RCUK REVIEW OF e-SCIENCE IN THE UNITED KINGDOM

EVIDENCE TO THE PANEL

NOVEMBER 2009

Research Councils UK (RCUK)
Polaris House, North Star Avenue
Swindon, SN2 1ET
Wiltshire, UK

http://www.rcuk.ac.uk
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1. Preface and Summary

This document has been produced in preparation for the 2009 RCUK Review of e-Science. The review is being organised by EPSRC, on behalf of RCUK and aims to inform stakeholders about the quality and impact of the UK science base.

The purpose of this document is to provide an overview of research in e-Science in the UK in terms of its people, funding, organisation and policy. This should inform the Review Panel’s deliberations as it addresses the issues raised in the evidence framework.

A variety of background data has been used and sources are acknowledged. The data has been provided for use by the Review Panel and will be published on the RCUK web site on completion of the Review (documentation provided in confidence will not be published). No data from this document may be quoted or used publicly without written permission from EPSRC.

Evidence in this document has been compiled from the Research Councils' management records and the UK e-Science research community. Note that due to the variety of sources some data is more up to date than others. However, wherever possible dates of the financial years 2001 to 2008 has been taken (UK financial years run from 1 April to 31 March).

Additionally panel members should note that the Research Council data in this document refers to the ‘e-Science Programme’, and the ‘e-Science Core Programme’ which now no longer exist.

It must be remembered when reading this document that no inferences or conclusions have been made from the data by the writers. It is not the purpose of this document to steer the opinion of the Panel in any way but merely to present the Panel with information it may interpret as it sees fit.

Authors: Jo Garrad and Sarah Fulford
Contributors: David Robey, AHRC
Michael Ball and David McAllister, BBSRC
Susie Douglas, EPSRC
Suzanne Mills, ESRC
Ghada Zoubiane, MRC
Michelle Truman, NERC
Trish Mullins and Malcolm Booy, STFC
The e-Science research community
### Table of acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AHM</td>
<td>All Hands Meeting</td>
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<tr>
<td>AHRC</td>
<td>Arts and Humanities Research Council</td>
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<tr>
<td>BBSRC</td>
<td>Biotechnology and Biological Sciences Research Council</td>
</tr>
<tr>
<td>BEP</td>
<td>Bioinformatics E-Science Programme</td>
</tr>
<tr>
<td>BERR</td>
<td>Department for Business, Enterprise and Regulatory Reform</td>
</tr>
<tr>
<td>BIS</td>
<td>Business, Innovation and Skills Department (established 2009)</td>
</tr>
<tr>
<td>CCLRC</td>
<td>Council for the Central Laboratory of the Research Councils</td>
</tr>
<tr>
<td>CERN</td>
<td>European Organisation for Nuclear Research</td>
</tr>
<tr>
<td>Co-I</td>
<td>Co-investigator</td>
</tr>
<tr>
<td>CSA</td>
<td>Chief Scientific Advisor</td>
</tr>
<tr>
<td>CSR</td>
<td>Comprehensive Spending Review</td>
</tr>
<tr>
<td>DELNI</td>
<td>Department of Education and Learning in Northern Ireland</td>
</tr>
<tr>
<td>DGSI</td>
<td>Director General of Science and Innovation</td>
</tr>
<tr>
<td>DIUS</td>
<td>Department of Innovation Universities and Skills</td>
</tr>
<tr>
<td>DTA</td>
<td>Doctoral Training Account</td>
</tr>
<tr>
<td>DTC</td>
<td>Doctoral Training Centre</td>
</tr>
<tr>
<td>DTI</td>
<td>Department of Trade and Industry (Abolished 2007)</td>
</tr>
<tr>
<td>EPSRC</td>
<td>Engineering and Physical Sciences Research Council</td>
</tr>
<tr>
<td>ESRC</td>
<td>Economic and Social Research Council</td>
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<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>fEC</td>
<td>Full Economic Costing</td>
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<tr>
<td>FTE</td>
<td>Full-Time Equivalent</td>
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<tr>
<td>HE / HEI</td>
<td>Higher Education / Higher Education Institution</td>
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<tr>
<td>HECToR</td>
<td>High End Computing Terascale Resources</td>
</tr>
<tr>
<td>HEFCE</td>
<td>Higher Education Funding Council for England</td>
</tr>
<tr>
<td>HEFCW</td>
<td>Higher Education Funding Council for Wales</td>
</tr>
<tr>
<td>HESA</td>
<td>Higher Education Statistics Agency</td>
</tr>
<tr>
<td>HPC</td>
<td>High Performance Computing</td>
</tr>
<tr>
<td>ICT</td>
<td>Information &amp; Communications Technology</td>
</tr>
<tr>
<td>ILL</td>
<td>Institut Laue-Langevin (France)</td>
</tr>
<tr>
<td>IP/IPR</td>
<td>Intellectual Property / Intellectual Property Rights</td>
</tr>
<tr>
<td>JISC</td>
<td>Joint Information Systems Committee</td>
</tr>
<tr>
<td>KT/KTN</td>
<td>Knowledge Transfer / Knowledge Transfer Network</td>
</tr>
<tr>
<td>KTP</td>
<td>Knowledge Transfer Partnership</td>
</tr>
<tr>
<td>LHC</td>
<td>Large Hadron Collider</td>
</tr>
<tr>
<td>MOD</td>
<td>Ministry of Defence</td>
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<tr>
<td>MRC</td>
<td>Medical Research Council</td>
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<tr>
<td>NCeSS</td>
<td>National Centre for e-Social Science</td>
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<tr>
<td>NERC</td>
<td>Natural Environment Research Council</td>
</tr>
<tr>
<td>NSF</td>
<td>National Science Foundation (US counterpart to UK Research Councils)</td>
</tr>
</tbody>
</table>

*In 2009, BERR merged with another Government department (DIUS) to form BIS (dept. for Business Innovation and Skills)*

*Formerly DIUS and BERR*

*Merged with PPARC to become STFC (Science and Technology Facilities Council)*

*Formerly OSI. In 2009, DIUS merged with another Government dept. (BERR) to form BIS (dept. for Business Innovation and Skills)*

*When the DTI closed many of its functions were transferred to BERR*
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Name</th>
<th>Description</th>
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<tbody>
<tr>
<td>OSI</td>
<td>Office of Science and Innovation</td>
<td>OSI was a Government department which was formerly known as OST (Office of Science and Technology), and became DIUS (Dept. for Innovation University and Skills)</td>
</tr>
<tr>
<td>OST</td>
<td>Office of Science and Technology</td>
<td>OST was established in 2007 and then became the OSI</td>
</tr>
<tr>
<td>PI</td>
<td>Principal Investigator</td>
<td></td>
</tr>
<tr>
<td>PPARC</td>
<td>Particle Physics and Astronomy Research Council</td>
<td>Merged with CCLRC to form STFC (Science and Technology Facility Council)</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
<td></td>
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<tr>
<td>RA</td>
<td>Research Assistant</td>
<td></td>
</tr>
<tr>
<td>RAE</td>
<td>Research Assessment Exercise</td>
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<tr>
<td>RAL</td>
<td>Rutherford Appleton Laboratory</td>
<td></td>
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<tr>
<td>RCUK</td>
<td>Research Councils United Kingdom</td>
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<tr>
<td>RDA</td>
<td>Regional Development Agency</td>
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<tr>
<td>SFC</td>
<td>Scottish Funding Council</td>
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<tr>
<td>SME</td>
<td>Small / Medium sized Enterprise</td>
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<td>SR</td>
<td>Spending Review</td>
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<tr>
<td>SRIF</td>
<td>Science Research Investment Fund</td>
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</tr>
<tr>
<td>STFC</td>
<td>Science and Technology Facilities Council</td>
<td>Formerly PPARC and CCLRC</td>
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</table>

1.1.1 Shown below is a diagram of the structural changes to the Government departments that support research.

**Figure 1** Structural changes to Government departments that support research

[Diagram showing structural changes from pre-2007 to 2007 to 2008]

- Pre 2007: Department for Trade and Industry (DTI) with Office for Science and Innovation
- 2007: Department for Innovation and Skills (DIUS), Research Councils, Technology Strategy Board
- 2008: Department for Business Innovation and Skills (BIS), Research Councils, Technology Strategy Board
1.2 Review of e-Science evidence framework

A framework is provided to assist the Panel during the Review week. The use of a standard framework is important in order to ensure coverage of all relevant strategic issues. The framework is not intended to restrict the panel; additional issues can be addressed as they arise. However, it is deemed helpful to have a framework for reference during the information-gathering and particularly in formulating conclusions and recommendations. The questions below were used for the public consultation exercise, which can be found in section 4. These questions have also been formulated in the ‘Panel Member diaries’, which are part of your panel pack.

A. Did the UK e-Science Programme build a Platform which enables e-Science tools, infrastructure and practises to become incorporated into mainstream research in the UK?

- Did the Programme create a critical mass of capability in developing and exploiting e-Science tools and techniques? Is this capacity being sustained?
- To what extent have the e-Science technologies developed through the Programme changed the way researchers in other disciplines work? Are there new areas of research that have been enabled by the e-Science Programme? What can be done to increase this happening? Are the present infrastructure and communication channels sufficient?
- To what extent did the e-Science Programme contribute to and benefit from multi-disciplinary research? What barriers to such research did the Programme overcome and what opportunities did it enable?
- How effective is the education/training of e-Science practises and techniques at ensuring sufficient take up and adoption? What barriers to effective knowledge exchange and information flow remain and how can they be overcome? What are the barriers to the uptake of these tools and techniques?

B. How does UK e-Science activity compare globally?

- How developed is the global e-Science Platform, and what has been UK e-Science Programme contribution?
- To what extent did the research undertaken through the Programme engage in “best with best” science-driven international interactions?
- In which areas of e-Science is the UK the international leader? What has contributed to UK strengths and what are the recommendations for continued strength? In which areas is the UK less strong and what are the recommendations for improvement?
- Are there sufficient numbers of research leaders of international stature evident in the UK, in comparison to other countries? If not, which areas have potential for growth?
- How does the UK compare internationally with its ability to attract, nurture and support e-Science researchers at every stage of their career?
- In the past eight years how has the UK’s global reputation for e-Science research changed?

C. What has been the impact (accomplished and potential) of the UK e-Science Programme?

- To what extent has the research undertaken through the e-Science Programme benefited the UK economy and our global competitiveness?
- To what extent did the research undertaken through the UK e-Science Programme address key technological/societal challenges?
- What evidence is there to show that the UK e-Science Programme supported the development of a creative and adventurous research base and portfolio?
D. What are the future opportunities for UK e-Science?

- Is the research community appropriately structured to respond to current and emerging technological/societal challenges? If not, what improvements could be implemented?
- What are the current strengths, weaknesses and opportunities in UK e-Science?
- Where should the Research Councils focus support for e-Science activity in the future?

E. How did the Programme Strategy (having a Core and individual Research Council Programmes, developing tools and applications in parallel) affect the outputs from UK e-Science?

- What progress would have occurred if a specific Programme had not been in place?
- What was the impact of the Programme on the provision of skills and trained people in the UK?
- What was the ‘added value’ of the Programme strategy? Is this a good model for cross-council Programmes? Could the model be improved and if so in what way?
<table>
<thead>
<tr>
<th>RCUK Review of e-Science 2009</th>
<th>Section 1</th>
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<tr>
<td>Information for the Panel</td>
<td>Overview: Funding of Science and Innovation in the UK</td>
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</table>

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2. **Current UK Science and Innovation Policy and Research Funding Overview**

### 2.1 Setting the scene – key developments in science and innovation in the UK

The main developments that have occurred in the UK over the last 5 years are listed below:

#### 2.1.1 Publication of the **“Science and Innovation Investment Framework (2004 – 2014)”** – government's long-term vision for UK science and innovation, together with ambitions for public and private investment in R&D to reach 2.5 per cent of GDP by 2014. The framework's main challenge to the research councils is to deliver two key outputs:

- **Output 1:** a healthy research base
- **Output 2:** better exploitation of research.

#### 2.1.2 Increased emphasis on knowledge transfer and economic impact, specifically through the **“Warry report”** which made recommendations on how research councils can deliver and demonstrate that they are delivering a major increase in economic impact, highlighting:

- The research councils’ role in leadership of the knowledge transfer agenda;
- Their role in influencing knowledge transfer behaviour of universities and research council institutes; and,
- The increase in their own direct engagement with user organisations.

#### 2.1.3 Establishment of the Technology Strategy Board as an independent body tasked with stimulating innovation in those areas which offer the greatest scope for boosting UK growth and productivity.

#### 2.1.4 Formation of the Science and Technology Facilities Council (STFC) in April 2007 by merging the Particle Physics & Astronomy Research Council (PPARC) and the Council for the Central Laboratory of the Research Councils (CCLRC).

#### 2.1.5 Proposals for the reform of the Research Assessment Exercise (RAE) after 2008 with the introduction of a more metrics-based approach.

#### 2.1.6 Changes in June 2007 to the structure of relevant Government departments. This led to the abolition of the Department of Trade and Industry (DTI) which was the Government department responsible for promoting the interests of UK businesses, employees and consumers. The Office of Science and Innovation (OSI) was hosted within the DTI which was also abolished. The OSI led for Government in supporting science, engineering and technology. The research councils reported to this Office. DTI and OSI were replaced by two new departments: the Department for Innovation, Universities and Skills (DIUS) and the Department for Business, Enterprise and Regulatory Reform (BERR). BERR's strengths were in shaping the enterprise environment, analysing the strengths and needs of the various parts of British industry, building strategies for industrial strength and having expertise in better regulation. DIUS's expertise was in maintaining world class universities, expanding access to higher education, investing in the UK's science base and shaping skills policy and innovation through bodies such as the Technology Strategy Board.

#### 2.1.7 DIUS and BERR have now been replaced by the Department for Business, Innovation and Skills (BIS).

**Department for Business, Innovation and Skills**

#### 2.1.8 The key mandate for BIS is to build Britain's capabilities to compete in the global economy. The Department was created by merging BERR and DIUS, creating a single department committed to building Britain's future economic strengths. It is suggested that to compete in a global economy and create the jobs of the future, Britain requires a regulatory environment that
encourages enterprise, skilled people, innovation, and world-class science and research. The merger of BERR and DIUS brings together the parts of the Government with key expertise in these areas. The change puts the UK's further education system and universities closer to the heart of Government with the idea that there is a chance to begin building now for the future economic upturn.

