagement cluster for the retail industry (RIBEN) - in collaboration with Universities of Southampton, Oxford and Leeds due to commence in Autumn 08.

3.
The sorts of service organisation that your institution is working with
Tesco plc (and other retail firms) eg. AIM (Advanced Institute of Management Research) research project on Retail Innovation, as well as other retail service firms eg. Verdict research

Where they are based
In the UK but often (eg Tesco) with large international operations

Whether these engagements are growing in number and importance
Yes. This growth is activity is part and parcel of ESRC's growing 'engagement' mission

The types of IP arrangements that apply to your work with service organisations

Usually sign informal 'contracts' which allow use of the material for 'non commercial research and teaching' ie. Ok to use in research papers (subject to the usual clearances eg. ethics etc) and teaching as long as work not being used in work for rival companies for example

4. Is research activity in your organisation steered by service organisations innovation needs?
Some research work is in some ways becoming quicker/dirtier in response to complex issues raised by firms re timing/depth of work required, but there is also a good deal of rigorous academic work taking place and firms seems to recognise the importance of taking a more long view approach in this respect

Has engagement with service organisations helped to shape the academic curriculum
Via teaching of Innovation eg recent MBA summer school

B) Stem people and service sector innovation

The movement of people from innovative service environments into academic settings

Appointment of Lecturer (Dr Steve Wood) who had previously worked at Verdict Research and Tesco plc into School of Management at University of Surrey.

**Academy of Medical Sciences**

Introduction

The Academy of Medical Sciences welcomes this study into the role of science, technology, engineering and maths (STEM) in service sector innovation. In this response, we draw on our previous published material to emphasise the role of innovation in the NHS and the very great importance of STEM for delivering effective health services. These issues are important for developing the NHS' own evidence-based culture and for the core role of the NHS in promoting innovation by other bodies. We would be happy to provide further information on any point covered.

A) The nature and extent of links between STEM and service sectors

*Case study: innovation in the NHS*

Overall, the UK has a good track record in using STEM for biomedical innovation in industry and academia. However, this has not always been the case in the NHS. In the past, it was recognised that R&D in the NHS had suffered through the diversion of money intended for research into other areas. Moreover, there has been a lack of incentives for R&D in NHS performance targets. Some specific areas have been particularly weak: the design and delivery of health services research and, more generally, poor links between research and policymaking, leading to delays in translating STEM advances into patient benefits.

Historically, the NHS has experienced difficulties in valuing innovation and in identifying and protecting its Intellectual Property. Its 'Innovation Hubs', which offer legal and commercial support to NHS staff who have a pre-market product, have enjoyed only limited success. There are lessons for the NHS to learn from other research funders, including MRC Technology, Cancer Research Technology and some universities, who have considerable experience in supporting knowledge transfer; this will be facilitated by the closer partnerships that are now possible within the Office of Strategic Coordination of Health Research (OSCHR).

The more systematic approach that has now been taken by the NHS to share best practice in innovation should also begin to translate into improved health services. The Academy greatly welcomes recent efforts by the NHS to inculcate a more effective research culture and to seek to capitalise on new opportunities arising from progress in STEM, e.g. experimental medicine, clinical trial design, and public health science. We acknowledge that significant progress is being made in tackling the barriers to innovation. The Department of Health's 'Best Research for Best Health' strategy has been a timely and valuable initiative, and the establishment of OSCHR is a vital step in building partnerships to use STEM among the NIHR, MRC and other private, charitable and public sector funders. The creation of new mechanisms to coordinate the translation of research into better healthcare, such as the OSCHR translational research board, promises to be fundamental to the progress of NHS innovation.

Below is a brief summary of ongoing NHS reforms required to build an increasingly effective innovation culture:

o Ensuring transparency of research funding allocations, high quality peer review, governance and decision-making.

o Developing a culture of inquiry with a sense of ownership of the research and innovation agenda by NHS staff, health professionals and Trust managers.

o Maintaining engagement by other major research funders from the charitable and commercial sectors.

o Avoiding barriers to interdisciplinary work between different types of health researcher and between different scientific disciplines.
o Coordinating NHS in England and the Devolved Administrations to harness existing STEM for innovation and to identify gaps and opportunities.
o Identifying new STEM areas that may lead to innovation for pump-prime funding, while avoiding the temptation to be prescriptive in selecting priorities and targets. Identifying areas for strategic support will be influenced by scientific opportunity – creative ideas, the availability of talented researchers and advances in technology. It is vital to invest in basic research to fuel the pipeline for translational exploitation.

In key respects, NHS support and use of research, built on excellence in STEM, can be regarded as a model for other government departments that provided public services (see Appendix 1). We now highlight two key areas where there is considerable potential for health services innovation to be influenced by STEM: 1) improving regulatory, governance and IT structures; and 2) implementing policy objectives.

*1. Improving regulatory, governance and IT structures*
The NHS is both a research resource and test-bed in which to develop, monitor and optimise healthcare products and services. The introduction of Connecting for Health (CfH) and the Electronic Patient Record offer unparalleled opportunities as a research resource. However, the Academy has been concerned that a number of factors, including confusing legislation and professional guidance, bureaucracy of process and an undue emphasis on privacy and autonomy, are having a detrimental effect on UK research activity in this area. We expect the Department of Health to take a leadership position, both in engaging the public to explain the innovative value of research using health care records and in ensuring that CfH and associated activities underpin the research mission of the NHS.

*2. Implementing policy objectives*
Special Health Authorities (in particular, the National Institute for Health and Clinical Excellence - NICE) and the Medicines and Healthcare Regulatory Authority (MHRA) as an Executive Agency, are also of great importance in taking forward departmental objectives. The Academy's views have been presented in detail elsewhere. Of particular relevance here is our analysis of MHRA strategic priorities, which noted the opportunities for building partnerships between the NHS, academia and industry to facilitate safety assessment, support innovation and promote public health. Our analysis of NICE raised some generalisable issues that are broadly relevant to the use of STEM in health services innovation: (i) the need for greater public engagement to improve understanding of processes and restore confidence in policies emerging from those processes; (ii) the need for better external scrutiny of basic assumptions and models used; (iii) the need to employ evidence more swiftly in decision-making and to compare with equivalent systems elsewhere to ensure consistent adoption of best practice; (iv) the need to improve procedures for gathering evidence.

*Nature of influence of STEM and types of engagement*
The Academy and our Fellows have, of course, many different types of contact relating to STEM within health services. In the particular case of health services research, a report of a meeting co-organised by the Academy and the Health Services Research Network provides a detailed perspective on the nature and scope for such research, on methodological challenges, on building engagement with the user community and on a range of issues for improving the quality, relevance, evaluation and impact.

The use of STEM to inform decision-making in public policy was also extensively discussed in the recent Academy report '*Identifying the environmental causes of disease*' and we suggest that some of the recommendations emerging from that work are relevant to this study (see Appendix 2).

In characterising the broader responsibility of the STEM community to engage with the Government we highlight two vital needs:
The importance of having an appropriate means of horizon scanning for identifying future science-related issues – we have welcomed the continuing commitment by government to its Foresight programme.
The Government must make best use of scientific advice, whether derived from its commissioned research or from other sources. Government faces critical societal issues where it must draw on expert, *independent*, sources of advice, particularly in clarifying what is known and what is uncertain in the evidence base. As the House of Commons Science and Technology Committee observed, learned societies have a key part to play in this process.

*Mechanisms to support engagement*
The Academy has been involved in multiple ways in engaging with the Department of Health/NHS: at the corporate level; through the work of individual Fellows; in the joint initiative to build the UKCRC; on specific projects; and in large programmes to support capacity building. We would be pleased to provide further information on any of these.

We take the opportunity here to highlight an additional issue relating to engagement between public health service organisations and their partners – the role of public procurement in supporting innovation. Promoting a culture of innovation within procurement provides incentives to reward commercial investment in R&D and, thereby, expand business innovation. Detailed discussion is beyond the scope of this response but it is important to ensure that government objectives to renegotiate the Pharmaceutical Price Regulation Scheme – to achieve greater efficiency in NHS expenditure – do not inadvertently impede pharmaceutical sector investment in R&D by significantly weakening the reward for innovation. Public health services must also build the flexibility to cope with an uncertain future: new pricing challenges will emerge if the promise of better therapeutic targeting of patients is to be achieved and new forms of expedited regulation of innovation introduced.

B) STEM, people, service sector innovation
*Movement of people between academic science environments and the NHS*
Previous work by the Academy has described the importance of encouraging career mobility between the NHS, academia and industry sectors and we have made specific proposals to achieve the desired movement. The Academy continues to be directly involved in identifying skill needs and in supporting skill development, for example through our mentoring schemes.

It should also be noted that other policy developments can inadvertently damage efforts to secure the next generation of medical scientists and this is a concern to all sectors. The initial introduction of changes via the Medical Training Application Service, as part of Modernising Medical Careers, imperilled the future supply of first-class, mobile, clinical academics. The Academy welcomed the proposed solution in the Tooke report and we emphasise the need for diversity, flexibility and excellence in medical training.