2.1.9 A Government Office for Science within BIS, headed by the Chief Scientific Adviser (CSA), reports directly to the Prime Minister and Cabinet on BIS’s progress towards its objectives. The CSA is an appointment of the Prime Minister, although the post is based in BIS. The remit of the CSA is to provide scientific advice to the Prime Minister and Cabinet. They have a responsibility across all Government departments (some of which have their own scientific advisors). Professor John Beddington took up the post of CSA on 1 January 2008. Previously he had been Professor of Applied Population Biology at Imperial College, London.

2.1.10 BIS manages the allocation of the “Science Budget” (currently over £3 billion per annum) into research via the seven research councils for which the Director General of Science and Innovation (DGSI), Professor Adrian Smith, is responsible. The DGSI is responsible for securing the successful and high-quality operation of the research councils and advising the Minister for Innovation, Universities and Skills on the allocation of the funds to the research councils, the Royal Society and the Royal Academy of Engineering. Prior to his current post, Professor Smith was Principal of Queen Mary, University of London for 10 years and previously he was at Imperial College, London, where he held a number of posts over an eight year period.

Technology Strategy Board

2.1.11 The Technology Strategy Board’s primary aim is not the creation of knowledge, but the translation of knowledge into innovation and new and improved products and services. The research councils have an on-going and increasing portfolio of engagement with the Technology Strategy Board to help them achieve their objectives. Technology Strategy Board funding over the next three years will be over £1 billion. This is planned to include co-funding of at least £120 million from the research councils, and co-funding of £180 million from the Regional Development Agencies. The Technology Strategy Board operates in a similar way to the research councils and is located on the same site.
2.2 How funding for science is secured

2.2.1 The science budget is set by the Government's Spending Reviews (SRs). This is the mechanism used by Her Majesty’s Treasury by which they determine how much tax payers’ money is put into various Government priorities. Each SR sets a three year budget for Government departments and associated targets. SRs overlap so that the last year of one SR period is also the first year of the next SR period. In addition to the SRs there are Comprehensive Spending Reviews (CSR) which start from a zero base rather than starting from existing spending levels and set the spending policy for periods of ten years. The last CSR was held in 2007 and the CSR prior to that was held in 1998.

2.2.2 Within the Spending Review framework, Treasury sets the overall limit for public spending and allocates resources between departments, according to Government's priorities and in the light of individual bids from the departments setting out their needs for funds. It is then up to departments to decide how best to manage and distribute this spending within their own areas.

2.2.3 BIS’s bid to Treasury is based on cases made by the research councils through delivery plan bidding documents. The delivery plans set out each council’s funding priorities and outline the activities that they intend to undertake over the spending review period. They form part of a comprehensive performance management framework which enables BIS to demonstrate the contribution that each research council is making towards achieving Government targets. More details are available at: [http://www.rcuk.ac.uk/aboutrcuk/deliveryplan](http://www.rcuk.ac.uk/aboutrcuk/deliveryplan).

2.2.4 The research councils’ delivery plans are developed following wide-ranging consultations with a broad range of stakeholders, including other research councils, researchers, industry and business. The final allocation to individual research councils is made by the Science Minister and the DGSI based on the proposals outlined in the delivery plans.

2.2.5 The 2007 Comprehensive Spending Review (CSR) provides BIS with a total budget of £18.7 billion in 2008-09, £19.7 billion in 2009-10 and £20.8 billion in 2010-11 for all their activities (not just the science component). This is equivalent to a 2.2% annual average real growth. This includes a 2.5% increase in real terms in the UK's public science base over the CSR07 period (2008 – 2011); and a 2% increase on spending on higher education and skills over the same period.

2.2.6 The research councils will use the additional funding to support new activities in six interdisciplinary programmes:

- Energy;
- Living with environmental change;
- Global security;
- Ageing research: lifelong health and wellbeing;
- Nanoscience through engineering to application; and
- Digital economy.

2.3 Funding for research

Introduction

2.3.1 There are two primary streams for the public funding of research in the UK. This approach is known as the ‘Dual Support System’. The first stream comes from Quality-Related funding which is provided to universities through the funding councils (e.g. HEFCE) as block grants. The level of funding is based on quality ratings of departments determined through the Research Assessment Exercise (RAE) and the volume of research activity. The other stream of research funding comes through the research councils. The total funding for research provided under the two streams comes close to £5 billion in 2008/09. Table 1 shows the distribution between the research and funding councils. It also shows that over the past 5 years there has been a relative shift from Quality-Related or funding council allocations, to the research councils’ allocations. The budget for the research councils has increased by 46%, whilst for the funding councils there has only been a 34% increase.
Table 1 - Research councils and funding councils research budget allocations for 2004/05 to 2010/11 (£000s)

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</tr>
</thead>
<tbody>
<tr>
<td>AHRC</td>
<td>67,746</td>
<td>80,536</td>
<td>91,379</td>
<td>96,792</td>
<td>103,492</td>
<td>53%</td>
<td>104,397</td>
<td>108,827</td>
<td>61%</td>
</tr>
<tr>
<td>BBSRC</td>
<td>287,571</td>
<td>336,186</td>
<td>371,644</td>
<td>386,854</td>
<td>427,000</td>
<td>48%</td>
<td>452,563</td>
<td>471,057</td>
<td>64%</td>
</tr>
<tr>
<td>EPSRC</td>
<td>497,318</td>
<td>568,193</td>
<td>636,294</td>
<td>711,112</td>
<td>795,057</td>
<td>60%</td>
<td>814,528</td>
<td>843,465</td>
<td>70%</td>
</tr>
<tr>
<td>ESRC</td>
<td>105,252</td>
<td>123,465</td>
<td>142,468</td>
<td>149,881</td>
<td>164,924</td>
<td>57%</td>
<td>170,614</td>
<td>177,574</td>
<td>69%</td>
</tr>
<tr>
<td>MRC</td>
<td>455,279</td>
<td>478,787</td>
<td>503,461</td>
<td>543,399</td>
<td>605,538</td>
<td>33%</td>
<td>658,472</td>
<td>707,025</td>
<td>55%</td>
</tr>
<tr>
<td>NERC</td>
<td>314,256</td>
<td>334,047</td>
<td>359,367</td>
<td>372,398</td>
<td>392,150</td>
<td>25%</td>
<td>408,162</td>
<td>436,000</td>
<td>39%</td>
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<td>PPARC</td>
<td>274,037</td>
<td>293,916</td>
<td>306,540</td>
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<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>CCLRC</td>
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<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>STFC</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>573,464</td>
<td>623,641</td>
<td></td>
<td>630,337</td>
<td>651,636</td>
<td></td>
</tr>
</tbody>
</table>

| Funding councils total | 1,351,662          | 1,534,532          | 1,651,987          | 1,747,910          | 1,810,540           | 34%                           |                   |                   |                               |

*Gross percentages shown (not adjusted for inflation) – these also reflect the introduction of full economic cost (fEC) funding model in September 2005.

**Estimated

***This information was unavailable.

Full economic costs

2.3.2 In order to address concerns over the sustainability of research funding, the funding model used by the research councils changed significantly in September 2005. All research grant proposals and fellowship applications submitted after this date are funded on the basis of a full economic costs (fEC) model whereby the research council provides 80% of the fEC of the project. Given that the full economic cost of the research varies with each university the additional cost to the research councils varies accordingly. However, the research councils estimate that post-fEC grants cost on average 45% more than pre-fEC grants. Along with the 80% of fEC included in new research council grants, a further 10% of the costs are provided through capital investment. This is contributed to by the research councils and distributed by the funding councils in the form of Science Research Investment Funding (SRIF).

The research councils

2.3.3 Research Councils UK (RCUK) is the strategic partnership of the UK’s seven research councils. The UK research councils fund world-leading research in order to generate new knowledge, which should drive advances in technology, business, policy, culture and the quality of life.

2.3.4 The research councils are the UK’s biggest public funder of research and postgraduate training and therefore play a key role in ensuring that the UK remains one of the most attractive locations in the world for science and innovation. There are many different training opportunities for researchers across the research councils. They also work closely with business and on public engagement.

2.3.5 The RCUK partnership is supported by the Strategy Unit, whose role is to foster cross-council collaboration. The Strategy Unit works equally across the councils to provide platforms, tools and impetus in order to keep the UK’s research base world-class.
2.3.6 RCUK has a number of key priorities which are detailed below.

- **Research excellence** - To ensure the delivery of independent, world class research with impact in globally competitive, networked institutions.

- **Impact** - Knowledge and expertise gained through the investment in people, creativity and innovation to allow the UK to maintain a technological edge, build a strong economy, exploit its unique cultural heritage and improve quality of life for its citizens.

- **Public engagement** - To help ensure that young people are increasingly attracted to research-based careers, thus bridging the impact and skilled people agendas and serving to increase the effectiveness of both.

- **Skilled people** - Maintaining a strong supply of skilled people for the research base, business and society in order to respond to unforeseen challenges, identify future opportunities and transfer knowledge between the research base and the private, public and voluntary sectors.

- **Facilities and infrastructure** - Access to a full range of world-class research facilities, in the UK or abroad, including traditional large physical installations and distributed, networked resources to underpin new collaborative modes of research.

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Table 2  The research councils

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<thead>
<tr>
<th>Research council</th>
<th>Remit</th>
<th>Investment</th>
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<th>Overview</th>
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<tr>
<td>Arts and Humanities Research Council (AHRC)</td>
<td>Languages, law, archaeology, English literature, design, creative and performing arts.</td>
<td>£105 million every year into 700 research awards and around 1,350 postgraduate awards.</td>
<td><a href="http://www.ahrc.ac.uk">www.ahrc.ac.uk</a></td>
<td>ftp://ftp.rcuk.ac.uk/AHRC</td>
</tr>
<tr>
<td>Biotechnology and Biological Sciences Research Council (BBSRC)</td>
<td>Life sciences, agriculture, healthcare, food, chemical and pharmaceutical research.</td>
<td>£450 million a year in research and training in universities and its own institutes.</td>
<td><a href="http://www.bbsrc.ac.uk">www.bbsrc.ac.uk</a></td>
<td>ftp://ftp.rcuk.ac.uk/BBSRC</td>
</tr>
<tr>
<td>Economic and Social Research Council (ESRC)</td>
<td>The study of society and the manner in which people behave and impact on the world including longitudinal studies, economics and development studies.</td>
<td>£200 million a year which supports over 2,500 researchers and more than 2,000 postgraduate students.</td>
<td><a href="http://www.esrc.ac.uk">www.esrc.ac.uk</a></td>
<td>ftp://ftp.rcuk.ac.uk/ESRC</td>
</tr>
<tr>
<td>Engineering and Physical Sciences Research Council</td>
<td>Chemistry, physics, mathematics, materials science, information and communications technology, engineering</td>
<td>£800 million a year in research and postgraduate training.</td>
<td><a href="http://www.epsrc.ac.uk">www.epsrc.ac.uk</a></td>
<td>ftp://ftp.rcuk.ac.uk/EpSRC</td>
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</table>
2.3.7 The research council’s funding processes rely on independent peer review to ensure that funding is used as effectively as possible to give the UK the highest quality research and training. There is a flexible approach and the only constraints are that:

- The research council’s involvement is publicised;
- Independent, expert guidance is used to help the research councils make investment decisions;
- Investment is mainly through universities; and
- Exclusive agreements are not entered into.

To help protect and encourage interdisciplinary research, the research councils have a funding agreement for considering proposals at the boundaries of each other’s remits.

### Training for students

2.3.8 The research councils exert a specific influence on the higher education (HE) sector through funding a major portion of the human research capital: supporting over 30,000 researchers at any one time including 15,500 doctoral students, 10,000 research staff in universities, 4,000 research staff in research institutes and 2,000 research fellows.

2.3.9 The five aims of the RCUK Research Careers Strategy are:

- Attract the most creative minds into research;
- Encourage researchers to get the training they need;
- Help research organisations manage their staff and develop their careers;
- Encourage people from all groups of society to take up research careers;
- Enhance the international reputation of UK research training

2.3.10 RCUK coordinates initiatives across the research councils in order to support transferable and career development skills for researchers.

2.3.11 In addition to funding the fees and stipends associated with students, research councils also pay an amount towards wider skills acquisition by postgraduate students. This funding arose from Sir Gareth Roberts’ ‘SET for success’ review of research and training (2001), which revealed that many science PhD students and postdoctoral researchers were lacking the skills required by employers. In response, the Government has provided money through the research
In addition to the provision of skills funding via Roberts Money, the same review included provision for the payment of enhanced stipends for shortage areas. These include: Engineering, Information and communications technologies, Materials and Mathematics (particularly statistics and operational research).

Cross-council priority themes

The research councils are focusing on the following grand challenges (leading council in brackets):

- **Energy (EPSRC):** Secure and sustainable energy supplies are needed to facilitate the economy and have become intrinsic to many people’s way of life. The Stern Review emphasises the need for an urgent global response to climate change including measures such as energy demand reduction and new technology in power generation, transport and energy use.

- **Living with environmental change (NERC):** Human activities are accelerating environmental change and increasing pressure on ecosystems and services. Her Majesty’s Treasury has identified this issue as a key challenge that the UK must address in the next decade, a concern supported by the Intergovernmental Panel on Climate Change Fourth Assessment, the Millennium Ecosystem Assessment and the Stern Review.

- **Global uncertainties: security for all in a changing world (ESRC):** Global challenges include the ongoing risks from international terrorism and conflict, rapid technological development, demographic, cultural, and socio-economic change, and increasing pressures on natural resources.

- **Ageing: lifelong health and wellbeing (MRC):** By 2051, 40 percent of the population will be over 50 and one in four over 65. There are considerable benefits to the UK in having an active and healthy older population with potential economic, social and health gains associated with healthy ageing and reducing dependency in later life.

- **Digital economy (EPSRC):** Information and communications technology (ICT) has the power to transform the way business operates, the way that Government can deliver and the way science is undertaken to improve life. A World Bank report identified that early adoption of ICT tools supported by research capacity and skilled people better positions a country to reap the economic and social benefits of those tools.

- **Nanoscience through engineering to application (EPSRC):** This field is maturing rapidly, with a trend towards ever more complex, integrated nanosystems and structures. It is estimated that by 2015 products incorporating nanotechnology will contribute US$1 trillion to the global economy and that the UK has a 10 percent share of the current market.

**Emerging Challenges**

The current priority themes will provide a framework through which the research councils can mobilise research to address ever-changing societal challenges. RCUK has recently identified three further challenges to which it believes the UK research base is well placed to respond. These three emerging challenges are now being developed.

- **Connected communities:** To maintain economic prosperity, health, sustainability and wellbeing in increasingly inter-connected, mobile and diverse communities by systematically addressing the opportunities and challenges they face.

- **Food security:** To maximise productivity sustainably without degrading natural resources and to do this within a socially and economically viable framework.
RCUK Review of e-Science 2009

Section 2

Information for the Panel

Overview: Funding of Science and Innovation in the UK

- **Fostering recovery and enhancing resilience:** To enhance significantly the prospects for economic recovery, particularly through green technologies, while helping those worst affected by a downturn.

**RCUK Offices Overseas**

2.3.15 An important means of delivering the international strategy is via RCUK’s overseas offices.

2.3.16 The Research Councils’ UK Research Office (UKRO), established in 1984, provides an information and advice service to UK academics on EU funding for research and higher education and aims to promote the involvement of UK researchers in EU research programmes.

2.3.17 RCUK also has offices in China (opened 2007), the USA (2007), and India (2008). These offices work with the research funding organisations and universities in their respective countries to facilitate collaboration between researchers in the UK and abroad. They also work closely with the Science and Innovation Network and others such as UK Trade and Industry and the British Council to align activities and present a joined up picture of UK research resources and expertise.

2.3.18 In addition to the overseas offices, RCUK has strong links with research agencies in other countries such as Japan and Brazil.

**The funding councils**

2.3.19 Funding councils in England, Wales, Scotland and Northern Ireland provide universities with block grants to support teaching and infrastructure. The four funding councils have arisen following devolution of Government in the UK, they are: the Higher Education Funding Council for England (HEFCE); Scottish Funding Council (SFC); Higher Education Funding Council for Wales (HEFCW); and the Department of Education & Learning in Northern Ireland (DELNI). They have similar, but not identical, policies. Examples where they differ include the conversion of Research Assessment Exercise (RAE) results into cash, or in the imposition of student fees.

2.3.20 The purpose of the RAE is to rate the quality of research conducted in universities and higher education colleges in the UK. The quality ratings, together with data on the number of research active staff, are used to inform the allocation of about £1.75 billion per year for unspecified research by the funding councils, the last RAE was in 2008, while the previous one was in 2001. In 2006, the Government outlined its intention that after 2008 the RAE would be mainly metrics based. This has caused considerable controversy and consultations are still ongoing regarding the implementation of these plans.

2.3.21 The Panel should be aware that whilst the 2008 RAE uses the same main principles of peer assessment as previous RAES there have been some significant changes:

- The results were published as a graded profile rather than a fixed seven-point scale. This allows the funding councils to identify pockets of excellence wherever these might be found and reduces the ‘cliff edge’ effect where fine judgments at the grade boundaries can have significant funding impacts.

- A formal two-tiered panel structure was been introduced for RAE 2008; it is hoped this ensured greater consistency and international calibration.

- Explicit criteria were set in each subject to enable the proper assessment of applied, practice-based and interdisciplinary research.

Further details about the RAE can be found at [http://www.rae.ac.uk](http://www.rae.ac.uk)

2.3.22 The funding councils are also the channels through which Government distributes the Capital Investment Framework (CIF). The CIF was developed to encourage HEIs to manage their physical infrastructure as an integral part of strategic and operational planning. The allocation of funds based on satisfying the requirements of the CIF comes into effect in 2008. The capital...
2.3.23 Four principal factors determine an institution meeting the requirements of the CIF.

- Responses to strategic questions.
- Metrics resulting from data submissions.
- Outputs and action plan from a self-assessment.
- Collective knowledge from HEFCE.

2.3.24 All HEIs had the opportunity to meet the requirements of the CIF by October 2007. Institutions that have met the requirements will not need to apply to receive their capital funds. The funds will be allocated directly by a grant.

2.3.25 Science Research Investment Funding (SRIF) was the forerunner to CIF. SRIF was a major programme of investment in the physical infrastructure for research and was funded jointly by the four UK higher education funding bodies and DIUS. The funding was intended to help address past under-investment in research infrastructure and promote the sustainability of the research base. It was used for:

- Refurbishment of premises for research;
- Replacement, renewal or upgrading of research equipment; and
- Replacement of premises or infrastructure for research by new-build or acquisition, where this was a better value solution than refurbishment.

2.3.26 The funding ran from 2001 to 2008 and consisted of three rounds. Institutions received allocations based on the level of their research activity.

2.3.27 The review of the first two rounds of the SRIF programme concluded that the funding had produced a wide range of benefits. The following were ranked as the most important:

- Making more universities more attractive partners for business.
- Increasing the research productivity.
- Creating the ability to perform new types of research and do research in new areas.
- Improved ability to attract research funding from the public and private sectors.

2.3.28 The Large Facilities Capital Fund (LFCF) is administered by BIS. It typically consists of £100 million per year and supports research councils’ investment in large research facilities and infrastructure with capital funding that could not be sensibly accommodated from within research council budgets.

2.3.29 The LFCF provides a funding contribution to the capital costs of:

- The construction of new facilities either nationally or internationally;
- The expansion or enhancement of existing facilities;
- The upgrading or replacement of existing facilities.

2.3.30 To qualify for LFCF funding facilities must be included in the RCUK Large Facilities Roadmap (http://www.rcuk.ac.uk/research/resinfra/lfroadmap.htm) and satisfy one or more of the following criteria:

- Have capital costs over £25 million;
- Have capital costs representing more that 10% of an individual research council’s budget.
- Serve the research communities of more than one research council.

Other sources of research funding

2.3.31 Industry is a major supporter of UK university research. Universities, departments or researchers may hold contracts with industrial and commercial partners as part of normal business.

2.3.32 Various learned societies and professional bodies, such as the Royal Society, also sponsor research.
2.3.33 The Wellcome Trust is a major charitable trust which spends over £600 million a year in the medical, biological and chemical areas, sometimes in partnership with the funding and research councils. Other trusts and charities, such as the Wolfson Foundation (£35M per annum), the Nuffield Foundation (£9M per annum), the Leverhulme Trust (£40M per annum) and Cancer Research UK (£330M per annum) support research in a variety of areas.

2.3.34 The EU Framework Programmes are also a significant source of funds for UK researchers, providing over £200 million in 2004-05.
RCUK REVIEW OF e-SCIENCE IN THE UNITED KINGDOM

SECTION 3 - EVIDENCE TO THE PANEL

NOVEMBER 2009
3. An Introduction to e-Science Research in the UK

3.1 Executive summary of data contained within this document

Investment in e-Science Research

3.1.1 In order for the UK to stay at the forefront of many key disciplines, the UK government ring-fenced funding for investment into e-Science technologies and infrastructures in both the 2000 and 2002 Spending Reviews. This activity is referred to here within as the e-Science Programme. e-Science was defined as research done through distributed global collaborations enabled by the internet, using very large data collections, terascale computing resources and high performance visualisation.

3.1.2 As there was a need to invest in solving problems of individual disciplines and in generic core technologies common to all disciplines, a proportion of the budget was allocated to each research council and also to a Core Programme, which was managed by the EPSRC on behalf of all the research councils. The data contained within this document pertains to both the Core and individual research council Programmes. The e-Science Programme was the first cross-council Programme and the first to develop tools and applications in parallel.

3.1.3 This review covers all aspects of UK e-Science research: both the development of e-Science tools and technologies and also the scientific application of these tools.

3.1.4 The e-Science Programme budget between 2001/02 and 2005/06 was £213 million – this accounted for 2.5% of the research council’s total research budgets.

3.1.5 Cumulative research council e-Science funding to institutions is clustered in a number of institutions. The top 15 institutions are shown below (2001-2009).

3.1.6 Figure 17 shows the distribution of funding for e-Science over the past eight years, with a significant proportion of the funds going to Glasgow, Edinburgh, Manchester and Southampton.

Figure 17  Distribution of funding for e-Science 2001-09

Note: Grant values are based on the Principal Investigator’s institution. £32.9M of Glasgow’s funding is for the GridPP project. CCLRC - The majority of these funds were used to support work through the CCLRC e-Science Centre (see Table 18 on Page 67).

Current Research

3.1.7 Since 2006, the budget for e-Science research has not been ring-fenced and the funding has been embedded into the individual research council research Programmes. In addition to this, a
few of the councils have specifically allocated funding to e-Science research. Full details of these activities can be found in Section 3.3.

People

3.1.8 Over the 7 year period from 2001 to 2008, there were at least 162 postgraduate students in the e-Science area registered at UK institutions.

3.1.9 It is difficult to estimate the number of e-Science researchers in the UK: the research council data records 1,516 academic staff funded through the e-Science Programme between 2001/08. However, since the ring-fenced Programme has ended it is not possible to calculate how many are now active in this field.

3.1.10 Approximately 97% of the researchers in receipt of grants from the research councils in e-Science are male.

Knowledge Transfer and Industrial Collaboration

3.1.11 Over the past eight years 138 stakeholder collaborations have been recorded on research council funded e-Science Programme projects/contracts; for example, over this period industry has contributed £7.1 million in cash and kind towards EPSRC research grants in e-Science related areas. In addition to these stakeholder collaborations, the DTI programme in 2001 specifically focussed on industrial collaboration where contributions from industry had to match the DTI input of £20M. The figures below relate to the 2000 Spending Review (additional funding in the 2002 Spending Review is shown at 3.3.3).

International Engagement

3.1.12 Over the past eight years 27 e-Science projects/contracts funded through the e-Science Programme have included overseas collaborations, a large proportion of which have been with researchers in the USA.

3.1.13 The Core Programme provided support for the e-Scientists to be involved in international activities to ensure the UK community was actively communicating and collaborating with the international community (see section 3.5). In addition to this, research councils run a number of schemes to enable international engagement and these are available to researchers in all fields within the research councils remits.
3.2 Background and Introduction

Introduction

3.2.1 The purpose of the Review is to benchmark UK e-Science research in relation to the best in the world. This data document is intended to provide the Panel with detailed background information about various aspects of UK e-Science research to help inform the Panel’s deliberations. The document provides an analysis of some key evidence to provide both a broad overview and to offer some insight into the questions in the evidence framework.

3.2.2 The Terms of Reference for this review are that the Panel will:
- Assess the impact of the programme on research areas nationally and internationally; on broader wealth creation and quality of life; and on e-Science itself;
- Assess and compare the quality of the UK research base in e-Science with the rest of the world via triangulation of data, panel and community perception;
- Comment on the added value of this programme; and
- Present findings and recommendations about the strength, weakness and opportunities for the future to the Research community and Councils.

3.2.3 In order for the UK to stay at the forefront of many key disciplines, the UK government ring-fenced funding for investment into e-Science technologies and infrastructures in both the 2000 and 2002 Spending Reviews. This activity is referred to here within as the e-Science Programme. e-Science was defined as research done through distributed global collaborations enabled by the internet, using very large data collections, terascale computing resources and high performance visualisation. The e-Science Programme was the first cross-council Programme and the first to develop tools and applications in parallel.

3.2.4 As there was a need to invest in solving problems of individual disciplines and in generic core technologies common to all disciplines, a proportion of the budget was allocated to each research council and also to a Core Programme, which was managed by the EPSRC on behalf of all the research councils. The 2009 RCUK review of e-Science will focus on the entire research council Programme, and therefore includes both core and individual research council investments since 2000. The review covers all aspects of UK e-Science research: both the development of e-Science tools and technologies and also the scientific application of these tools.

3.2.5 Evidence in this document has been collected from the following sources:
- Research council’s data sources;
- e-Science grant/contract holders.

3.2.6 The Arts and Humanities Research Council (AHRC) did not exist when the Programme was established, and therefore no data relating to this council is included within this document. AHRC did launch a separate A&H e-Science initiative in 2005, with support first from JISC and then from EPSRC. The Panel will have the opportunity to meet with researchers who were involved in the A&H e-Science Programme during the review week.

3.2.7 The DTI also invested heavily in the first phase of the Programme (see figure 3) however as the focus of the review is on the research council investment, data pertaining to the DTI Programme is not contained within this document. Mr Ray Browne who managed the e-Science Programme for the DTI will provide a briefing to the review Panel on the DTI Programme on Sunday 6th December 2009.

3.2.8 This data document is complemented by a number of additional sources of data:
- An overview document titled ‘Support for Science and Innovation in the UK’ (section 2);
- A compilation of key stakeholder responses to questions posed in the evidence framework (section 4);
- Submissions prepared for the panel by the research groups who will be presenting to the Panel (see Panel members ftp site ftp://ftp.rcuk.ac.uk/ for which usernames and passwords have been distributed separately.)
Funding for Research in the UK

3.2.9 There are two primary streams for the public funding of research in the UK. This approach is known as the ‘Dual Support System’. Under this system, block grants known as Quality-Related funding are provided to universities through the Funding Councils, to support teaching and infrastructure. Over £1 billion is allocated annually based on quality ratings of departments determined through the Research Assessment Exercise (RAE) (to be replaced by the Research Excellence Framework (REF) from 2014) and the volume of research activity, together with data on the number of research active staff.

3.2.10 The other stream of research funding comes through the research councils. The research councils have UK-wide responsibility to provide funding for research and (with the exception of Northern Ireland) postgraduate and postdoctoral training. The funding provided through research councils amounted to some £3.2 billion in 2008-9.

3.2.11 For a more detailed overview please refer to the companion document ‘Support for Science and Innovation in the UK’ (see section 2).

What is e-Science Research?

3.2.12 In brief terms e-Science has been defined as being the invention of computer-enabled methods and their application to research. These methods facilitate distributed global collaborations over the internet, and the sharing of very large data collections, terascale computing resources and high performance visualisations.

The Presentation of Evidence

3.2.13 The evidence is presented in six sections: Section 3.3 presents data about funding for e-Science research;
- Section 3.3 presents funding for e-Science research in the UK;
- Section 3.4 presents bibliometric evidence collected from Principle Investigators;
- Section 3.5 describes international engagement;
- Section 3.6 relates to support for people, including students;
- Section 3.7 refers to knowledge transfer, including collaborative funding;
- Section 3.8 contains information on further related funding.

3.2.14 The data, along with notes about the data sets and analyses will be provided as an electronic annex on a portal for Panel members (this will be an FTP site). This will contain documentation giving an overview for each research council, as well as individual institution responses giving information about their strategic plans and research group activities. If further information or advice is needed about the data please contact EPSRC, Jo Garrad: jo.garrad@esprc.ac.uk.