C) Enhancing the contribution of STEM to service sector innovation
*The main barriers to further innovation*

To enhance health services innovation, it is necessary to continue tackling challenges across a broad front:

Redoubling efforts to use the NHS to grow partnerships across the public, charitable and private sectors.
Building innovation capacity by developing, recruiting and exchanging staff.
Facilitating NHS uptake of innovation from outside.
Taking a leading international role, e.g. in the European Innovative Medicines Initiative.
Developing UK coherence in policies to support innovation. The Health Innovation Council is an important new entity with a core responsibility for overseeing innovation. This body must ensure that its objectives and actions are well integrated with other functions, particularly the Technology Strategy Board, which has recently adopted enhanced roles following the Sainsbury Review, and the sector-specific Long-term Strategy Groups and Innovation Teams created by government departments for pharmaceuticals, diagnostics and other medical devices.

The recent Darzi report on the strategy for the NHS in England rightly observes that the consideration of innovation should not be confined to research but is rather *'a broader concept encompassing clinical practice and service design'.* Among the specific recommendations in the Darzi report, relevant to points made earlier in this response, are:
Establishing Health Innovation and Education clusters bringing together partners from the NHS, academia and industry.
Requiring Strategic Health Authorities to have a legal duty to promote innovation.
Ensuring that clinically and cost effective innovation in medicines and medical technologies is adopted.

We commend this growing recognition of the importance of innovation in public health services.

## Appendix 1: Model attributes of NHS

There is evidence to show that the underlying processes required for the effective transfer of knowledge from different sources into improved services are shared across different types of service. An analysis of the common features of key service systems was provided recently by the University of Cambridge Institute for Manufacturing; a commentary by the Foundation for Genomics in Public Health observes the particular application in health care services systems.

This commonality detected between different service systems reinforces the points made in a recent contribution by the Academy to the Office of Science and Innovation Review of Science in the Home Office, where we suggested that in several areas the recent research and innovation practice already accepted by the Department of Health provides a model for other government departments. This was based on a 2006 Academy symposium on 'Science of Violence', which brought together biomedical scientists, policymakers, legal professionals, the media, the general public and law enforcers to discuss ways in which epidemiological, medical and public health sciences could contribute to the evidence base underpinning policymaking about violence.

The meeting drew attention to the opportunities medical science can offer improve public service delivery in the Home Office. Key messages relevant to role of STEM, particularly medical science, in innovation in the service industry include:
1. Increase the use of randomised controlled trials in research into services provided by the Home Office. This could be achieved through the establishment of a dedicated fund for such applied research, as well as a field trials unit.

2. Establish an 'Institute of Excellence' to guide delivery of public services in the Home Office based on the NICE model.
3. Develop a national cadre of crime analysts for Crime and Disorder Partnerships whose role is to root Home Office policy in quantitative and experimental methodology.
4. Develop police and offender management schools based on the medical school model, where service delivery, research and training are undertaken in close conjunction.

Appendix 2: 'Identifying the environmental causes of disease: how should we decide what to believe and when to take action?'
A report by the Academy (2007) exploring the use of research evidence in public health decision-making offers several recommendations to government that are relevant to the use of STEM in promoting innovation:

*Report Recommendation 1*
Government should build upon their recent efforts to integrate science into policy making by further increasing capacity building by means of:
Embedding researchers into policy teams
Providing senior civil servants with scientific training
Seconding scientists to government
Building a cadre of ''evidence brokers'' within government who are trained in both science and policy.

*Report Recommendation 3*
The Department of Health and other relevant government departments should ensure that there is greater emphasis on both pilot studies and systematic rigorous evaluation of the effects of interventions in developing and implementing health policy.

*Report Recommendation 5*
The Department of Health, Research Councils and charities funding research into the environmental causes of disease and interventions to prevent or treat disease should continue to involve the public and patient organisations by inviting them to participate in their expert scientific advisory committees.

**CBI**

Tony may already have passed this to you, but I thought I'd send through this CBI/QinetiQ report on innovation in the service sector that we produced earlier in July (if you would like a hard copy then please let me know). The report is based on some detailed case study interviews that we did with 16 service sector firms chosen because they were either recommended to us as being innovative by other companies or because we had some prior experience of their innovation activities.

We didn't ask specifically about the importance of STEM disciplines to their innovation work, but 9/16 told us about technology driven innovations in the case studies and I think that 12/16 actually have at least a proportion of their innovations underpinned by scientific skills, maths and/or engineering and technology developments (e.g. creating services around an available technology or technology platform or taking/adapting/amalgamating technology to meet the needs of their customers and offer this as a service). As you might expect, all of the firms made very good use of IT.

Interestingly, I'd say that although all but one or two take on STEM-qualified individuals, it is probable that only about half of the case study firms have what you might call STEM-specific positions (certainly if you take the general IT support staff out of this equation).

10/16 had or are developing links with universities, though not all of these are for STEM-related things... 4 were much more on the design side (in architecture, product design, engineering and IT design), and one of the firms only has links with universities outside of the UK.

One of our interesting side observations in the study was the overwhelming importance of data and how it can be used to create further innovations. It was apparent that service firms collected (or had the potential to collect) vast amounts of data in their client/end customer engagements. Of course, much of this either has to remain confidential and/or the company is using it themselves to underpin customer service and innovation activities, but huge amounts of data aren't being analysed, brought together or used creatively. We think there are some real opportunities here if companies can be encouraged to share this data (in an appropriately bulked up or anonymous way) with university researchers.

**University of Manchester**

I have been asked by the President to respond to your letter seeking a contribution from the University of Manchester to your report on the influence of STEM in the service sector.

Your survey instrument is a very well informed set of questions, which, if they were all answered, would provide you with some high quality data. As a former innovation researcher myself, I recognise all the issues. Sadly, to answer all your questions about how this University has directly contributed to service innovation would require a full research project itself. I have been forced I'm afraid to be rather selective in choosing which parts of your survey to respond to. In what follows I focus on STEM graduates, and on service innovation research.

The University is a major supplier of graduates to all types of employer with 12,000 students graduating in 2007 and 4000 recruiters targeting the University.

Recruiters in the service sector target STEM graduates at the University of Manchester primarily for their numeracy, IT and analytical skills, but also for their experience of project management and disciplined problem solving. Many of these recruiters are in the financial services/IT sectors and examples of companies active on campus include Lehman Brothers, Credit Suisse, Morgan Stanley, Dresdner Kleinwort, Bank of America and Deutsche Bank. Companies in the health services sector also target STEM students, in particular life scientists and computer scientists. Examples of active recruiters from this sector are Cerner and the Adephi Group. SMEs in the service sector also look to recruit STEM graduates. Recent examples from local SMEs include a financial trading company seeking a maths graduate with programming skills and an energy consultancy looking for a software engineer.

More recently we have seen retail companies such as Tesco and Ocado target STEM graduates for their engineering, advanced refrigeration, energy solutions, IT, customer analysis and research etc, programmes. Tesco has also targeted engineers to train as buyers on the basis that as they purchase increasing amounts of non-food items they need staff able to understand the technical specifications from potential manufacturers and suppliers.

However, as I am sure you know we need better understanding of how innovation happens in the service industries. Is innovation planned or does it happen by luck? If it is planned, is innovation driven by crisis, survival, competition, creative CEO etc?

Part of the University's response to questions like these is to create "The Centre for Service Research" within the Manchester Business School. The co-directors of this new Centre are Professors Ian Miles and Linda Macaulay. The Centre will be carrying out world class research in services and will generate a new synergy from inter/multi disciplinarily and business-academic partnerships in research.

The Centre has already identified a number of key research themes including service design and technology and knowledge intensive business services which will investigate how technological and technical change impact on/drive service innovation. The Centre will be developing reliable UK economic data on knowledge intensive service activities to underpin service innovation. The Centre will also develop key strategic links with leading service research centres in the UK, Europe and the US.

It has been recognised that a critical element of growth in the services economy is the need to change the shape of the academic curriculum that will be required to provide businesses with the best graduates. The new Centre is planning an MSc in Service Design, Management and Innovation to start in September

2009. One of the key learning outputs for the graduates will be the ability to apply scientific, engineering and managerial methods and tools to identify, design, deliver and evaluate innovative services in organisations of different business sectors and markets.

The Centre will work with employer stakeholders from both the public and private sectors and with large and small business. The benefits will include linking practitioners in public and private service firms to world class researchers, influencing the curricula needed to generate world class graduates, networking with other practitioners and collaborating on the design and funding of research.

As you have written separately to Professor Macaulay I am sure that she would be happy to provide you with further details about the work being progressed in the Manchester Business School.