Analysing the Evidence

3.2.15 A number of caveats apply to the data that is provided. These arise because of the different ways in which research councils collect and store their respective portfolios. The situation is compounded by the fact that the Higher Education Statistics Agency (HESA) does not have a category for recording e-Science research and so they are unable to provide the basic data on academic research staff and students. The following points must be borne in mind when interpreting the data:
- Information on funding and staff numbers is provided based on grant/contract coding;
- Information on total student numbers is based on Awarded (funded through the Doctoral Training Award mechanism) and Project (funded through research grants) Students

\[1\] Funding Councils are as follows: Higher Education Funding Council for England (HEFCE); Scottish Funding Council (SFC); Higher Education Funding Council for Wales (HEFCW); and the Department of Education and Learning in Northern Ireland (DELNI).
3.2.16 In summary the data on research staff and students should be regarded as broadly indicative rather than a precise descriptor of e-Science research in the UK.

3.2.17 Another point to remember when comparing the data is the introduction of a new research council funding model based on full economic costs (fEC) in September 2005. For all research grant proposals and fellowship applications submitted after this date, the research council provides 80% of the fEC of the project. Given that the full economic cost of the research varies with each university the additional cost to the research councils varies accordingly. However, the research councils estimate that post-fEC grants cost on average 45% more than pre-fEC grants. The Panel should bear this in mind when comparing year on year figures.

3.2.18 Along with the 80% of fEC included in new research council grants, a further 10% of the costs are provided through capital investment, contributed to by the Department for Business, Innovation and Skills (BIS) and distributed by the funding councils. For further information please refer to ‘Support for Science & Innovation in the UK’ (see section 2).
3.3 Funding for e-Science Research in the UK

Funding for e-Science Programme

3.3.1 Table 3 shows the Office of Science and Technology (OST) Spending Review for the e-Science Programme in 2002. The OST provided £115 million over two years to extend the work started in the Spending Review 2000 (£98 million over 3 years), enabling the programme to:

- Solve major research challenges in processing, communication and storage of very large volumes of valuable data;
- Provide generic solutions to needs of individual disciplines and applications;
- Establish best practice across disciplines;
- Provide infrastructure and facilities needed for next major stages of international collaborative research; and
- Build on the leading international role established following the Spending Review 2000.

3.3.2 The Core Programme continued the development of generic middleware and supported infrastructure for the science pilot applications. The Core Programme acted as a focus for UK activities and partnerships with other countries and ensured dissemination of best practice amongst the applications.

Spending Reviews

3.3.3 The 2000 Spending Review originally allocated £98M to the e-Science Programme (this included £9M for High Performance Computing). This was increased to £213M in the 2002 Spending Review (please note that this incorporates the original £98M). Table 3 shows the Spending Review for e-Science in 2002.

Table 3 Spending review for e-Science (2002)

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3.3.4 Subsequent to the 2002 Spending Review, funding for e-Science research was no longer ring-fenced and became embedded within the research councils. In addition, some research councils continued to run a specific e-Science Programme using their individual budgets. See section 3.8 for further funding.

Management of the e-Science Programme

3.3.5 The e-Science Programme consisted of the individual research councils’ e-Science Programmes and the Core e-Science Programme which supported generic core technologies common to all disciplines. This was the first cross-council research programme and the first to develop tools and applications in parallel.

3.3.6 In March 2001, Prof Tony Hey from the University of Southampton was appointed by EPSRC as Director of the e-Science Core Programme. To support the Director, Prof Sir David Wallace was appointed by the Office of Science and Technology (OST) to Chair an e-Science Steering Committee which was tasked with providing strategic advice for the effective coordination and planning of the e-Science Programme. The Director also established a Technical Advisory
Group (TAG) to provide advice on technical issues and strategy. The membership of TAG consisted of eight computer scientists, four industrialists and four international representatives.

3.3.7 To ensure efficient coordination between the different research council e-Science Programmes, officials from the councils held bi-monthly e-Science Operations Group (eSOG) meetings.

Figure 4: Original e-Science Programme Management Structure

3.3.8 The Steering Committee consisted of members of the national and international research and business communities. The original Steering Committee membership April 2001-March 2002 consisted of:

- Professor David Wallace (Chair), Independent, Vice-Chancellor Loughborough University;
- Professor Geoffrey Barton, BBSRC community representative, University of Dundee;
- Dr Simon Bright, Syngenta;
- Professor Paul Durham, CCLRC community representative, Head of CCLRC e-Science Centre, Daresbury;
- Dr Neil Geddes, PPARC community representative, Director PPARC;
- Professor Carole Goble, EPSRC community representative, University of Manchester;
- Professor Julia Goodfellow, Birkbeck College London (until 31 December 2001);
- Professor Robert Gurney, NERC community representative, Director Environmental Systems Centre, University of Reading;
- Mr David Hendon, DTI representative;
- Professor Tom Kirkwood, MRC community representative, University of Newcastle;
- Dr Paul Messina, Independent, Argonne National Laboratory;
- Professor Steve Oliver, University of Manchester;
- Professor Tom Rodden, ESRC community representative, University of Nottingham;
- Dr Tony Storey, Independent, IBM UK Laboratories;
- Mr David Williams, Independent, IT Division CERN;
- Professor Alan Thorpe, Director NERC Centre for Atmospheric Science;
- Zofia Stott, Logica.

3.3.9 In 2004, the Director established a User Group whose membership consisted of representatives from all research council communities.
3.3.10 The Core Programme supported a variety of Task Forces which were a collection of UK and international academic and industrial experts who advised the Director on key areas of e-Science (Architecture, Databases, Security, Human Factors, Software Engineering etc.).

3.3.11 The Director put in place a number of mechanisms to monitor the Programme. All the e-Science centres attended 6-weekly meetings; the original centres had quarterly reviews (including reviews of centre projects); all projects delivered six-monthly reports on progress against a standard proforma; all projects attended the annual All Hands Meetings (AHM) to allow maximum technology read across different application areas. In 2008, the AHM was one of four networks which were funded by the EPSRC and this support has been secured until 2010.

3.3.12 In June 2005, Prof Tony Hey left his post as Director to pursue a career at Microsoft, and Prof Anne Trefethen took over this role for one year. The post of Director was disbanded in 2006 and an EPSRC Official, Dr Hugh Pilcher-Clayton, was appointed Programme Manager for the e-Science Core Programme. In order to advise the Programme Manager, EPSRC appointed Prof Malcolm Atkinson, University of Edinburgh, as UK e-Science Envoy. This was a five year post to provide advice on e-Science, engage in international e-infrastructure negotiations, and publicise and champion e-Science research covering all research council remits. As a result of the change in leadership the management structure was amended (see figure 5).

Figure 5: e-Science Programme Management Structure 2006

3.3.13 The membership of the e-Science Steering Committee was updated and in line with other EPSRC Programmes became the e-Science Strategic Advisory Team. The membership of this team was as follows:
- Professor John O’Reilly, EPSRC CEO;
- Dr Jamil Appa, BAE Systems;
- Professor Malcolm Atkinson, University of Edinburgh;
- Dr Ray Brown, Programme Manager, DTI;
- Professor Peter Clarke, Director of NeSC, University of Edinburgh;
- Dr Neil Geddes, Director of e-Science Centre, RAL;
- Professor Anne Trefethen, University of Oxford;
- Dr Daron Green, British Telecom;
3.3.14 The membership of the User Group was also updated and it received input from the Digital Curation Centre (DCC), e-Science Centres, OMII, National Grid Service and e-Science Envoy.

3.3.15 In 2008, EPSRC reorganised and the roles of Programme Manager for e-Science Core Programme and for High Performance Computing were combined into the role of Head of Research Infrastructure Programme. This post is held by Jane Nicholson and also encompasses EPSRC’s interests in centralised facilities which are provided by STFC (e.g. ISIS, DIAMOND). The Head of the Research Infrastructure Programme is advised by the Research Infrastructure Strategic Advisory Team (SAT) which is made up of e-Science, HPC and facilities experts:

- Professor David Delpy EPSRC Chief Executive Officer (Chair);
- Professor David Bird, University of Bath;
- Dr Stewart Cant, University of Cambridge;
- Professor Jeremy Frey, University of Southampton;
- Professor Robert Jones, University of Nottingham;
- Dr Michael Kirton, QinetiQ;
- Professor Peter Knowles, University of Nottingham;
- Dr Bryan Lawrence, RAL;
- Professor Richard Sinnott, University of Glasgow;
- Professor Mark Smith, University of Warwick;
- Professor Anne Trefethen, University of Oxford;
- Professor Malcolm Atkinson, University of Edinburgh, e-Science Envoy (Observer).

3.3.16 Officials from the research councils still meet every three months to discuss e-Science and HPC related topics. This cross-council group is organised by EPSRC. The e-Science Centre Directors continue to meet every three months. These meetings are chaired by Prof Malcolm Atkinson, in his role as e-Science Envoy, and are held at the various centres. The meetings are attended by an EPSRC officer and other research council officers as available.

Research Council Spend Profiles for e-Science Funding

e-Science Core Programme

3.3.17 The overall goals of the e-Science Core Programme (eSCP) were to:

- Assist the development of essential, well engineered, generic Grid middleware usable to both e-Scientists and industry;
- Provide necessary infrastructure support for UK e-Science projects;
- Collaborate with the international e-Science and Grid communities;
- In collaboration with scientists, computer scientists and industry, develop a framework to promote the emergence of robust, industrial strength Grid middleware, to not only underpin individual application areas but also to be of relevance to industry and commerce.

There was an Open Source/Open Standards requirement on all middleware developed within this Programme.

3.3.18 In the 2000 Spending Review (SR2000), the e-Science Core Programme was given £15M, augmented by an allocation of £20M from the Department of Trade and Industry (DTI). The
Programme was awarded a further £16.2M in SR2002 and extended to April 2006. The Core Programme was managed by EPSRC on behalf of all of the research councils. Since 2006 EPSRC have continued to support the Core Programme and they are now the sole funders.

3.3.19 The e-Science Core Programme funded or co-funded 90 grants (83 projects) totalling £42.0M across 40 departments (including Computer Science, Physics, Astronomy, Meteorology, Medicine, Chemistry, Social Science, Engineering, Humanities, Music and French) from 29 Institutions. Half of the 93 grants in terms of both number and value were awarded to 5* RAE rated departments.

Phase One of the Core Programme – Creation of Activities
Implementation of a National e-Science Grid based on a Network of e-Science Centres

3.3.20 At the beginning of the Programme there was a need for the UK to develop a nucleus of people who had experience in the detail of running a Grid. Therefore, with co-funding from the DTI, nine regional centres were established (see below). A primary role for the centres was to donate a specific amount of computing and storage resource for use in the construction of a national e-Science Grid. The donated resources range from time on supercomputers and commodity clusters to databases and other repositories. Gaining experience in the use of digital certificates for single sign-on and authentication across the Grid was a key purpose of this work and sorting out problems with the security, firewalls and policy issues at each of these sites proved to be difficult tasks.

Figure 6 Geographical Representation of Regional e-Science Centres in 2003

National & Regional e-Science Centres
- National e-Science Centre (NeSC) & eSi
- Belfast e-Science Centre (BeSC)
- Cambridge e-Science Centre (CeSC)
- CCLRC e-Science Centre (CCLRCeSC)
- e-Science North West (eSNW)
- Grid Support Centre (GSC)
- London e-Science Centre (LeSC)
- North East e-Science Centre (NEeSC)
- Oxford e-Science Centre (OeSC)
- Southampton e-Science Centre (SeSC)
- Welsh e-Science Centre (WeSC)

e-Science Centres of Excellence
- The White Rose Grid
- UCL
- University of Bristol
- Lancaster University
- University of Birmingham
- Reading University
- Leicester University

3.3.21 The centres also had a role to engage industry in Grid/e-Science projects/contracts and in establishing an appropriate regional outreach programme. This took various forms from a seminar series to joint projects and/or visits to relevant organisations in the region. The National Centre in Edinburgh (NeSC) was funded more substantially for such activities, which include running training courses and a national seminar series.
3.3.22 In 2002, with DTI funding, the e-Science Institute (eSI) was established at the University of Edinburgh as the national UK centre and the meeting place for e-researchers. This was in response to the need to form a UK e-Science community across all disciplines and to help it develop an understanding of the challenges and available solutions, and consequently to develop skills to manage these. The institute ran a programme of workshops, lectures, conferences and tutorials with hands-on training. It also hosted international visitors, and e-researchers were able to share knowledge and ideas about their particular research projects, forge new interdisciplinary activities and investigate ways in which distributed computing could advance their research.

3.3.23 In 2003 the centre network was extended to include seven centres of excellence (see figure 6) which were funded till 2006. The purpose of these centres was to:

- Add and coordinate expertise in technologies and applications important to e-Science;
- Add experience and resources to the existing UK e-Science Grid;
- Add regional coverage to the existing UK e-Science Grid;
- Host Access Grid nodes for multi-site remote conferencing.

Interdisciplinary Research Collaboration (IRC) Grid projects

3.3.24 EPSRC had funded three, six-year, computer science (CS) oriented, Interdisciplinary Research Collaborations (IRCs). These were major projects that funded key CS research groups from a number of universities to undertake long-term research in three important areas:

- The Equator project, led by Tom Rodden from Nottingham, was concerned with technological innovation in physical and digital life;
- The Advanced Knowledge Technologies project (AKT) led by Nigel Shadbolt from Southampton was concerned with the management of the knowledge life cycle;
- The DIRC project, led by Cliff Jones from Newcastle and Ian Sommerville from Lancaster, was concerned with the dependability of computer-based systems;
- The MIAS project, co-funded by MRC and led by Mike Brady from Oxford is an application focussed IRC concerned with translating data from medical images and signals into clinical information of use to the medical profession.

The Core Programme provided additional funding to these IRCs in order to leverage their computer science research activity and extend it to apply to the Grid. All projects had industrial partners, leveraging just under £1M of in-kind contributions.

Promotion of generic Grid middleware development

3.3.25 The challenge was to deliver to each of the different research council communities Grid middleware and tools that the users welcomed and used. An open call for Grid middleware projects was released, which had a flexible framework for assembling relevant consortia and projects.