**Centre for Service Research at the University of Exeter**

## Innovation in services: the role of science, technology, engineering & maths (STEM): A Report from the Centre for Service Research, University of Exeter

"All innovation begins with creative ideas . . . We define innovation as the successful implementation of creative ideas within an organization. In this view, creativity by individuals and teams is a starting point for innovation; the first is necessary but not sufficient condition for the second" (Amabile et al, 1996)

Service innovation is a challenging topic, and we hope to contribute to the Royal Society's report in two ways; first, by describing what the centre does that is related to STEM and service innovation in questions 1 to 7 of the call and second, by collating evidence from our own experiences and reporting our analysis in appendix A.

### Work at the Centre for Service Research related to STEM and Service Innovation

There is a perception that 'service' is all about the 'soft, flaky stuff'. As one manager puts it: "Service is 'what else can I do for you sir, and a curtsy'". There isn't obvious recognition of the fact that STEM tools and techniques are useful for the service sector, particularly for industries where *people* (rather than widgets) deliver value to the customer. In addition, there is an attitude amongst organisations that 'service just happens' (as opposed to the production of tangible products). Such attitudes often impede service innovation.

The centre believes that there is a need to recognise service as a deliberate and organised system, not merely the 'front end bits' that 'just happens,' and that service innovation is about empowering people in the system to think creatively and put ideas to work in a systematic, scientific manner. In other words, we need more science in service for service innovation.

However, we recognise that there is baggage that comes with the term 'service'. Consequently, the centre has been using the term *service science* as a catalyst to change mindsets. Although this term was coined by IBM, we see *service science* as the vehicle for the use of STEM tools in service, and for getting organisations signed up to the idea that there is a science to service. This has been particularly effective in bringing organisations to the table to talk about service innovation, research and development.

The centre works in close collaboration with the Exeter Centre for Systems, Processes & Operations (XSPO) in the service sector. Specific questions are answered below:

### A) The nature and extent of links between STEM and services sectors

*1. Please tell us about two or three important services sector innovations that have been influenced by Science, Technology, Engineering and/or Maths (STEM) or other disciplines from your organisation over the last ten years.*

STEM-based projects (UK only) include:

1. Using systems modeling to provide an innovative solution to the re-design of the Royal Devon and Exeter NHS's Accident and Emergency unit. This resulted in publication in a top-ranked journal, and the solution has been implemented at the hospital.

2. Working with a large parcel delivery company to develop a complete systems architecture for the entire business. This systems model was used to test alternative business scenarios.
3. Using the latest workflow software to re-design a direct marketing process at a large telecommunications organisation.
4. Developing a decision support tool (software) to optimise amorphous service capacity – ongoing project.
5. Developing a framework of value co-creation through a mathematical model for a defence organisation – ongoing project.
6. Contributing to stakeholder mapping of a $150 million bid.
7. A service cost engineering project for a support solutions organisation – ongoing project.
8. Constructing price mechanisms for service contracts to understand the separation of purchase and consumption of services and pricing through-life services – ongoing project.

*2. Was the influence of STEM and the other disciplines mainly:*
*Direct and formal – e.g. via formal relationships with firms or other organisations such as collaborative or contract research, consultancy, licensing arrangements?*
*Direct and informal – e.g. staff undertaking private consultancy?*
*Indirect – e.g. recruitment of graduates and post-graduates, the diffusion and application of knowledge and technology via intermediaries such as research and technology organisations, consultants and suppliers?*
*A combination of these, or none of these?*

A mixture of both, but mostly formal through contractual arrangements such as contract research, consultancy projects and Knowledge Transfer Partnership (KTP) programmes.

*3. Please tell us about your engagement with services organisations. Among other things we are interested in:*
*o The sorts of services organisations that your institution is working with*
*o Where they are based*
*o Whether these engagements are growing in number and importance*
*o The types of IP arrangements that apply to your work with services organisations*

Together with XSPO, we have worked with the following organisations over the last five years on various projects ranging from KTPs and consulting, to contract, ESRC and EPSRC research:

TNT Express, Vodafone UK, Vodafone Global, France Telecom, BT, Virgin Media, Lloyds TSB, Scottish Widows, Britannia Building Society, South West Water, e-ON, EDF Energy, Scottish Power, Royal Bank of Scotland (RBS), Met Police, AXA, Met Office, UKHO, RD & E NHS Foundation Trust, Sutton Borough Council, BAE Systems, MBDA, Northcote Devon Foundation, Harmonic Ltd, Handle with Care Ltd, NHS, and Selex Galileo. New projects are in the pipeline with Fujitsu UK, Lloyds Cardnet and RBS.

We have seen growing activity in the sector and the centre is now facing more enquiries than its researchers can actually cope with. However, the nature of the work is at a very high level, contributing both to research as well as practice, and such work cannot be undertaken at a junior level. There is insufficient number of researchers in the UK who understand the nature of service well enough to undertake such work, and this has led to capacity problems. To help alleviate this, the centre hopes to invest in more PhD students and research fellows who are able to work in the area of service, but this is a slow and time-consuming exercise that requires resources. The centre is also engaging in collaborative

work with STEM communities in other universities to enable STEM researchers to gain a better understanding of service.

Since much of the work is at a high level, the centre is more willing to take on work that enables it to retain the IP even if it means partial retention only – this means that contract research and KTP programmes are more prevalent. However, consultancy projects that apply the knowledge are also taken on concurrently to encourage exploitation of the knowledge created.

*4. What mechanisms does your institution use to support engagement with services sector organisations? (For example journals, industry-university consortia, conferences, collaborative research programmes supported by the Research Councils).*

Mechanisms for engagement are:
1. Convening the Service Science Forum where the centre brings together approximately 20 organisations with our researchers to discuss challenges in the service economy. These companies include Thomson Reuters, Fidelity, Virgin Media, Lloyds TSB, BAE Systems, Rolls Royce, IBM, Atkins Global, Vodafone, Mizuho Bank, Selex Galileo, Harmonic and Adurasys. The forum meets twice a year, and the last 2 meetings have brought to light issues related to service innovation.
2. Conferences (e.g. EUROMA Service Operations Meeting with XSPO),
3. Collaborative Knowledge Transfer Programmes [e.g. with Harmonic Ltd, Handle with Care, and Hospice Care (conducted by XSPO)]
4. Collaborative Research Programmes with other universities and research councils (e.g. EPSRC/BAE Systems S4T project on Service Transformation worth £2 million, AIM Fellowship service research currently in discussion with Lloyds Cardnet and Fujitsu UK)
5. Funded research studentships and fellowships in the area of service (e.g. NHS Research Fellow, Scottish Widows)
6. Executive Education programme (e.g. with Southwest Water and Britannia Building Society, Generali, Selex Galileo, and current discussions with Royal Bank of Scotland)

*Is research activity in your institution steered by service organisations' innovation needs? If yes, how is academic research changing in response to these needs?*

Research activity is driven by both the innovation needs of service organisations and the researchers' relevant expertise in the area of service. Much time is spent discussing and scoping research possibilities with service organisations. These needs drive our PhD agenda, and we are currently developing new approaches to process design, pricing mechanisms, service contracts, value co-creation models and service capacity based on industry demand.

*Has engagement with services organisations helped to shape the academic curriculum?*

Academic research in services is now challenged to become much more interdisciplinary, and this has compelled the researchers within the centre to work with the engineering faculty and to collaborate on service in the management department between operations management, marketing, social psychology, etc.

We work with many service practitioners who help us identify the appropriate skills for their businesses, and most of these companies also support our postgraduate courses at the university.

The centre's MSc Service Science & Management programme was developed in conjunction with service organisations through the Service Science Forum. This has resulted in innovative modules such as the Consulting Practicum where a student is tasked to learn the skills of a consultant and 'sell', plan and implement a project with the industrial partner; the Advanced Service Seminars which will be conducted by industry practitioners in concert with academics (through a visiting speaker programme); and Auditing a Service: Service Blueprinting for Quality and Innovation where students are required to go on a field trip to document a service experience and map that against the various service theories across disciplines. We have also developed a 10-week internship programme with our industrial partners.

This programme has received £35,000 from the University's strategic development fund for pump priming, and £43,500 from the EPSRC Collaborative Training Account to secure matched funding from industrial partners.

**B) STEM, people and services sector innovation**

*5. Please tell us about the movement of people between academic science environments and services organisations. Among other things we are interested in:*
*The employment of STEM graduates or scientifically trained people in services organisations*

We currently do not have any formal placement activities or opportunities to place STEM graduates in service organisations.

*The movement of people from innovative service environments into academic settings*

We are seeing growing interest among experienced and mature practitioners from service organisations in taking up research at our centre and at our school. Many find existing knowledge in services to be inadequate and are keen to make a difference, although they often need to go through rigorous research training (often STEM-based) before they are able to undertake the demands of a research project. However, they bring with them many years of practice experience, and have been very resourceful in helping define the most important research questions for the advancement of knowledge in services.

*Whether you are working directly with services organisations on the development of STEM skills at the graduate/postgraduate level*

We are working with a few organisations on internships in services and discussing ways on our service science students could add value to these organisations. However, because there is often no explicit recognition of 'service' in service organisations (except in roles such as 'customer service'), students trained in service science as a whole do not fit into current organisational structures.

*Whether you have evidence that services firm's STEM skills needs are changing (qualitatively or quantitatively)*

We have been constantly adopting and adapting STEM tools and techniques for service organisations, and we find it a challenge to engage with STEM researchers who prefer to apply their 'tried and tested' tools rather than modify them for a service environment. Part of the reason for this is the discomfort that STEM researchers have about behavioural issues and the level of uncertainty in service environments.

**C) Enhancing the contribution of STEM to services sector innovation**

*6. We are interested in 'fertile areas' of the service economy (important business or societal challenges) in which the UK could develop, accelerate or scale-up innovative service capabilities, but which would*

*require new or different offerings from the STEM community. Please tell us if your institution is working in any of the following (or other) areas which could underpin innovations in or across services sectors. Data – e.g. information management, data security, data analysis, data modelling and visualisation and supply chain logistics?*

The centre is working on the understanding of service support solutions (which includes logistics of spares and equipment) under the S4T project with BAE Systems and MBDA, but we have found serious challenges, many of which are highlighted in the analysis below. We also feel that there is serious inadequacy on the part of the STEM community in addressing the links between data and information to inform pricing and revenue models in services.

*The interface between people and services – e.g. human responses and interactions with services and systems?*

Yes, in bringing in service and management analytics to the co-creation of value between the customer and the organisation which includes human interfaces with BAE Systems, MBDA, Lloyds, Fujitsu (to be confirmed), NHS, Harmonic Ltd; in pricing and mechanism design of contracts in services with Lloyds and Fujitsu (to be confirmed).

*People and skills – the development and supply of appropriately skilled and entrepreneurial individuals?*

Yes, with South West Water and Britannia Building Society. We have developed bespoke postgraduate programmes with both these companies to meet their needs.

*7. What are the main barriers to further links between your institution and services organisations?*

Barriers to service innovation and barriers to further links between the centre and service organisations are covered in our report in appendix A.

*What steps could be taken by companies, universities or government to enhance the impact of STEM on innovation in the services sectors?*

*Steps by companies*
For organisations to invest in service innovation involving STEM tools and techniques, there needs to be a mindset change from service-is-just-what-the-organisation-does-naturally or merely viewing the customer facing parts as service, towards a deeper understanding of service as a deliberate, organised and well-designed system that include behaviours. We have encountered organisations that invest millions in technological product innovation without recognising that service is often what unlocks the value of a product to the customer. The whole organisation is structured towards getting the tangible components designed, organised, manufactured, packed and delivered while the service 'just happens'. Similarly, service organisations (such as hotels, transportation etc.) often focus on the tangible aspects (seats, rooms, vehicles) rather than on the value that the entire service system delivers. Such an attitude impedes the organisation's competitive advantage, even if the tangible product is best in class. Companies need to invest in change and transformation programmes, and there is a need to develop leaders that are both able and empowered to communicate across silos to gain a full understanding of service and what service innovation means.

Organisations should recognise the benefit of having academia provide cross-sectoral learning through a more abstract understanding of service, and should collaborate with universities on the use of STEM-based tools and techniques in services. This again, would require empowerment and leadership from the organisation to break through existing mindsets. Current service organisations often do not know how to work with academia, or fail to see how academia is able to help them. Due to a dearth of service-based STEM tools and techniques, academics do not have quick fixes and fast solutions either. Both parties need to come together on research projects that are able to advance knowledge in services and that are exploitable for organisations.

*Steps by universities*

Among the academics within the centre, we find that working with the service sector requires researchers to have a strong interdisciplinary inclination and to be relevant to practice; both qualities are a rarity amongst management academics. Solutions for STEM-based tools in service organisations are much more challenging academically, because they are not easily found and require bespoke intellectual input. The good news of course, is that there is greater scope for publishing academic papers. The challenge is to build research capacity of people who understand service and STEM techniques, who are inter-disciplinary and are able to work at an advanced level. It is not our contention that product-centric STEM-based technologies are not useful. On the contrary, many are immensely useful, but as academics we must be cognisant of the fact that service characteristics do change tools and if there is insufficient research into how and when such tools need modification, we run the risk of a potter being enslaved by his/her own clay.

Universities should recognise that silo-ed, mono-disciplined mentalities therefore inhibit engagement with the service sector. If the objective is to stimulate research into how an organisation can innovate in service, service itself should not be constrained by the political and territorial boundaries of disciplines. To be truly interdisciplinary so as to encourage innovative research, service needs to be free of its disciplinary boundaries, and the paradigmatic research influences of each discipline. In short, service needs to evolve into a discipline in its own right. Unfortunately, universities often have to manage practical issues such as 'which school or department should house the new discipline (of service)?' and the political nature of such a question has led to the service discipline being trapped by institutions' unwillingness to change. To engage with the service sector fully, service research should be liberated from school and departmental territories and sit autonomously within the university, free to bring in top academics of other disciplines to advance the cause of service innovation.

*Steps by government*

Government should proactively fund service research in areas that address the challenges stated above. Specifically, STEM tools and techniques that need modification due to the nature of service (perishability, inseparability, intangibility, heterogeneity) needs further research. In addition, the interface between academic leaders and business leaders in the service sector would also require investment. Industry has much to offer academia through the service innovation outcomes of entrepreneurialism and empowerment (for example, Google, etc.). Academia has also much to offer industry in providing abstracted language, tools and techniques (STEM or otherwise) so as to facilitate more cross-sector learning.

The government could offer small-scale grants for companies to work with academia. It is astonishing how even large companies e.g. RBS, TNT, Vodafone have little knowledge of working with academia. Funding to seed the process with small amounts of money would help initiate more joint projects. We have found KTP schemes in the area of services to be very useful in helping companies think of

STEM-based tools and techniques in services. A dedicated tranche of KTP funds for the service sector would be helpful.

We hope that our report is useful to the Royal Society. With productivity levels reaching their peaks in both the manufacturing and service sector, innovation is the next frontier. It is our firm belief that the service sector is in need of a paradigmic shift from a product-centric industrial era mindset. However, we do realise that change happens slowly, and will do what we can to participate in that change.

The centre gratefully acknowledges the contributions of Professor Roger Maull and Professor Ian Tonks in the construction of this report. If more information is needed, please do not hesitate to contact Professor Irene C L Ng, Director, Centre for Service Research at Irene.ng@exeter.ac.uk.

**University of Exeter**

## A) THE NATURE AND EXTENT OF LINKS BETWEEN STEM AND SERVICES SECTORS

1. Please tell us about two or three important services sector innovations that have been influenced by Science, Technology, Engineering and/or Maths (STEM) or other disciplines from your organisation over the last ten years.

(i) Using systems modeling to provide an innovative solution to the re-design of the Royal Devon & Exeter Hospital's Accident and Emergency unit subsequently implemented at the hospital and resulting in publication in a top-ranked journal.

(ii) Using high-end statistical verification for forecasting of extreme weather events and the implications of this for an global insurance and re-insurance company (Willis Network).

(iii) Applying whole-life costing (WLC) approach in combination with computational optimization techniques to capital and operational water distribution networks. The associated cost benefits arising from more efficient resource (infrastructural and water) management should be passed onto the consumer and the new approaches to underground asset management have world-wide potential with the UK water industry and its consulting agencies benefiting from a competitive edge in the consulting market.

(iv) Developed a 'whole business' complete systems architecture for a large parcel delivery company. The resulting systems model was used to test alternative business scenarios.

2. Was the influence of STEM and the other disciplines mainly: o Direct and formal – e.g. via formal relationships with firms or other organisations such as collaborative or contract research, consultancy, licensing arrangements? o Direct and informal – e.g. staff undertaking private consultancy? o Indirect – e.g. recruitment of graduates and post-graduates, the diffusion and application of knowledge and technology via intermediaries such as research and technology organisations, consultants and suppliers? o A combination of these, or none of these?

Potentially a combination of all these mechanisms but predominantly direct and formal via contract research or collaborative research (co-funded by the Research Councils), CASE studentships and KTPs.

3. Please tell us about your engagement with services organisations. Among other things we are interested in: o The sorts of services organisations that your institution is working with; o Where they are based; o Whether these engagements are growing in number and importance; o The types of IP arrangements that apply to your work with services organisations

The University is actively engaged – often through multi-level relationships - with service organisations drawn from several sectors that are regional, national and international in their operations. These include: Public Sector and Utilities (NHS/PCTs, South West Water, Thames Water, Yorkshire Water, The Met Office, Lyonnaise des Eaux, UKHO, National Air Traffic Service, Metropolitan Police, e-ON, EDF, Scottish Power, Local Authorities); Telecommunications (Vodafone UK, Vodafone Global, France Telecom, BT, Virgin Media); Finance and Insurance (Lloyds TSB, Scottish Widows, Britannia Building Society, Royal Bank of Scotland, AXA, Willis Network); Engineering and Business Consultancies (Lanner, Ewan Group).