3.3.26 The open call for proposals funded 19 projects across 21 institutions in a variety of key application and technology areas, with a total investment of £7.7M. In-kind contributions from industry totalled approximately £4.5M on these projects.

Establishment of a support structure for e-Science pilot projects

3.3.27 The various research council e-Science Programmes were supporting application based projects, which meant that application developers were being asked to use tools that were not polished and in some cases were still under development. Therefore the Grid Support Centre (GSC) was established to support the pilot projects in using the middleware software. The centre provided support via the normal mechanisms of email, web and phone as well as providing “hand holding” to new partners.

3.3.28 The GSC was centred at CCLRC (now STFC). The GSC hosted teams located at CCLRC (Rutherford Appleton Laboratory (RAL)) and had associates at CCLRC (Daresbury) and Manchester and Edinburgh Universities. The GSC was charged with supporting the implementation and operation of the UK e-Science Grid and supporting associated research council pilots, centres and projects. In the first year, the GSC had 6 FTE positions across the three partners. During the second year, it became clear that this was insufficient and 2 further
FTEs have since been added. These were primarily for the support of the OGSA-DAI software and further effort for the Engineering Task Force.

3.3.29 There was also a need to have a central ‘Certificate Authority’ (CA) in the UK to provide secure authority certificates for the use of the Grid. The CA policy which was developed was accepted by several international CAs which allows inter-operation across international Grids.

3.3.30 In the second phase of the Programme the GSC evolved in to the Grid Operations Support Centre (GOSC), which supported users in general but supported the National Grid Service (NGS) (details below) in particular. GOSC also operates the UK Certificate Authority.

Support for involvement in international activities and outreach activities (in all phases of Programme)

3.3.31 The Core Programme provided support for the e-Science community to be involved in international activities. This aimed to ensure the UK community was actively communicating and collaborating with the international community. Support was provided in several ways:

- Funding for members of the community to play an active role in the development of internationally agreed Grid protocols through the Global Grid Forum (GGF). UK researchers were involved in 20 Working Groups at GGF and 23 Research Groups, leading several of the activities.
- The Core Programme funded a booth each year at the US Supercomputing Conference between 2002 and 2006, to enable researchers to demonstrate activities from the UK programme.
- During the Programme there were international meetings with China, USA, Australia, Singapore, Japan and Korea. The Core Programme Directorate provided support and guidance on many international strategies including in Europe, Australia, China, and Singapore (amongst many others).
- The e-Science centres and researchers within the Core Programme were involved in the major EU Grid initiatives. The National e-Science Centre led the training element of the EGEE (Enabling Grids for e-Science) and many sites within the UK are partners. (EGEE is Europe’s leading Grid computing project which provides a computing support infrastructure for over 10,000 researcher’s world wide).
- The Core Programme held three calls for networking activities to collaborate with international projects which had common interests (either in an application area or in the technologies used). It funded 11 ‘sister’ projects, with most of the collaborations being with US-based projects. The total cost of this activity was £400,000, and although the grants awarded were relatively small (max £41,200), these projects produced a number of joint papers between the UK researchers and their international partners.
- The Core Programme has been the largest sponsor of the annual All Hands Meetings (AHM) since the first meeting in 2001. These meetings were initiated for the whole e-Science Programme and, to ensure maximum technology sharing across different application areas, all projects funded across the research council programmes were obliged to attend. In 2008, the AHM was one of four networks which were funded through an EPSRC e-Science Networking Call, and this support has been secured till 2010.

Support for e-Science networking requirements

3.3.32 The eSCP in conjunction with PPARC (now STFC) ran a call to engage computer science groups with the EU Data Grid, the (then) primary Particle Physics Grid project based around the Large Hadron Collider (LHC) at CERN. Five projects, at a cost of £743,820, were funded and ran from the end of 2001 to 2003.

Phase Two of Core Programme – Development of Activities

A National Grid Service (NGS) supported by the Grid Operations Support Centre (GOSC)

3.3.33 The e-Science Centres contributed a heterogeneous collection of resources, including supercomputer and cluster computing systems and diverse data storage systems, to make up the UK e-Science Grid. This Grid was used as both a test platform for new Grid middleware and
as a resource available to e-Science projects. This service led to the development of the National Grid Service (NGS) which has a number of core cluster machines and data services.

3.3.34 The NGS was formally established in 2004 as a joint initiative funded between the Core Programme and JISC. It aimed to provide coherent electronic access to all computational and data based resources and facilities that UK researchers required to carry out their research. This was independent of resource or researcher location.

3.3.35 NGS provides integrated, single sign on access to the full range of the UK’s computation and data based research facilities, together with a range of sophisticated services to support novel collaborative and cross resource activities. The resources span the complete space from advanced real time facilities such as the DIAMOND synchrotron through to complex queries on historical data stored in national or institutional data centres and use of the UK’s HPC facilities.

3.3.36 In 2009 the NGS is in its third phase of funding. It consists of four core sites (at Rutherford Appleton Laboratory (RAL), University of Oxford, White Rose Grid (Leeds) and The University of Manchester), seven partner sites and seventeen affiliate sites. It has secured funding from EPSRC and JISC until March 2011.

3.3.37 The European Grid Initiative is an ESFRI Design Study Project which aims to link together the individual National Grid Initiatives in each European country. The UK NGS will be the UK National Grid Initiative (NGI) contribution to the EGI. However, the full range of NGI functions includes activities currently covered in the UK by a combination of the NGS and the UK Grid for Particle Physics (GridPP) along with smaller contributions from other activities. NGS and GridPP are working closely to coordinate the delivery and evolution of these functions.

An Open Middleware Infrastructure Institute (OMII)

3.3.38 OMII was created in order to ensure sustainability of the middleware developed in the Programme beyond the Programme life. OMII was established in January 2004 as an institute at the University of Southampton at a cost of £6.6M. The institute worked in collaboration with IBM UK.

3.3.39 OMII had a number of objectives:

- Create a repository for the software which has been developed in e-Science research projects for future generations of e-Scientists to use;
- Validate and test this software and improve its quality by re-engineering, documenting and integrating it with the greater corpus of software held by OMII;
- Conduct a managed programme of research to develop easy-to-install and easy-to-use middleware (colloquially known as the OMII stack);
- Obtaining, integrating and supporting a large corpus of software was an overarching long-term commitment.

3.3.40 In January 2006 OMII was given additional funding to expand and include two further nodes: one at the University of Edinburgh (building on the success of the OGSA-DAI effort) and one at The University of Manchester (building on the myGrid project effort) to make OMII-UK. At the same time OMII joined with other Research Centres in Europe to form OMII-Europe, which attracted a modest additional budget from the European Commission. The original mission of the OMII in Southampton is now shared across these two consortia, with OMII-UK concentrating on e-Science applications and OMII-Europe driving the inter-operability between different infrastructure software systems.

A Digital Curation Centre (DCC)

3.3.41 A national Digital Curation Centre (DCC) was established between the Core Programme and JISC to develop best practice and to research key issues in scientific data curation, preservation and open access issues. The £1M grant ran between September 2004 and February 2008, and the DCC is now solely funded by JISC.

3.3.42 The DCC was established to research a range of sub-topics under the umbrella of enhancing the digital curation facilities available to the UK academic, scientific and industrial communities.
These sub-topics ranged from straightforward tasks (typically investigations into current practice) to high-risk, high-payoff projects over a longer period. They include the annotation of data and provenance tracking, data integration and publication, appraisal and long-term preservation, socio-economic and legal contexts, and performance and optimisation.

3.3.43 The DCC aims to be:
- The centre of excellence in digital curation and preservation in the UK;
- An authoritative source of advocacy and expert advice and guidance to the community;
- A key facilitator of an informed research community with established collaborative networks of digital curators.

**Phase Three of the Core Programme – Sustainability of Activities**

3.3.44 In 2006, the focus of the Programme moved towards sustaining the activities which had been developed.

**e-Science Institute and network of regional e-Science Centres**

3.3.45 A call for centres was launched and funding for a further two person-years was awarded to:
- National e-Science Centre (NeSC)
- Oxford e-Science Centre (OeSC)
- White Rose e-Science Centre (WReSC)
- North East Regional e-Science Centre (NEReSC)
- e-Science North West (eSNW)
- Lancaster e-Science Centre
- Belfast e-Science Centre (BeSC)

3.3.46 A further £2.7M of funding over five years was provided to the e-Science Institute (eSI) to continue its role as the national UK centre and the meeting place for e-researchers. In this period of funding the eSI changed its focus to longer-term and research-centred topics. They achieved this by running ‘themes’ that develop a topic over a period of six months to a year, through a series of workshops and meetings at eSI and elsewhere.

**e-Science Envoy**

3.3.47 In 2006, to encourage the continued development of e-Science within the UK, Professor Malcolm Atkinson was appointed as an EPSRC Senior Research Fellow and the first e-Science Envoy. In this five year role the Envoy spends 30-50% of their time advising and supporting EPSRC on the e-Science Core Programme and serving as an ambassador for e-Science more generally.

3.3.48 The Envoy’s responsibilities include developing advice on e-Science, engaging in international e-infrastructure negotiations, and publicising and championing e-Science research. This requires pro-active engagement with the communities, organisations and government bodies that are commissioning, planning, developing, operating and using advanced e-infrastructure. As a researcher, the Fellow will tackle strategic design issues concerning long-lived e-infrastructure, which must undergo incremental change while delivering a stable and continuous service and concerning the reliable handling of information over long periods and across multiple heterogeneous administrative domains.

**e-Science Demonstrator Projects in the arts and humanities**

3.3.49 To expand the scope of e-Science into the arts and humanities, the e-Science Core Programme launched a call for proposals in association with AHRC asking for e-Science Demonstrator Projects in the arts and humanities. Three projects were funded in 2006 and £100,000 was invested. As demonstrator projects they lasted for up to five months. The purpose of these projects was, together with an AHRC call for e-Science workshops, to launch the AHRC e-Science Programme prior to a call for research projects later in 2006.
Focusing of sustainability strategy (2007 to date)

3.3.50 From July 2007, following discussions with the e-Science Strategic Advisory Team, the key elements the programme is currently focussing on are:

- Research into advancing, applying and extending e-Science methods;
- Research pioneering novel ICT to enable new e-Science approaches;
- Investment in infrastructure and support that allows researchers to benefit and exploit e-Science approaches.

3.3.51 To deliver these objectives the Programme will focus on:

- **User support** - In March 2008 underpinning flexible support was provided to four centres through Platform Grant funding at a total cost of £3.4M. This funding was provided to help embed e-Science Centres across the breadth of the research councils' remits into their institutions and regions. The organisations that hold a Platform Grant are: National e-Science Centre (Universities of Edinburgh and Glasgow), Belfast e-Science Centre, e-Research South (Universities of Oxford, Southampton and Reading) and White Rose Grid (Universities Leeds, York and Sheffield).

- **Networking** – In order to provide opportunities for researchers to meet and share experiences and best practice, both in the UK and internationally, EPSRC funded four networking grants at a total cost of £1M. These were awarded in March 2008 to: National e-Science Information Network (NIN, based at National e-Science Centre); UK e-Science Engineering Task Force Network; Adding Value to Data; Digital Repositories in Research Infrastructures; All Hands Meeting Network. These networking opportunities should enable novel approaches to continue to be proposed. In addition, new communities will be able to see what they may be able to achieve if they use the new methods.

- **Supporting essential facilities** – providing infrastructure and support:
  - In conjunction with JISC two years additional funding was granted to the National Grid Service at a cost of £1M to EPSRC and £2M to JISC;
  - Open Middleware Infrastructure Institute (OMII-UK) was granted additional funding to enable all three sites to continue until March 2010;
  - A consultation with the e-Science community to identify the e-infrastructure facilities and services which are required to conduct high quality research, highlighted the management, curation and development of robust software as being a key area to support. As a result EPSRC has released a £5M call to provide underpinning, flexible support to a research infrastructure which will aid the long term sustainability of software which in turn enables high quality research. The outcome of this call will be announced in February 2010.

**e-Science Programme at BBSRC**

3.3.52 Between 2002 and 2006, BBSRC invested over £23M in the Bioinformatics and e-Science Programme (BEP) as part of the wider UK e-Science Programme.

**Background**

3.3.53 For BBSRC, SR2000 provided a ring-fenced allocation of £8M, which was topped up with baseline funds of £1M. A further £10M was allocated through SR2002. This was supplemented by £4M from the SR2002 proteomics allocation.

3.3.54 The majority of this funding was committed through two BEP initiatives, BEPI (grants announced February 2002) and BEPII (grants announced April 2004). These initiatives provide a baseline of flexible support (a platform) that can be used for the retention of key staff, feasibility studies, longer-term research and international networking. This flexibility should enable the group to take a strategic view of their research which will be enhanced by the submission of responsive mode applications during the lifetime of the Platform Grant.
supported ten large ‘pilot’ projects and a number of smaller research projects. The pilot studies funded through BEPI and BEPII were aimed at projects at the forefront of developing e-Science tools applicable to the BBSRC scientific community. Later BEPII pilot projects were funded to engage additional members of the BBSRC community. The remaining projects were enabling technologies that acted as platforms for other bioscience research projects. These projects supported the development and use of algorithms, software and analytical methods to solve defined biological problems by encouraging the interaction between the biological sciences, bioinformatics, IT, computer science, mathematics, statistics, physics and other disciplines.

3.3.55 The two calls were intended to cater to both those researchers who were at the leading edge of e-Science research and those researchers who had promising e-Science projects but who had not at that time built up a critical mass of e-Science expertise. The call for proposals also emphasized that those researchers adopting bio-informatic approaches should take into account software being developed in distributed computing environments (e.g. the Grid).