These organisations are drawn from regional, national and international actors with numbers growing through active engagement with individual researchers as well as a number of dedicated research centres based at the University of Exeter such as the Centre for Services Research, the Centre for Water Systems, the Exeter Manufacturing Enterprise Centre (X-MEC) and the Exeter Centre for Research in Strategic Processes and Operations (XSPO).

With regard to IP arrangements, we start with the premise of IP share but each contract is individually negotiated dependent on the type of research/collaboration being undertaken, the anticipated outcomes and client needs.

4. What mechanisms does your institution use to support engagement with services sector organisations? (For example journals, industry-university consortia, conferences, collaborative research programmes supported by the Research Councils). o Is research activity in your institution steered by service organisations' innovation needs? If yes, how is academic research changing in response to these needs? o Has engagement with services organisations helped to shape the academic curriculum?

The Centre for Service Research convenes the "Service Science Form" which brings together a number of leading service organisations and academic researchers to explore challenges in the service industries. The University's Business Leaders Forum hosts four large-scale events per year which bring onto campus business leaders from over 100 regional organisations to network with the University's leading researchers and to demonstrate recent research advances in both STEM and social science sector relevant to business sectors.

The cross-disciplinary nature of service organisation needs has seen increased collaboration between our business/management researchers and colleagues within the School of Engineering, Computing and Mathematics (SECaM). Academic research is responding through increases in applied research activity (and increased academic recognition of the value of such research) and through academics seeking novel approaches and solutions to meet service organisations needs. These needs also shape PhD agendas where these are driven by industry needs via CASE awards and sponsorship.

Our academic curriculum is research-led and hence modules and teaching undertaken by those academics collaborating with industry, business and service organisations are inevitably influenced by their experience of applying advances in scientific knowledge and technologies to "real world" scenarios. In the area of service sciences this has led directly to the establishment of an MSc in Service Science and Management, an MSc in Financial Mathematics delivered jointly by SECaM and the Exeter Business School plus new modules on the MBA programmes.

**B) STEM, PEOPLE AND SERVICES SECTOR INNOVATION**

5. Please tell us about the movement of people between academic science environments and services organisations. Among other things we are interested in: o The employment of STEM graduates or scientifically trained people in services organizations; o The movement of people from innovative service environments into academic settings; o Whether you are working directly with services organisations on the development of STEM skills at the graduate/postgraduate level; o Whether you have evidence that services firm's STEM skills needs are changing (qualitatively or quantitatively)

Our Graduate Destination data for 2006/07 shows that 40% (208) of respondents (519) from the STEM subjects (biosciences, engineering, computing, mathematics and physics) were working in the

services sector in posts as diverse as Performance Analyst with Devon and Cornwall Police, Presenter in the Education Department, Living Coasts Zoo; Graduate Scheme, Thomson-Reuters. We identify the services sector to encompass public services, business and finance services, retail, and the utilities (water, energy, etc).

Senior practitioners are increasingly wishing to engage with latest research through 'Executive Education' programmes (leading to formal qualifications) or through extended 'visiting fellowships' which enables them to extend their research skills and understanding by undertaking independent research under the supervision of a leading academic.

We have visiting speaker programmes to undergraduate and MSc programmes within both the Exeter Business School and the School of Engineering, Computing and Mathematics.

There is anecdotal evidence that more systems modeling skills and computing skills are required although we have not carried out a systematic study of needs.

## C) ENHANCING THE CONTRIBUTION OF STEM TO SERVICES SECTOR INNOVATION

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| 6. We are interested in 'fertile areas' of the service economy (important business or societal challenges) in which the UK could develop, accelerate or scale-up innovative service capabilities, but which would require new or different offerings from the STEM community. Please tell us if your institution is working in any of the following (or other) areas which could underpin innovations in or across services sectors: o Data – e.g. information management, data security, data analysis, data modelling and visualisation and supply chain logistics? o The interface between people and services – e.g. human responses and interactions with services and systems? o People and skills – the development and supply of appropriately skilled and entrepreneurial individuals? |

We have expertise in advanced research in manufacturing technology, systems, and management including Agile, Lean and e-business/e-Manufacturing. Exeter Advanced Technologies (X-AT) has expertise in real-time data acquisition and processing, analysis and feedback; we can interface with high precision laboratory equipment, rapid prototyping and additive layered manufacturing equipment, and machining centres often, made available online via web pages or proprietary interfaces. Through its Informatics Research Institute, we are presently carrying out research in methods of very high density data storage (sub micron level) and new storage devices, materials and techniques to overcome barriers that face traditional storage/memory approaches.

During the past two years, Exeter has hosted approximately ten KTP Fellows within both STEM and business/management departments funded by organisations from the service sector.

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| 7. What are the main barriers to further links between your institution and services organisations? o What steps could be taken by companies, universities or government to enhance the impact of STEM on innovation in the services sectors? |

Financial resources remain a constant barrier to first-time engagement between academia and service organisations. Even large companies do not always have experience of working with academia nor do they recognise the time commitments required to identify, scope and develop even small-scale collaborative projects. Small grants for companies to seed fund work with academia – and demonstrate the value of *engaged* collaboration – would prove invaluable. This would also serve to rectify what

currently can be a "mismatch of aspirations" where an organisation believes the information they seek already exists and hence should be quick to deliver (suggesting consultancy rather than collaboration) which in turn alienates academic researchers who see little advantage in such work which fails to meet their RAE/REF aspirations.

Within STEM subjects where infrastructure costs can be high, consideration could be given to the RDAs contributing to the financial cost of such infrastructure (e.g. through subsidy of technician salary costs) to enable service organisations to access such infrastructure for exploratory/ experimental work.

Momenta and the Research Councils could consider the potential to encourage wider engagement through the simple measure of 'ringfencing' a tranche of money to support KTPs dedicated to engagement with the services sector. Consideration should be given for this to be inter-disciplinary (ie, not restricted to Research Council disciplinary 'silos') to enable genuine collaboration across the STEM subjects and social sciences to ensure the innovation agenda is taken .

**University of Portsmouth**

I am writing in response to your letter of 20 June seeking examples of ways in which STEM subjects have benefited the service sector in the UK over the past decade. I am sure that my University could find a number of important examples of the role of research in improving health but I imagine that you will have many of these from universities with a more comprehensive range of medically related research than we have in Portsmouth. So I have concentrated on two areas of innovative work and I shall be very happy to give you more details of these in you feel it would be appropriate to pursue them further.

The first example comes from our activities in human physiology. Our team in this area has made major advances to the analysis of the response of the human body to extreme conditions, particularly heat and cold. We have had contracts with a number of organisations including the Royal Navy, the RNLI and companies working on oil platforms in the North Sea. These have tended to focus on the improvement of life-saving equipment and survival clothing for those who may fall into extremely cold water. There are several examples of the way in which the work that we have done has led to an improvement in safety equipment and no doubt therefore to considerable saving of lives. The same team has worked also with the Fire Service on the clothing needed for protection against extreme heat and I am sure that this has similarly led to improvement in standards. We have also been able to advise athletes on the improvement (in legal ways) of their performance in extremes of temperature, including advice to the current Olympic squad and to Sir Ranulph Fiennes before he has embarked on some of his more extreme adventures. The University has invested in significant equipment including chambers which can be heated and cooled and a swimming flume in which athletes' performance can be monitored.

In terms of the criteria mentioned in the notes attached to your letter, I can confirm that we have had collaborative and contract research and consultancy with a number of organisations and that we have trained a number of post-graduate students both in the use of the facilities and in monitoring techniques for assessing performance. The area has also proved fertile for undergraduate research topics for those studying Sport and Exercise Science. I should add that all of this work is conducted under appropriate medical supervision and we have a robust programme of ethical consideration of all such research projects. As far as I know there are no significant intellectual property issues in this area as we are not ourselves developing products for use in the life-saving sector but we are testing and no doubt suggesting improvements to the equipment through our work. I anticipate that this range of work will continue to grow and that our team of researchers and post-graduate students will continue to expand.

The second area which I would highlight concerns the work of our Department of Psychology particularly in relation to interviewing witnesses, including children, and the techniques which can be used to increase the probability of detecting that someone is not telling the truth. The work involves analysis of non-verbal behaviour and some physiological measures and challenges which are raised by conventional lie detection techniques. Conventionally these assume that liars are nervous and will show various reactions. The work that we are doing allows police forces and others to assess the likelihood that these reactions really do demonstrate that the individual is not telling the truth. The principal researcher in this area has a large project which is funded by the US and UK secret services (and again subject to significant ethical scrutiny) but the outcome of this is classified and it might therefore not be a very helpful project for the focus of your enquiry. We have a significant number of people in our physiology and criminology departments who are experts in assessing the appropriate methods of gaining truthful witness recall. This work has been influential within the Home Office and in Police forces in the UK and the US.

I shall be very happy to provide you with further information if either of these areas are of interest in formulating the response from the Royal Society in this area.

**Additional - University of Portsmouth**

I wrote to you a few days ago following your call for examples of the role of science in the service sector. One of my examples in that was the work of our human physiologists in improving survival prospects in extreme environments. Since I wrote I have heard that the team involved have won the Ergonomics Society Prize for the best PhD produced in 2008 (the Ulf Aberg Award). The student is Dr Tara Reilly whose research focuses on survival suits and sea survival scenarios, working with the R&D department of a Survival Training company in Canada. In the UK she has been responsible for the development of fitness standards for the Royal National Lifeboat Institution and she has published research regarding hyperbaric lifeboats and Offshore Oil work. In addition, the RNLI Occupational Fitness Standards work has been chosen as a finalist in the Safety and Health Practitioner awards run by the Institute of Occupational Safety and Health.

**University of Cumbria**

Thank you for your letter of the 20th June to Professor Carr. The University supports the need for a better understanding of the contribution that STEM research, education and training are making to the service sector. The University's response to the issues is as follows:

**1 & 2** The University identifies two broad categories of Innovation input from STEM subjects into the service sector: The first (direct) is concerned with scientific discoveries and technological innovations, for example, whereas the second (indirect) is concerned with 'enhancements in process or practice'. The nature of the University means that we currently have less that would fit in the former category but are potentially important contributors in the latter. Examples include:

- **i.** Medical Imaging: work in image perception and enhancing the 'diagnostic return' from medical images
- **ii.** Research into improving techniques in 'breaking bad news' to patients who have just been screened
- **iii.** Nursing/Midwifery and Occupational Therapy: Improving practice in patient care
- **iv.** Social Work: Enhancing advance practice in CBT
- **v.** Delivery of the Every Child Matters/Youth Matters agenda
- **vi.** In Education: Enhancing the teaching process in newly qualified teachers (not least in the STEM subjects) across the age-range and enhancing the role and development of Teaching Assistants

**3** The University works with a range of services across Cumbria, North Lancs and beyond particularly in Health, Social Care and Education. Since the inception of the University, and the greater emphasis on research and knowledge transfer partnerships, these engagements have been growing in number and importance. The University also works in the international arena, playing an important role on the world stage in the field of Image Perception.

**4** The University uses a variety of mechanisms to support engagement with the service sector including conferences, seminars, collaborative work and various publications. An example of the latter is the bi-annual Cumbria Economic Bulletin produced by the Centre for Regional Economic Development which is a multidisciplinary research centre within the University of Cumbria. The Bulletin is a way of providing significant socio-economic data to the local region for the information of Service and Business sectors.

**5** The University is keen to promote the movement of people between academic science environments and service organisations. Its graduates are highly employable and many with STEM/allied subject related backgrounds are employed in the service sectors particularly in the Education and Health sub sectors. The University works closely with service organisations on the development of service skills and this is intensifying as such organisations seek added value.

**6** The University is working in the fertile areas of the economy. A major example of this is the recent establishment of the Institute of Logistics and Supply Chain Management which will work with industry partners System Group and Stobart Group to contribute to business development and increased professionalism in the industry through offering full and part-time Foundation Degrees and other work based learning opportunities. This programme will have its emphasis on vocational study that meets the needs of individuals and employers.

**7** The main challenge in developing further links between the University and services organisations is the need to continue to communicate clearly to such organisations the role the University plays/can play in facilitating their work and to continue to develop productive links on this basis. More broadly in this context – in terms of enhancing the impact of STEM on innovation in the service sectors – is the influence the University has on improving the teaching of STEM subjects which enhances the number of children pursuing those subjects and thus enhances contributions in the future. This is vital if these disciplines are to flourish.

**Benfield UCL Hazard Research Centre**

**The Centre**

*The Benfield UCL Hazard Research Centre* (BUHRC) has been in existence since 1997. The Centre is hosted at UCL by the Departments of Earth Sciences and Space & Climate Physics, and is sponsored by the world's foremost independent risk intermediary, *Benfield*. The BUHRC is one of Europe's leading, multidisciplinary, natural hazard research centres, with more than 50 core staff, research students and affiliates. The Centre comprises three groups: Geological & Geotechnical Hazards, Climate Extremes & Seasonal Forecasting and Disaster Studies and Management. The Centre undertakes cutting-edge research into hazard mechanisms and processes, operates two post-graduate courses (M.Sc Geophysical Hazards; Postgraduate Certificate Natural Hazards for Insurers) and is involved in consultancy and knowledge exchange activities, in relation to the service (particularly financial services) sector.

**STEM input to Service Sector innovation**

Through the sponsorship agreement with risk intermediary, Benfield, the BUHRC has strong knowledge exchange and consultancy links with the financial services sector, most notably in the fields of re/insurance. STEM output generated by the Centre feeds service sector innovation through providing insurers, reinsurers and other stakeholders in the financial sector, with the intellectual and practical tools required to make more informed decisions in their day-to-day encounters with natural hazard exposure and loss. STEM output to the sector is accomplished via a number of strands.

- **Postgraduate teaching**: The BUHRC operates a unique science-based post-graduate certificate course in Natural Hazards for Insurers. This is the only academic course in the UK accredited by the Chartered Insurance Institute (CII). Successful completion of the NHFI programme will qualify the candidate for 60 non-unit specific credits at Advanced Diploma level towards the CII examinations framework. Alternatively a CII member may count the successful completion of the NHFI certificate towards CII Fellowship. The NHFI course is also linked to a modular UCL Masters programme in Geophysical Hazards, allowing successful certificate students to continue on the Masters programme. The NHFI certificate course attracts financial service professionals, including catastrophe modellers, brokers, underwriters and actuaries.

- **Human resources transfer**: Each year, 10 percent or more of our Geophysical Hazards Masters graduates take up positions working in the re/insurance sector, primarily in the field of catastrophe modelling. Two completed STEM PhD students have also joined the sector in the last five years, taking up more senior positions in the actuarial and catastrophe modelling fields.

- **Knowledge Exchange**:
    - *Training*: The Centre organises frequent one-day training workshops on topical hazard and risk science themes, which are held at City venues. Recent themes include: *Storm Force: What's New on the Windstorm Front; UK Flood: Recent Lessons and Future Prospects, and Shaking Cities: Current Issues in Urban Seismic Hazard and Risk*. Attendance at the workshops counts towards CPD targets for those studying for the ACII (Associate of the Chartered Insurance Institute) qualification. The BUHRC also offers companies in the financial services sector, bespoke, in-house, courses on more specific themes, such as anti-seismic design, ground conditions etc.

    - *Publication*: The BUHRC promotes further hazard and risk science knowledge exchange via two publication strands: (i) Issues in Risk Science, which is a thematic series of publications that addresses specific topics in hazard and risk science, such as *Tsunami*

*Hazards in the Atlantic Ocean; Earthquakes and a Brave New China* and *Future Flood: Risk Management in London and Along the Tidal Thames*, (ii) the annual Hazard & Risk Science Review. This is a digest for re/insurance professionals of the 'pick' of pertinent peer-reviewed hazard and risk science papers published in the preceding 12 months.

- **Product development**

With financial sponsorship and input from the re/insurance companies, the BUHRC has developed two innovative online products that enable businesses to assess risk and evaluate potential losses as a consequence of tropical cyclones and European windstorms. *Tropical Storm Risk* (http://tsr.mssl.ucl.ac.uk/tracker/dynamic/main_.html) uses cutting-edge science and technology to develop innovative products to benefit risk awareness and decision making in business, government and society. Examples include:

- Application of seasonal hurricane forecasts in U.S. property catastrophe reinsurance. Through a breakthrough in forecasting US hurricane activity published in *Nature*, and in collaboration with the Bank Leu, TSR has provided the first direct demonstration of the business relevance of hurricane forecasts for selling and buying (re)insurance cover.
- Tropical Storm Tracker and its forecast wind probabilities and wind fields. TSR has developed the leading global tracker on the market. Tropical Storm Tracker won the British Insurance Award for London Market Innovation of the Year in 2004. The judges cited that the Tracker was "innovative, relevant and unquestionably an asset to the London market".
- Seasonal probabilistic forecasts of basin and landfalling tropical cyclone activity worldwide. TSR has developed innovative probabilistic models for predicting seasonal basin and seasonal landfalling tropical cyclone activity in the North Atlantic, NW Pacific and Australian regions. These forecasts are updated monthly and provide skilful outlooks for assessing the likelihood of upcoming damage and disruption.
- Tropical storm alert feeds. During 2004 Tropical Storm Risk introduced tropical storm alert feeds to Reuters AlertNet, the global humanitarian news portal, and to the United Nations World Food Programme. There were 865,000 page views of TSR sourced content at AlertNet between February and September 2004.

*EuroTempest* (http://www.eurotempest.com/) provides innovative weather risk products to benefit the warning and management of weather risk across Europe. It offers a unique suite of products designed to meet the needs of those with exposure to extreme winter windstorms and unseasonal weather. EuroTempest's services are of specific benefit to insurers, reinsurers, risk managers and loss adjusters. EuroTempest can also provide services that are relevant to companies and organisations in other industry sectors whose performance is influenced by extreme high winds.