Bioinformatics and e-Science Programme

Table 4  Summary of funding committed to the BEP initiative

<table>
<thead>
<tr>
<th>Activity</th>
<th>Funds Committed £ M</th>
<th>Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projects funded through BEPI initiative</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Application pilot projects</td>
<td>4.95</td>
<td>5</td>
</tr>
<tr>
<td>Enabling technology projects</td>
<td>2.95 (inc. 0.21 from baseline budget)</td>
<td>12</td>
</tr>
<tr>
<td>2 summer schools</td>
<td>0.09</td>
<td>2</td>
</tr>
<tr>
<td>Grid support centre</td>
<td>0.22</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total no of projects</strong></td>
<td><strong>20</strong></td>
<td></td>
</tr>
<tr>
<td>Additional activities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27 studentships and 1 fellowship</td>
<td>1.03 (baseline budget)</td>
<td></td>
</tr>
<tr>
<td>Workshops</td>
<td>0.05 (baseline budget)</td>
<td></td>
</tr>
<tr>
<td>International Collaboration – 2 meetings with China</td>
<td>0.05 (baseline budget)</td>
<td></td>
</tr>
<tr>
<td>Biological Text Mining Service pilot (with JCSR)</td>
<td>0.04 (baseline budget)</td>
<td></td>
</tr>
<tr>
<td>20% of Hinxton HGMP-RC network upgrade</td>
<td>0.05 (baseline budget)</td>
<td></td>
</tr>
<tr>
<td><strong>Total BBSRC funds committed</strong></td>
<td><strong>9.43</strong></td>
<td></td>
</tr>
<tr>
<td>Additional Funds from other sources (to co-fund peer reviewed BEP projects)</td>
<td>£500,000 DTI; £113,065 SEERAD; £169,000 MRC;</td>
<td></td>
</tr>
</tbody>
</table>

3.3.56 BBSRC was awarded £8M over three years through SR2000 to support ‘bioinformatics and e-Science applications in post-genomics and other areas of bioscience’. A total of 20 grants were announced under the initiative.

Table 5  Pilot studies funded under the BEP initiative

<table>
<thead>
<tr>
<th>Project title</th>
<th>Institute</th>
<th>PI</th>
<th>Value (£M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A distributed pipeline for structural-based proteome annotation using GRID technology</td>
<td>Imperial College, University College London, European Bioinformatics Institute</td>
<td>Professor M J E Sternberg, Professor D T Jones, Professor J M Thornton</td>
<td>0.39, 0.38, 0.39</td>
</tr>
<tr>
<td>A GRID Database for biomolecular simulations</td>
<td>University of Oxford</td>
<td>Prof Mark Sansom</td>
<td>0.73</td>
</tr>
<tr>
<td>An e-Science resource for high throughput protein crystallography</td>
<td>University of York CLRC Daresbury Laboratory, University of Oxford</td>
<td>Dr K Cowtan, Dr C Nave, Professor D I Stuart</td>
<td>0.2, 0.82, 0.365</td>
</tr>
</tbody>
</table>
### Table 6 Enabling projects funded through the BEP initiative

<table>
<thead>
<tr>
<th>Project title</th>
<th>Institute</th>
<th>PI</th>
<th>Value (£M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D visualisation and modelling of cellular interactions in plant meristems</td>
<td>University of Cambridge</td>
<td>Dr J P Haseloff</td>
<td>0.2</td>
</tr>
<tr>
<td>Bio-Logical: an intelligent database for knowledge discovery in functional genomics</td>
<td>University of Wales – Aberystwyth</td>
<td>Dr RD King</td>
<td>0.6</td>
</tr>
<tr>
<td>Developing a strategic approach to protecting biodiversity - Landscape Opportunities Visualisation Toolkit (LOViT)</td>
<td>Oxford Brookes University</td>
<td>Dr S Thompson</td>
<td>0.15</td>
</tr>
<tr>
<td>Development and distribution of genetic circuit models for seasonal reproduction</td>
<td>University of Warwick</td>
<td>Dr A J Millar</td>
<td>0.33</td>
</tr>
<tr>
<td>Development of an information repository for microbial genome comparison using a parallel, object based architecture</td>
<td>University of Newcastle</td>
<td>Dr A Wipat</td>
<td>0.17</td>
</tr>
<tr>
<td>Development of generic software for analysis, archiving and internet dissemination of brain and systems physiological data</td>
<td>University College London</td>
<td>Dr D S Holder</td>
<td>0.18</td>
</tr>
<tr>
<td>Model sharing and co-simulation standards for system biology</td>
<td>University of Hertfordshire</td>
<td>Professor H Bolouri</td>
<td>0.17</td>
</tr>
<tr>
<td>MultiFlora II: combining information extraction and knowledge representation for biodiversity informatics</td>
<td>The University of Manchester, University of Sheffield</td>
<td>Dr M M Wood, Dr H Cunningham</td>
<td>0.092, 0.029</td>
</tr>
<tr>
<td>Novel approaches to the analysis of genetic diversity in germplasm collections</td>
<td>SCRI</td>
<td>Dr DF Marshall</td>
<td>0.152</td>
</tr>
<tr>
<td>Structure-based function prediction using peer-to-peer distributed computing</td>
<td>University College London</td>
<td>Professor D T Jones</td>
<td>0.19</td>
</tr>
<tr>
<td>Studying biochemical networks using probabilistic knowledge discovery</td>
<td>Imperial College</td>
<td>Professor S H Muggleton</td>
<td>0.43</td>
</tr>
<tr>
<td>XSPAN: A cross-species anatomy network - a novel tool for bioinformatics</td>
<td>University of Edinburgh, Heriot-Watt University</td>
<td>Dr J B L Bard, Mr A Burger</td>
<td>0.19, 0.19</td>
</tr>
</tbody>
</table>

3.3.57 BBSRC, with additional funding from the baseline allocation, committed a total of £9.43M to the initiative. A breakdown is provided in Table 4.

3.3.58 The SR2002 stated that BBSRC would support: “e-Science applications which focused on the development of software tools, algorithms and analytical methods that would allow the integration of new and existing data from all levels of biological organisation to improve the understanding of biological systems and processes, underpinning the BBSRC user communities in agriculture, food and healthcare. Funds would also be available to support courses for training and knowledge transfer to ensure the tools and resources developed were fully utilised in the community”.

**BEPII**

3.3.59 A multidisciplinary initiative, Bioinformatics and e-Science Programme II (BEPII) was initiated to support the development and dissemination of new tools. It was hoped that these would allow
the reliable integration of biological data between different levels of biological organisation and therefore address specific biological problems within BBSRC’s remit. In addition to standard research grants, the initiative included support for: new Grid pilot projects that focused on integrating data from different sources to inform about systems; community-driven projects to develop data standards/ontologies/data tracking and provenance; (short) training courses e.g. summer schools.

3.3.60 The BEP II initiative committed £12.5M to support research grants, including five new pilot projects. The stated purpose of the BEP II fund was to support bioinformatics and e-Science research. This built upon the previously identified priorities of genomics, structural biology, dynamic processes in cells and biodiversity and also extended into the areas of integrative biology and proteomics. The remit, derived from the delivery mechanism articulated by strategy board was:

- To work towards a common UK goal of establishing Grid-compatible methods of sharing data;
- To support the development and use of algorithms, software, analytical methods and protocols to allow the reliable integration of biological data of known provenance between levels of biological organisation to address specific biological problems;
- To facilitate the wide dissemination and use of algorithms, software, analytical methods, protocols, data collections and best practice, generated by the initiative;
- To provide training in bioinformatics and e-Science to address the needs of relevant user communities.

<table>
<thead>
<tr>
<th>Project Title</th>
<th>Institute</th>
<th>PI</th>
<th>Value (£M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-performance QTL analysis via the grid</td>
<td>University of Edinburgh, Roslin Institute</td>
<td>Dr P M Visscher, Professor C S Haley</td>
<td>1.50, 0.235</td>
</tr>
<tr>
<td>An e-Science infrastructure for comparative functional genomics in fungal species</td>
<td>The University of Manchester, University of Exeter</td>
<td>Professor N W Paton, Professor N J Talbot</td>
<td>0.59, 0.321</td>
</tr>
<tr>
<td>IntBioSim: an integrated approach to multi-level biomolecular simulations</td>
<td>University of Oxford</td>
<td>Professor M S P Sansom</td>
<td>1.47</td>
</tr>
<tr>
<td>ComparaGrid - enabling GRID technologies for comparative genomics</td>
<td>Roslin Institute, European Bioinformatics Institute, John Innes Centre, The University of Manchester, University of Newcastle</td>
<td>Dr A S Law, Mr P M Rice, Dr J Dicks, Dr R Stevens, Dr A Wipat</td>
<td>0.16, 0.18, 0.01, 0.18, 0.29</td>
</tr>
<tr>
<td>ISPIDER - a pilot grid for integrative proteomics</td>
<td>UMIST, Birkbeck College, European Bioinformatics Institute, UCL</td>
<td>Dr S Hubbard, Dr N Martin, Dr R Apweiler, Professor D T Jones</td>
<td>0.33, 0.18, 0.38, 0.2</td>
</tr>
</tbody>
</table>

3.3.61 Including the pilot projects in Table 7, a total of 16 projects were funded representing a commitment of £10.3M. A breakdown of the project funding under the remit headings is given in Table 8.
### Table 8  Summary of funding committed to the BEPII Initiative

<table>
<thead>
<tr>
<th>Activity</th>
<th>Funds committed £M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid-compatible methods</td>
<td>4.44</td>
</tr>
<tr>
<td>Integration of biological data</td>
<td>5.36</td>
</tr>
<tr>
<td>Dissemination of algorithms, software, analytical methods, protocols,</td>
<td>0.52</td>
</tr>
<tr>
<td>data collections and best practice</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10.32M</strong></td>
</tr>
</tbody>
</table>

#### 3.3.62 Additional monies were provided to establish a critical mass in bioinformatics research in the BBSRC sponsored institutes. Grants of ~250K were provided to Babraham, IAH, IFR, IGER, JIC, Roslin and Rothamsted. These grants are listed in Table 9.

### Table 9  Summary of BBSRC Institute e-Science projects funded through BEPII

<table>
<thead>
<tr>
<th>Title</th>
<th>Institute</th>
<th>PI</th>
<th>Value (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioinformatic analyses of neuronal ensemble recordings and the evolution of genomic imprinting</td>
<td>Babraham Institute (BI)</td>
<td>Kendrick K</td>
<td>£267,405</td>
</tr>
<tr>
<td>Bioinformatics tools and systems development</td>
<td>Institute of Food Research (IFR)</td>
<td>Kemsley E K</td>
<td>£264,843</td>
</tr>
<tr>
<td>Dynamic integration of functional genomics data</td>
<td>John Innes Centre (JIC)</td>
<td>Walsh S</td>
<td>£254,030</td>
</tr>
<tr>
<td>Genetical genomics: bioinformatics for high throughput characterisation of interacting loci controlling gene-expression</td>
<td>Roslin Institute (RI)</td>
<td>Haley CS</td>
<td>£269,877</td>
</tr>
<tr>
<td>Integration and exploitation of data derived from post-genomic technologies</td>
<td>Rothamsted Research (RR)</td>
<td>Verrier PJ</td>
<td>£264,532</td>
</tr>
<tr>
<td>Multivariate data-mining for determining biological principles underlying sustainable livestock-based land management</td>
<td>Institute of Grassland and Environmental Research (IGER)</td>
<td>Ougham HJ</td>
<td>£251,853</td>
</tr>
<tr>
<td>Differential co-expression in DNA microarray data and it’s application to Animal Health</td>
<td>Institute of Animal Health</td>
<td>Watson, MB</td>
<td>£374,296³</td>
</tr>
</tbody>
</table>

### PEST

#### 3.3.63 Training in proteomics and e-Science was supported through the £0.5M Proteomics and e-Science Training (PEST) fund.

#### 3.3.64 The call text stated that ‘This call aims to provide biological scientists with the necessary training and education better to pursue research that is both highly quantitative and information rich. It is focused at the leading edge of biology – proteomics and e-Science – where this skill set is urgently required’.

³ This grant was awarded later than the other Institute grants. Taking into account indexation and fEC, the baseline value was raised to £350K.
Funding was intended to provide training and courses for the BBSRC community in universities and BBSRC institutes. However, the call was also designed to be flexible. Funds could be requested, for example, for organising summer / winter schools, workshops, short courses, or developing distance learning materials, etc. The training could be focused at a particular stage of career development (e.g. students, senior researchers) and could be of a general, introductory or advanced nature. Activities were able to run over a period of up to three years. The courses which were run are detailed in Table 10.

### Table 10  Summary of BBSRC Proteomic and e-Science Training scheme (PEST) projects

<table>
<thead>
<tr>
<th>Course title</th>
<th>HEI</th>
<th>PI</th>
<th>Start date</th>
<th>Duration</th>
<th>Value (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural and Practical Proteomics Course</td>
<td>University College London</td>
<td>Jones D</td>
<td>01/01/2006</td>
<td>12</td>
<td>£41,977</td>
</tr>
<tr>
<td>A Training Course for Proteomics Data Management</td>
<td>The University of Manchester</td>
<td>Hubbard SJ</td>
<td>21/1/2006</td>
<td>40</td>
<td>£84,770</td>
</tr>
<tr>
<td>Practical Proteomics: A training course for the BBSRC community</td>
<td>University of York</td>
<td>Thomas-Oates J</td>
<td>01/01/2006</td>
<td>36</td>
<td>£69,067</td>
</tr>
<tr>
<td>Short courses in Practical High Throughput Bioinformatics</td>
<td>Imperial College London</td>
<td>Butcher SA</td>
<td>01/07/2006</td>
<td>24</td>
<td>£83,250</td>
</tr>
<tr>
<td>Bioinformatics for High Throughput Proteomics (Short Course)</td>
<td>Cranfield University</td>
<td>Bessant C</td>
<td>09/02/2006</td>
<td>30(^4)</td>
<td>£53,513</td>
</tr>
</tbody>
</table>

**e-Science Development Fund**

3.3.66 A £1M e-Science development fund was also set up, with the intention of developing e-Science and the Grid as a working research tool and to support researchers within BBSRC’s remit in three main categories of project:

- Meetings, workshops etc to establish multidisciplinary, collaborative groups/networks of researchers with the view to develop e-Science tools for a specific biological problem;
- Pump-priming projects to provide preliminary data demonstrating how particular e-Science/Grid tools might be applied to a specific biological problem;
- Projects to develop sustainable software arising from existing e-Science/Grid projects.

3.3.67 The e-Science Development Fund projects supported were to run for no more than one year, and had a £60K maximum value.

3.3.68 The grants are detailed in Table 11, below.

### Table 11  Summary of funding for the BBSRC e-Science Development Fund (eSDF)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Funds committed (£M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meetings, workshops</td>
<td>£0.150</td>
</tr>
<tr>
<td>Pump-priming projects to provide preliminary data demonstrating how particular e-Science/Grid tools might be applied to a specific biological problem</td>
<td>£0.482</td>
</tr>
<tr>
<td>Projects to develop sustainable software arising from existing e-Science/Grid projects.</td>
<td>£0.784</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>£1.056M</strong></td>
</tr>
</tbody>
</table>

\(^4\) The end date for this grant has been amended to 08/08/2009
Although the final outcomes of all the grants are yet to be determined, it is clear that projects that were well fitted to the remit of the call were funded. There has also been notable success in obtaining community buy-in to the Grid system, which at the time of the first call was low.