- **Research and consultancy**

Specific, commercial-in-confidence, hazard and risk science research studies are undertaken for a range of insurance, reinsurance and brokering companies within the financial sector. These have tended to focus on natural hazard risk evaluation and have been used by companies to make more informed decisions and to develop new and innovative re/insurance products.

**BMT Group Ltd**

**A) The nature and extent of links between STEM and services sectors**

1. Please tell us about two or three important innovations in your organisation that have been influenced by Science, Technology, Engineering and/or Maths (STEM) and other disciplines over the last ten years.

Since 1985 BMT has been involved in pioneering and developing innovative marine environment information systems for operational decision-support. For example:

**SARIS**: Search and Rescue Information System; a PC based decision-support system developed for UK Coast Guard Agency incorporating fast-time forecasting model to predict movement of drifting objects at sea and identify location areas and logistics needed to task the deployment of sea and airborne search assets. SARIS represented the first computerisation of the paper based IAMSAR (International Aeronautical and Maritime Search and Rescue) Manual for operational UK adoption. SARIS has been adopted by many European SAR agencies. SARIS is based on the OSIS (Oil Spill Information System) platform which pioneered the development decision-support systems incorporating fast-time simulation of complex marine environment processes, such as movement and fate of oil spills. OSIS became internationally recognised as the leading oil spill information system available with numerous world wide sales.

**PROTEUS** Pollution Risk Offshore Technical Evaluation System: a PC based decision-support system specially developed for offshore oil and gas industry sector to simulate the dispersion and dilution of aqueous discharges containing contaminants such as produced waters and drilling discharges and compute their impact on the surrounding marine environment and ecosystem. The basis for complex core components such as ecotoxological impact was derived from extensive collaborative research projects involving theoretical and experimental studies. The system involved a high level of STEM innovation including fast-time Lagrangian particle model simulation and random point contouring and visualisation. The system has been used extensively to address environmental impact compliance in the offshore oil and gas industry and is currently being migrated onto a web service platform to provide new improved levels of service and information.

**REMBRANT**: A PC based ship simulator incorporating mathematical models of ship hydrodynamic behaviour and responses together with ship characteristics used to investigate the manoeuvring and movement of large vessels and aid the training of ship pilots and masters. Incorporates long heritage of BMT ship testing and modelling research expertise. REMBRANT provides high level of 2D and 3D visualisation and has been adopted as training tool by the major cruise line operators today.

2. Was the influence of STEM and the other disciplines mainly: Internal – e.g. from your own research and development?; External and direct – e.g. via formal relationships with universities, research institutes or other firms such as collaborative or contract research, consultancy, licensing arrangements?; External and indirect – e.g. recruitment of graduates and post-graduates, the diffusion and application of knowledge and technology via intermediaries such as research and technology organisations, consultants and suppliers?; or a combination of these, or none of these?

BMT has developed a range of information service products in context of stand–alone (or web service based) marine environment information systems (MARIS). Their evolution and development is based on understanding market needs and proposing innovative products based on understanding the underlying technologies and adopting new research findings that may be developed internally or externally or in

collaboration. Our model is illustrated below by extracts from an internal document: discussing innovation product management in BMT.

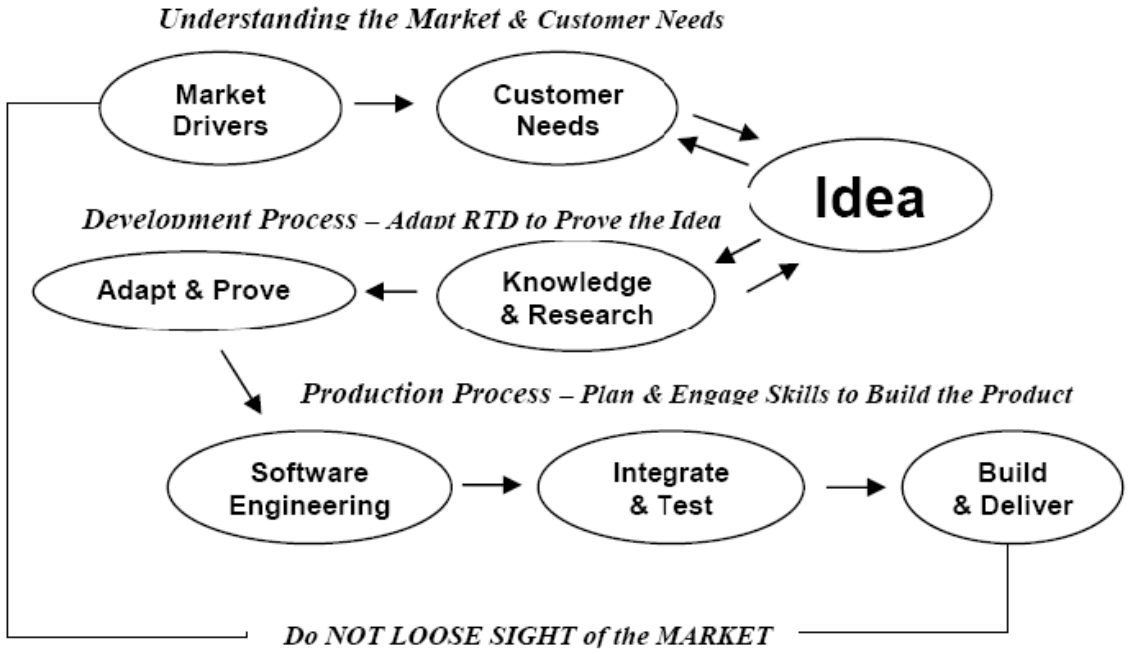


**Figure 3.** The innovation process chain from initial idea to end deliverable.

3. At which point(s) in your organisation‟s value chain does STEM contribute to innovation? How does the STEM input at this/these point/s impact innovation in your organisation? If possible, please describe the importance of the contribution of STEM in comparison to other factors in innovation in your organisation. The following comments address the question quite comprehensively and are again extracted from the internal BMT document on innovation product management.
The following comments address the question quite comprehensively and are again extracted from the internal BMT document on innovation product management:

The diagram presents three distinct components or phases;

I. *Understanding the market* drivers and customer needs in order to underpin any new product/services idea that addresses emerging drivers and needs. The idea will invariably be founded in some perceived adoption of research knowledge.
II. The *development process* is the real *innovation proving phase* where appropriate research knowledge and expertise has to be invoked and adapted to demonstrate the validity of the initial proposition.
III. The *production process* is simply the final phase of planning and executing the build of the product which requires input of *software engineering* skills.

Success and continuity is dependant (wholly) on understanding and facilitating the human factor elements that are involved namely;

- *The idea* is generally proposed by one individual who has good understanding of the market and may (should) also have relevant research knowledge. That individual is motivated by belief in the idea and a desire to show it will work.
- *Proving the idea* involves engaging a *knowledge expert* with appropriate research expertise and adaptation skills – mathematical and programming. This person becomes a key co-owner of the idea and its realisation as a product. A close working relation develops with the idea originator.
- *Producing the product* depends on its complexity but generally involves software engineering expertise that works directly with the knowledge expert to build and test an operational prototype. Once approved the final production system can be produced under supervision of the software manager.

The human elements in the innovation process can be represented simply as;


**Figure 4.** The human elements making up the innovation process chain.

In early PC based technology environments – the knowledge expert was often also the software engineer. In later more advanced PC environments the requirement for separate software engineering expertise becomes established. In order for things to work – it is necessary to have ***mutual trust, mutual respect and continuity***. If any of these is damaged the whole process will fragment and eventually fail.

4a. What mechanisms does your organisation use to support engagement with the STEM community in universities and research institutes? (For example journals, industry-university consortia, conferences, collaborative research programmes supported by the Research Councils).

Lead knowledge experts involved in new product development in BMT are drawn from research institutes and universities. BMT has a long heritage of maritime research innovation and prior to privatisation in 1985 represented the two leading UK research laboratories; NMI (National Maritime Institute) and BSRA (British Ship Research Association). BMT now consists of a group of 30 companies distributed internationally; most of them are founded in some form of specialised STEM activity.

BMT is a key participant in collaborative UK and European research programmes and senior staff act as advisors and evaluators to FP6/7, NERC and EPSRC programmes.

Several BMT experts are members of NERC Peer Review College and have been closely associated with guiding development of e-Science in NERC and CCLRC.

BMT is active in conferences and speciality workshops related to market sectors.

In 1992 BMT established the first joint venture with Polish Academy of Sciences. The company is now a fully owned subsidiary of BMT and is the leading exponent of innovative large scale GIS applications in Poland; e.g., noise mapping of Warsaw.

In 1999/200 BMT proposed to sponsor the establishment of a new research Chair in the emerging field of marine informatics; the Chair was established at Reading University in 2000 and is hosted at ESSC; a NERC centre of excellence.

4b Do your organisation"s innovation needs steer research activity in academia? If yes, how is academic research changing in response to these needs?

YES: Our future vision of commercial scale services in environment information systems recognised the need to exploit advances in web service architectures, collaborative computation systems, global climate modelling, satellite remote sensing and the transfer and visualisation of large data volumes over the internet. Several of these topic areas developed into core themes of research at ESSC which is now established as a lead centre in environmental e-Science research in UK.

BMT believes that it has helped to stimulate the emergence of environment informatics as a key integrated multidiscipline science for environmental systems innovation in the UK science sector.

4c Has engagement with the universities helped to shape the academic curriculum?

BMT has minimal input into academic content of emerging "environment informatics" courses. Environment informatics is deemed to have originated in UK academia!

**B) STEM, people and services sector innovation**

5. Please tell us about scientifically trained people employed in your organisation. Among other things we are interested in: Numbers/proportions of employees who are STEM graduates or scientifically trained; The kinds of roles they occupy and how this has changed in the last five to ten years; Whether STEM graduates/postgraduates are meeting your requirements; Whether you expect your organisation"s STEM skills needs to change (qualitatively or quantitatively) in the next five to ten years (and if so, why).

BMT has a staff compliment of 1200; 80% are graduates and of these 35-40% are science graduates/postgrads.

Most BMT S&T graduate are engaged in contract project work, consultancy and project management. Some 30-50% will be engaged in innovative project activities and 10-15% in product development and research related activities.

It is difficult to find graduates (or postgraduates) with the levels of knowledge, training and skills needed to support innovation requirements in today"s BMT marketplace. This is why BMT invests in nurturing advanced knowledge transfer and exchange mechanisms such as the BMT Chair of marine informatics at Reading University.

As BMT increases effort to develop the emerging opportunities within the environment information services market – there will be a demand placed for specialist STEM staff to work in that particular market sector.

6. Please tell us about the influence of service users or customers on innovation in your organisation. Among other things we are interested in: Whether and how you involve users/customers in your innovation processes; How STEM can help your organisation to understand consumer needs and their responses to service innovations; Whether developments in STEM (e.g. ICT) are driving customer demand for, and consumption of, innovative services.

As illustrated in the Figure 3 diagram above and described under item 3; customers are very closely involved in the innovation process for new services.

STEM is already used in how BMT addresses customer needs. As for the customer; he is often unable to appreciate STEM or has no interest – as long as it provides a more cost effective and improved performing product or service.

Advances in ICT should be regarded both as important drivers and enablers of customer demand of new innovative services. Advances in communication systems, computation resources and web service technology will profoundly change the whole market for information service provision and stimulate development of whole new generations of innovative information products and services.

*UK seems to be presently unaware of the needs involved to position itself to address the change and the opportunities – the UK e-Science programme which has only now began to foster effective cross-discipline collaboration and uptake of ICT across the academic research community has ended with no forward strategy in place.*

**C) Enhancing the contribution of STEM to services sector innovation**

7. We are interested in „fertile areas" of the service economy in which the UK could develop, accelerate or scale-up innovative service capabilities. Please describe two or three important business opportunities or strategic challenges faced by your organisation that would require new or different offerings from the STEM community. If appropriate, please expand on any developments relating to innovative capabilities in the following areas (or any others): Data – e.g. information management, data security, data analysis, data modelling and visualisation and supply chain logistics. The interface between people and services – e.g. human responses and interactions with services and systems. People and skills – the development and supply of appropriately skilled and entrepreneurial individuals.

All the above issues are extremely relevant and in the case of marine data a new integrated approach is being coordinated by DEFRA however; these issues need to be addressed within a holistic e-Science framework that embraces the various science research disciplines within new informatics driven cross-discipline themes focused on innovative knowledge derived products and services.

For example; if UK industry is to become proactive in developing innovative environmental services (which I believe is the role and obligation for industry) then it needs easy access to data (measurements and

model generated) held within the UK academic research community and government agencies. This presents major obstacles in UK and also challenges a perception that innovation is the preserve of academia and not industry. This conflict has to be addressed.

As noted above – the crucial e-Science enabling programme has now been phased out and, industry is not being engaged to guide the academic strategy of innovation management for developing information services of the future. *Absence of these features will serve to disable UK's ability and competitiveness in innovation.*

8. Where you would expect to access this specific STEM input from? (Inside your own organisation? Other businesses? UK universities? Overseas universities? Other sources? A mixture of these?).

The enabling components for STEM and the adopting practitioners have to generated within the UK academic research sector, this in turn requires a holistic vision and strategy that embraces the role of ICT and e-Science as key enablers that have to form a part of a revised higher education agenda. See my other comments above.

9a. What are the main barriers to further links between your organisation and the STEM community?

No barriers regarding BMT and STEMS community. My concern is for the rest of UK industry and academia.

9b What steps could be taken by companies, universities or government to enhance the impact of STEM on innovation in the services sectors?

First there is need to establish a more formal analysis of the innovation process ( such as indicated in Figure 3 above) and then map it onto the particular service sector of interest. I believe that there is a deep inconsistency in the understanding of knowledge transfer and innovation management across both academia and industry; and there is *need for industry and academia to share a common view of the innovation process and to agree respective contributions to it.*

Since web service driven information products offer a major market opportunity for the future it is necessary to look closely at the components making up the innovation process chain. It is evident that cross-discipline sciences within a geospatial informatics framework are the enabling elements that will produce the type of innovative service needed to meet emerging and future needs. *This has to be recognised and adopted within the UK higher education strategy.*

Since the latter requirements *are not* features easily accommodated in the UK academic environment; it becomes necessary to find ways of fostering change quickly.

The role and *importance of e-Science should be reappraised urgently* and if necessary a new programme for its further integration and adoption into the academic research and education sector should be put in place.

*Industry must be engaged more closely* in moving forward any agenda for stimulating development of innovative services in UK.

## BT Centre for Major Programme Management

The BT Centre for Major Programme Management at the University of Oxford Saïd Business School was established by a donation from BT and launched in November 2007 under the Academic Directorship of Dr Janet Smart.

[A major programme is defined as a suite of projects that together approach US$1 billion in cost and last at least five years. Major programmes are highly complex, and managers of such programmes require knowledge of systems engineering, commercial and contract law, lifecycle planning, risk management, programmatics, organisation leadership and communication. Major programmes are likely to involve multi-national consortia, so awareness of legal and cultural practices in different countries and organisations is also essential. Examples of major programmes include large-scale IT projects, construction projects, aeronautical projects, and major events such as the Olympics. Typically their outcome impacts millions of people.]

The BT Centre for Major Programme Management aims to become the pre-eminent world-wide centre of knowledge and expertise on major programme management. Members of the Centre will collaborate with leading international academics and practitioners in the field to build up a collection of case studies and exemplars from sectors such as construction, ICT, banking, and energy. The research will be multi-disciplinary, involving engineering, economics, law, computer science, finance and management.

The Centre will become a resource for practitioners and policy-makers to locate the latest thinking on specialist topics, as well as being the natural home for the best postdoctoral talent to pursue research into topics relating to major programme management. Members of the Centre will disseminate their research findings via working papers, published articles and monographs, seminars, and an annual conference, aiming to reach the widest possible audience

The research agenda of the BT Centre builds on links with colleagues around the University (including the Computing Laboratory, Engineering Sciences, Oxford e-Research Centre, and the Oxford Internet Institute).
A new MSc course on Major Programme Management will admit its first students in October 2009. The MSc in Major Programme Management is aimed at students from a mix of technical and commercial backgrounds. Consequently, the course will combine technical elements (e.g. Systems Engineering) with management science components (e.g. Organisational Behaviour).

The links with external organizations take many forms:

· Direct and formal : The link with BT is of this nature, since they provided the endowment for the chair, and are keen to contribute to the shaping and delivery of the Centre. They are also committed to helping with the recruitment of students. BT is represented on the Advisory Board of the BT Centre and on its Steering Committee.

· Indirect: In setting up the BT Centre, BT made it clear that they were doing so to address the shortage of suitably qualified and experienced personnel in the area of programme management. They are assisting with the marketing of the new MSc in Major Programme Management course by encouraging their collaborators, suppliers, clients and other global organizations to send students on the course. Examples include Raytheon (USA), NATO, Systematic (Denmark), Lockheed-Martin (USA), Ericsson (Italy),

NHS, Department of Work and Pensions (DWP) and Infocom Development Authority (Singapore). Students currently applying to the course come from a wide range of organizations and sectors, including transport, charitable foundations, banks and consultancies.

The BT Centre interacts with the project and programme management sector in a number of ways, including: through links with professional organizations; running joint academic-practitioner workshops; customized executive education courses; and high profile lectures. In addition, the BT Centre Advisory Board includes representatives from industry and government.

The service organizations that work with the BT Centre are drawn from a range of sectors including IT, construction and transport, banks, and engineering consultancies.

The BT Centre is very keen to encourage participation from service organizations, in the broadest sense, so the number and type of interactions will continue to grow. We anticipate that the teaching- and research-based links will broaden and deepen as the BT Centre develops over the next two to three years.