### e-Science Programme at EPSRC

In the 2000, 2002 and 2004 Spending Reviews EPSRC was allocated a total of £44M towards their e-Science Programme (£17M in SR2000, £18M in SR2002 and £9M in SR2004).

The EPSRC e-Science Programme started in 2001, and was made up of three phases, each with specific objectives reflecting the maturity of the general e-Science activity.

#### First Phase of EPSRC Programme (2001 – 2005)

EPSRC and PPARC (now STFC) were the first research councils to start their e-Science Programmes. In 2001, EPSRC funded six projects to bring together researchers to develop and demonstrate e-Science tools and use them to achieve scientific results. The idea was to develop generic technologies through application specifics and to engage both computer and application scientists. In all projects there was an emphasis on technology transfer across projects, disciplines and research councils (also JISC).

These projects were awarded further funding from industry (>£8M) and EPSRC provided an additional commitment of £2.2M from their other Programmes and their Doctoral Training Account (see EPSRC Overview in Panel portal which explains DTAs) to help the researchers promote the take-up of techniques in academia and industry.

The application projects can be summarised as follows:

- **Application areas**
  - engineering, materials, molecular biology & bioinformatics, combinatorial chemistry, environmental monitoring, electrical and electronic engineering, civil engineering, chemical engineering.

- **Problems being addressed**
  - computational steering, (real time) data mining, compute intensive simulation and analysis, sensor and device management, distributed information access & integration, collaboration, product life cycle, multi-scale model integration, knowledge management, IP discovery.

- **Technologies**
  - PSE, portals, visualisation, discovery, collaboration environments;
  - workflow, data integration, semantic technologies (ontologies and metadata), provenance management, notification, registries, auditing;
  - HPC, data access, computational resource sharing, data shipping;
  - Security, Open Grid Software Architecture (OGSA), frameworks;
  - Standards for data formats, type systems, protocols;
  - Collaboration toolkits and remote instrument services, data access services.

The projects were:

- **Comb-e-Chem – structure-property mapping: combinatorial chemistry and the Grid**
  - Comb-e-Chem showed that Grid computing can transform the way in which chemistry is done, from the writing of a laboratory notebook to the publication of data and results. The National Crystallographic Service has adopted its methods.
  - Cost: £2,314,665
  - Number of Universities Involved: 1
  - Number of Project Students: 4

- **DAME - distributed aircraft maintenance environment**
  - DAME has demonstrated the use of Grid technologies to make sense of the vast amount of data returned by sensors on aircraft engines during flight. DAME technology is now being further developed for use by real aircraft maintenance crews.
  - Cost: £3,096,172
Number of Universities Involved: 4
Number of Industrial Partners: 2
Number of Project Students: 6

- **Discovery Net – an e-Science test bed for high-throughput informatics**
  The Discovery Net project has developed a service-based computing infrastructure for high throughput informatics that supports the integration and analysis of data collected from various high throughput devices. This infrastructure has been designed and implemented based on a workflow model, allowing the composition of data analysis services and resources declared as web/grid services. The Discovery Net infrastructure is currently used by research scientists worldwide to conduct complex scientific data analysis in three important research areas: Life Sciences, Geo-hazard Modelling and Environmental Modelling.
  Cost: £2,082,704
  Number of Universities Involved: 1
  Number of Industrial Partners: 3
  Number of Project Students: 1

- **GEODISE – Grid-enabled optimisation and design search for engineering**
  GEODISE developed tools for the engineer. The project enabled design engineers to share knowledge by working in virtual organisations with access to widely distributed software, computing power and databases. The technology has been demonstrated in several engineering applications, for example aircraft wing design and is being taken forward in real applications.
  Cost: £2,872,450
  Number of Universities Involved: 3
  Number of Industrial Partners: 7

- **myGrid – directly supporting the e-Scientist**
  myGrid have developed workflows to enable researchers to cope with and make best use of the data deluge now engulfing them. myGrid has rapidly become the bioinformatician’s tool for extracting information and knowledge from the wealth of data now stored in databases all over the world, often in incompatible formats. It is also finding use in many other fields, including research in psychiatry, chemistry and engineering.
  Cost: £5,847,423
  Number of Universities Involved: 5
  Number of Industrial Partners: 8
  Number of Project Students: 6

- **RealityGrid – a tool for investigating condensed matter and materials**
  This project developed a tool for investigating condensed matter and materials, modelling complex structures at the meso- and nano-scales. It extends the concept of a virtual reality centre across the grid, linking it to massive, high performance computing resources.
  Cost: £3,441,471
  Number of Universities Involved: 6
  Number of Industrial Partners: 7

3.3.76 All of the pilot projects had links with other research council funded projects:

- myGrid links to CLEF, CLEF-2, PsyGrid (MRC); Geodise & IB (EPSRC); e-Fungi, iSPIDER & ComparaGrid (BBSRC); Rosalind Franklin Centre for Genomics Research; BioMOBY; OntoGrid, Provenance, SIMDAT, NextGRID, EMBRACE (EU);
- Geodise links to Integrative Biology e-Science (EPSRC); Genie (NERC); myGrid (EPSRC); BioSimGrid (BBSRC); active participation in ETF; G-Markets project (DTI) and GEM (DTI); OntoGrid (EU);
- CombeChem: National Crystallography Service being brought into general use with certificated security;
- RealityGrid links to IB (EPSRC), Integrative BioSim (BBSRC), UniGRIDS (EU);
- DNet Links to Integrative Biology in silico (BBSRC), IXI (CP), SIMDAT (EU).

3.3.77 All of the pilot projects were active in Global Grid Forum (GGF - now Open Grid Forum [http://www.ogf.org/]) Working Groups (WG) and Research Groups (RG)
Information for the Panel

Funding for e-Science Research in the UK

- Dave De Roure (Comb-e-Chem) & Carole Goble (myGrid & Geodise) Chair Semantic Grid RG;
- Dave De Roure (Comb-e-Chem) on Grid Forum Steering Group;
- Norman Paton (myGrid) Chairs OGSA-DAIS WG;
- Steven Newhouse (RealityGrid) co-Chair Service Management Frameworks Research Group;
- Dave Snelling (RealityGrid) co-Chair OGSA-WG;
- John Brooke (RealityGrid) co-Chair Grid Protocol Architecture WG;
- GGF Grid School 2 - Geodise, DAME and myGrid teaching;
- Good citizenship;
- Participation N+N meetings (US, China, Japan, Australia, Korea) and numerous visits.

Second Phase of EPSRC Programme (2004 – 2008)

3.3.78 In the second phase of funding, there was again an emphasis on technology transfer across projects (UK and internationally, disciplines and other RCs including JISC), in order to provide a base for long term research.

3.3.79 Two further pilot projects (at a total cost of £4M) were funded in 2003 to increase the applications investigated by e-Science technologies.

- **GOLD**
  To save on time and costs, companies working together on the development of a new chemical process need to manage their collaborations efficiently. The GOLD project developed Grid technologies to enable them to work in virtual organisations that will allow them to streamline their interactions. [http://www.goldproject.ac.uk/](http://www.goldproject.ac.uk/)
  Cost: £2,093,725
  Number of Universities Involved: 2
  Number of Industrial Partners: 6

- **Integrative Biology**
  Cancer or heart disease kills six out of every ten people in the UK. The Integrative Biology project’s aim was to produce detailed, accurate computer simulations of cancer tumours and of the heart, based on research at the molecular and cellular level. Such simulations could eventually lead to new treatments based on a clearer understanding of how organs function and the conditions that result when they go wrong.
  Cost: £2,437,814
  Number of Universities Involved: 6
  Number of Industrial Partners: 1
  Number of Project Students: 11

3.3.80 EPSRC also funded (at a cost of £800k) four one year ‘best practice’ projects which took the successful outputs from the pilots and adapted them for use in other e-Science projects. The aim was to make sure that the lessons learned and the best tools developed were not lost but carried forward in new ways.

- **myIB: complex in silico experiments in integrative biology**
  The aim of this one year project was to transfer and extend the work on workflow support and information nodes developed in the myGrid pilot project to support the requirements of in silico experimentation in the Integrative Biology project.

- **myTea: bringing e-Science into bioinformatics practice**
  The project extended experience from the Smart Tea project (part of the wider Comb-e-Chem pilot project) and myGrid project to develop the principles and framework for a smart application for bioinformatics.

- **Rapid prototyping of usable Grid middleware**
  This proposal brought together UK partners from RealityGrid, Comb-e-Chem, Integrative Biology and myGrid, and US collaborators working with RealityGrid. The central aim was to develop and apply lightweight Grid middleware, for ease of installation, maintenance and manageability, by a variety of computational science groups with interests in condensed matter modelling and simulation in the physical and
life sciences. By working with end-users the tools developed were useful and usable and more likely to be incorporated into mainstream research.

- **Real-time text mining for the biomedical literature**
  The aim was for the Discovery Net and MyGrid pilot projects to develop a unified real-time text-mining service by developing a common inter-operability framework to provide high-level integration methods specific to access, integration and composition of grid-based text mining services.

3.3.81 In 2005 EPSRC invited all six original pilot projects to bid for Platform Grant\(^5\) funding. Four proposals were funded for up to five years, at a total cost of £1.7M: myGrid, Comb-e-Chem, RealityGrid and Discovery Net.

3.3.82 In order to provide a base for long term e-Science research, EPSRC allocated 50% of its funding from the 2002 Spending Review to computer science projects. The broad vision of e-Science brought a challenging research agenda for the computing community to the fore. New theories and models were needed to provide a sound foundation for the tools used to specify, design, analyse and prove the properties of future e-Science technologies and applications. Fundamental research was needed in order to build a future e-Science infrastructure and to understand how to exploit the infrastructure to best effect. EPSRC ran five calls for proposals to address the computer science challenges to emerge from e-Science. They funded 42 projects at a total cost of £9.7M (See ‘Funded Projects’ spreadsheet tab EPSRC CS Projects on e-Science ftp site for full details).

3.3.83 EPSRC also set aside £1.8M on ‘Joint Working’ activities to help incorporate e-Science technologies into mainstream research. These included a £1M Usability Call, which was given additional funding by ESRC, to fund projects in areas which had been highlighted by the Usability Task Force’s Usability Agenda. The remaining £800k was used to co-fund grants with EPSRC’s other Programmes: Physics, Engineering, ICT and Life-Science Interface, and projects with other research councils and JISC.

3.3.84 EPSRC also released a call for research into security, specifically aimed at authentication and authorisation, auditing, privacy, confidentiality and trust. Six projects were funded at a cost of £1M.

- Professor Chadwick, University of Kent: Easy Expression of Authorisation Policies
- Professor Clarke, University of Edinburgh: Defending the Weakest Link: Intrusion via Social Engineering
- Professor Coveney, University College London: User-friendly authentication and authorisation for grid environments
- Professor Mitchell, Royal Holloway University of London: Trust establishment in mobile distributed computing platforms
- Professor Paterson, Royal Holloway, University of London: Novel security architectures and policy management techniques for e-Science
- Professor Sasse, University College London: Easy Expression of authorisation policies

**Third Phase of EPSRC Programme (2006 – 2011)**

3.3.85 The focus for the third phase of funding was on “enabling the science” and technology transfer. In 2006, EPSRC funded three final pilot projects which addressed key grand challenge problems.

- **MESSAGE: Mobile Environmental Sensing System Across Grid Environments**
  This is a three year project led by Imperial College London, including researchers at Universities of Cambridge, Leeds, Newcastle and Southampton. The project also has the support of nineteen non-academic organisations from public sector transport operations, commercial equipment providers, systems integrators and technology suppliers. The project will develop and demonstrate the potential of diverse, low cost sensors to provide data for the planning, management and control of the environmental impacts of transport activity at urban, regional and national level. This includes their\(^5\) EPSRC Platform Grant funding provides a baseline of flexible support (a platform) that can be used for the retention of key staff, feasibility studies, longer-term research and International Networking. This flexibility should enable the group to take a strategic view of their research which will be enhanced by the submission of responsive mode applications during the lifetime of the Platform Grant.
implementation on vehicles and people to act as mobile, real-time environmental probes, sensing transport and non-transport related pollutants and hazards. Three sensor platforms will be developed as part of the project. 
http://bioinf.ncl.ac.uk/message/
Cost: £3,431,906
Number of Universities Involved: 5
Number of Industrial Partners: 20
Number of Project Students: 5

- **CARMEN: Code Analysis, Repository and Modelling for e-Neuroscience**
  CARMEN is a four year project to deliver a virtual laboratory for neurophysiology, enabling sharing and collaborative exploitation of data, analysis code and expertise. This project is led by Newcastle University and involved 10 UK universities in collaboration with other academic and commercial partners.
  http://www.carmen.org.uk/
  Cost: £4,037,770
  Number of Universities Involved: 10
  Number of Industrial Partners: 4
  Number of Project Students: 4

- **NanoCMOS: Meeting the design challenges of nano-CMOS electronics**
  This four year project led by the University of Glasgow and involving four other universities, brought together semiconductor device, circuit and system experts from academia and industry and e-Scientists with strong Grid expertise. The over-arching aim is to revolutionise existing nano-CMOS electronics research processes by developing the methodology and prototype technology of a nano-CMOS Design Grid. Through this process they will create Grid-savvy nano-CMOS e-researchers able to Grid-enable their own simulations, to correctly annotate their own data, to design workflows reflecting their design processes, and share all these with other researchers in the nano-CMOS design space.  
  http://www.nanocmos.ac.uk/
  Cost: £3,744,356
  Number of Universities Involved: 5
  Number of Industrial Partners: 6
  Number of Project Students: 6

### e-Science Programme at ESRC

**Background**

3.3.86 ESRC received an allocation of £13.6m from the cross-research council e-Science Programme in 2000. The ESRC programme started with a variety of components: four scoping studies, completed in 2003; a joint ESRC/JISC training and awareness raising programme (with three projects, Fast Track, Agenda Setting Workshops and ReDReSS); eleven e-social science pilot demonstrator projects and a network of eight access grid nodes. The National Centre for e-Social Science (N CeSS) was later commissioned along with a series of thirteen small grant projects.

3.3.87 The National Centre for e-Social Science (N CeSS) forms a key part of the Council's strategy to drive forward the development of leading edge methodological tools, techniques and services to address increasingly complex social science questions. N CeSS was established in 2004 as a distributed centre with a 'hub' at The University of Manchester and a network of research 'nodes' spread across the UK.

**Aims of the Centre**

3.3.88 The aim of N CeSS as a whole is to enable social scientists to make best use of emerging e-Science technologies, in order to address some of the key challenges in their research fields in new ways. In pursuit of this objective, N CeSS aims to stimulate the uptake and use across the social science research community of technologies, data infrastructures and collaboration mechanisms by coordinating e-social science research and making available information, training, advice, support and resources.
Commissioning the Centre

3.3.89 The Centre was commissioned in four phases. Firstly, the co-ordinating hub was established in 2004 to lead, co-ordinate and develop the e-social science initiative. It had funding of £1.5M over three years initially and was renewed in 2007, with funding of £2.2M for a further five years. Further rounds of commissioning then followed to create a set of 'nodes' that would draw upon emerging centres of excellence in e-social science, which were starting to develop through the pilot projects. Total funding for the nodes between NCeSS 2004 and 2012 is £10.3M.

Nodes Research Programme

3.3.90 The 'nodes' carry out specific substantive interdisciplinary research projects, showcasing the value of e-social science in both quantitative and qualitative and in particular mixed methodological research.

3.3.91 The nodes were commissioned in two main phases. The breakdown of nodes and their activities is as follows:

**Phase I**

The Digital Records for e-Social Science (DReSS) Node based at the University of Nottingham has been developing a new tool (Digital Replay System) that enables the synchronization, replay and analysis of audio and video recordings.

The PolicyGrid Node based at the University of Aberdeen has been exploring ways of using semantic web technologies to support evidence based policy, encouraging interdisciplinary research collaborations between environmental and social scientists.

The CQeSS Node at the University of Lancaster developed mechanisms that enable researchers to access Grid-enabled data and computational resources via common desktop statistical packages.

The MiMeG Node at the University of Bristol developed a suite of tools to support the collaborative analysis of video data by distributed research groups.

The work of the University of Oxford e-Social Science Node (OeSS) has been addressing legal, ethical and social issues arising from the use of e-social science, relating to confidentiality, privacy, data protection, intellectual property rights, accountability and trust and risk in distributed collaborations.

**Phase II**

The GENeSIS project involves merging the activities of two existing nodes GeoVUE at UCL (CASA) and MoSeS at the University of Leeds (CSAP). The MoSeS Node had developed large scale simulation tools to support policy-makers in strategic priority areas such as population change. GeoVUE had developed GIS-based visualisation tools, ranging from a simple to use tool based on Google Maps, for displaying social-economic data and to more sophisticated tools for overlaying real-time data (such as air pollution) on 3-D simulations of urban environment.

LifeGuide based at the University of Southampton are working to develop an internet-based set of resources, a 'Behavioural Intervention Grid', that would allow researchers to flexibly create and modify websites to provide tailored advice and long-term support for behaviour change. The node has completed a systematic review of 91 internet-delivered behavioural interventions, to be submitted for publication in early 2009 in a leading social science journal.

Obesity e-Lab, based at The University of Manchester are developing an e-infrastructure for interdisciplinary collaborative research into obesity, this will enable social and biomedical researchers to share data, information and analytical tools for obesity research.

The DAMES Node at the University of Stirling has been developing tools for managing data. DAMES had undertaken some initial planning sessions to link social scientists requirements in the analysis of data with practicable e-Science services. DAMES has been engaging with experts in the field such as the NCRM ADMIN node, NDS and ADLS.
An eighth Node e-Stat based at the University of Bristol started 1 September 2009, commissioned to address the gap in the programme in quantitative e-social science. The Node aim is to develop a mix of advanced computational tools and techniques which, in combination with quantitative data and quantitative (statistical and econometric) methods, to support social science research.

**National Director for e-Social Science**

3.3.92 As the NCeSS hub contract ended on 30 September 2009, the ESRC has recently recruited Professor David De Roure to the National Strategic Director for e-Social Science post. Professor De Roure started 1 October 2009, supported by a co-Director Dr Marina Jirotka (Oxford). The overall aim of the post will be to develop new national strategy for e-social science, to maximise the uptake, use and impact of new e-technologies across the social science community. To help achieve this aim, the Director will be responsible for coordinating and managing the overall activities of the Centre, including support for the research nodes and the development and maintenance of the NCeSS website. This will be critical to developing and delivering a new national strategy for e-social science.

### e-Science Programme at MRC

3.3.93 MRC was allocated £8m *via SR2000* and these funds were used to support 18 awards and contributions; funds leveraged from other agencies contributed a further £1.1m. These investments include:

- 7 e-Science pilot projects, 3 of which are jointly funded with other councils (2 with BBSRC, 1 with PPARC) and 1 with the Core e-Science Programme; development of middleware and data interoperability were pre-requisites for funding.
- 6 “informatics” investments deliberately clustered around the e-Science pilots (4 bioinformatics; 1 neuroinformatics; 1 network connectivity).
- 5 underpinning activities (3 bioinformatics posts; 1 jointly funded health informatics workshop; conference attendance funds).

3.3.94 MRC focussed its SR2000 allocation on pilots in the priority areas of clinical research, cancer, brain sciences, post genomics and ageing with deliberate clustering of the “informatics” investments to underpin these areas.

3.3.95 MRC also committed an additional £6.7m of baseline funds to related e-Science activities such as training and career development, the Joint Research Equipment Initiative and Discipline-hopping awards.

3.3.96 The main gap in the SR2000 portfolio related to clinical trials and longitudinal studies, areas of UK and MRC strength. MRC was allocated £13.1m *from SR2002* to develop a comprehensive UK Grid around clinical trials and longitudinal studies. A call for outline proposals was issued in July 03, following a scoping workshop, seeking:

- Up to 5 large multidisciplinary networked consortia;
- Mix of discipline-led and tools-led consortia;
- Engagement of key national/international stakeholders;
- Development of grid architecture to access multiple/diverse datasets;
- Solutions to problems: ethics, confidentiality, security of patient data;
- Ambassadors to explain aims and encourage take up of grids;
- Interfaces with SR2000 pilots, core programme and e-Science centres.

3.3.97 In addition, the proposals were to be networked to cover the UK and engage clinicians, GPs, researchers, trialists and patients. Links were to be made with other agencies, particularly the Health Departments, NHS and also with industry. The full proposals were to be of three years duration and cost in the order of £2-3M each.

3.3.98 Five successful awards were made in May 2004, with start dates early 2005, and were again based in MRC priority areas; cancer, neuroscience and primary care. One of the awards is a
follow-up to a pilot funded from SR2000. Additional funds of £1M were leveraged from the Department of Health for co-funding another award.

3.3.99 MRC also made a contribution towards ESLEA, a project aiming to deliver the potential of optical networking in several application areas including e-Health (jointly funded with EPSRC, PPARC, DTI).

3.3.100 Other major activities undertaken have been the organisation of workshops/initiatives/steering groups in key areas of particular importance to MRC funded projects: Health Informatics; Consent and confidentiality; Data sharing and preservation; the NHS National Programme for IT/Connecting for Health.

Selected key highlights include:

- CLEF repository now available containing data on more than 22,000 cancer cases as an interactive knowledge source for academic researchers and clinicians to access latest medical information;
- Additional funding from DTI to accelerate development of software (AXIOPE) and foster industrial links (CLEF);
- e-FAMILY used globally to generate target lists for structural genomics;
- The AXIOPE pilot has spun out Axiope Ltd – AXIOPE software has been rolled out to 100 neuroanatomy labs worldwide;
- CLEF is making a major contribution to the privacy and confidentiality framework and is working closely with NPfIT/Connecting for Health;
- Breaking new ground in clinical management and enhanced survival of cancer patients (ANN);
- Contributing to the development of international database development using Grid services (BioCMAT);
- International recognition database is pre-eminent web resource on proteolytic enzymes and their inhibitors (MEROPS);
- Funds of £1M leveraged from DH to support a recent consortia ward to enhance research and development capacity in mental health service settings and improve the understanding and treatment of people in their first episode of psychosis (PsyGRID);
- Underpinning work of the pilot project BASIS led to a further award from BBSRC/EPSRC to establish a Centre for Integrated Systems Biology of Ageing and Nutrition;
- Participation in setting a UK policy on privacy and security for health service information used in research (CLEF).

Table 12 Overview of MRC e-Science funding

<p>| Overview summary data | Total Programme funding – the Programme has committed £21.1M from SR2000 and SR2002 in research grants and underpinning activities together with an additional £6.7M commitment of baseline funds to related e-Science activities such as training and career development (see Training), the Joint Research Equipment Initiative and Discipline-hopping awards. |
| Shape and size of Programme | Consortia/groups funded – 7 pilots, 5 consortia and 1/6 “informatics” awards consist of multidisciplinary teams; 5/6 “informatics” awards went to single PIs. |
| Pilot projects: | Integration of protein sequence and structural family data – e-Family: <a href="http://www.efamily.org.uk/">http://www.efamily.org.uk/</a>. |
| | Artificial neural networks in cancer management – |</p>
<table>
<thead>
<tr>
<th>Consortia projects:</th>
<th>Networking with the community and stakeholders</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Developing open standards for clinical cancer trials/informatics – CancerGRID: <a href="http://www.cancergrid.org">www.cancergrid.org</a>.</td>
<td>▪ See also activities under links to international and national e-Science programmes and projects.</td>
</tr>
<tr>
<td>▪ Co-operative clinical e-Science framework – CLEF: <a href="http://www.clinical-escience.org">www.clinical-escience.org</a>.</td>
<td>▪ e-FAMILY – links to and advises structural genomics groups, national and international, participates in EU-funded EMBRACE e-Science network and ZF-MODELS.</td>
</tr>
<tr>
<td>▪ Range of academic input – the 105 departments involved include oncology, computer science, psychiatry, neurology, imaging sciences, informatics, biostatistics, statistics, epidemiology, medicine, cardiology, primary care, physics &amp; astronomy, surgery, physiology, biochemistry, molecular biology, bioinformatics and genetics.</td>
<td>▪ AXIOPE – numerous visits and presentations to labs worldwide to spread uptake of AXIOPE Catalyzer software, industry links with Neurolucida, Microbrightfield and Universal Imaging Corporation.</td>
</tr>
</tbody>
</table>

**ANN (MRC/PPARC):**
- Biology of Ageing e-Science Integration and Simulation System – BASIS (BBSRC/MRC): [www.basis.ncl.ac.uk/technology.html](http://www.basis.ncl.ac.uk/technology.html).

**Biology of Ageing e-Science Integration and Simulation System – BASIS (BBSRC/MRC):** [www.basis.ncl.ac.uk/technology.html](http://www.basis.ncl.ac.uk/technology.html).

**Mouse atlas database – BioCMAT:** [www.ncl.ac.uk/ihg/EADHB](http://www.ncl.ac.uk/ihg/EADHB).

**National federated database of mammographic images – eDIAMOND (Core/MRC):** [www.ediamond.ox.ac.uk](http://www.ediamond.ox.ac.uk).

**Consortia projects:**
- Grid-based network of neuroimaging centres and neuroimaging tool-kit – NeuroGRID: [www.neurogrid.ac.uk](http://www.neurogrid.ac.uk).
- Range of academic input – the 105 departments involved include oncology, computer science, psychiatry, neurology, imaging sciences, informatics, biostatistics, statistics, epidemiology, medicine, cardiology, primary care, physics & astronomy, surgery, physiology, biochemistry, molecular biology, bioinformatics and genetics.

**Networking with the community and stakeholders**
- See also activities under links to international and national e-Science programmes and projects.
- e-FAMILY – links to and advises structural genomics groups, national and international, participates in EU-funded EMBRACE e-Science network and ZF-MODELS.
- ANN – engaged particularly with British Computer Society Primary Healthcare Specialist Group.
- BASIS – strong links with Unilever Corporate Research, Biology of Ageing research community, hosted international workshops in ageing.
- CLEF – extensive liaison and links with NHS, DH, UK National Cancer Research Institute’s cancer/health informatics, Northwest Institute for Bio-Health Informatics, industry including IBM, Oracle, BT, SUN, Kodak UK, CISCO.
- AXIOPE – numerous visits and presentations to labs worldwide to spread uptake of AXIOPE Catalyzer software, industry links with Neurolucida, Microbrightfield and Universal Imaging Corporation.
- NeuroGRID – links to NHS, IBM.
- PsyGRID – links to NHS, Mental Health Research.
Network, Northwest Institute for Bio-Health Informatics.
- VOTES – has extensive links to primary care research networks, NHS, NHS Scotland, UK Biobank, and IBM.

Training
- Pilots have provided training to 16 research fellows, 8 PhD students and several MSc students.
- 3 pilots have organised workshops; 2 pilots teach on PhD/MRes courses; 1 pilot contributes to regular industry workshops.
- 1 pilot has organised an annual summer school attracting a total of 120 PhD students, postdocs and professors in neuroscience and computer science from EU, US and UK.
- Each of the 5 recent consortia awards has additionally been awarded a PhD studentship.

Impact
- Contribution to e-Science international standards, middleware, etc – all pilots are making contributions via: Development of Morph ML and Neuro ML – AXIOPE software rolled out to 100 neuroanatomy labs worldwide; systems biology mark up language; CLEF influencing international standards for Electronic Health Records; Grid standards; the development of DAS and open source projects such as BioPerl, BioSDAS and BioJava; e-FAMILY used globally to generate target lists for structural genomics.
- Number of conference proceedings – 54 including a number of invitations as keynote speakers.
- All projects report numerous presentations at workshops.

Management and monitoring structures
- All grantees are required to submit annual progress reports.
- All e-Science grantees to attend national AHM and MRC AHM.
- For the large consortia awards only, project steering groups are mandatory along with Head Office representation on these groups.

Facilities
- National High End Computing Services.
- Other facilities – Several pilot projects and consortia awards engage with OMII; NeuroGRID engaging with National Digital Curation Centre.
- e-Science centres – all pilots and consortia awards engage in various ways with one or more of the centres.

Links
- Active Collaborations to other UK e-Science Programmes and projects
  - CLEF has links to myGRID (EPSRC), PsyGRID (MRC/DH), CancerGRID (MRC).
  - VOTES has links to the eDIKT team and the BRIDGES project (NeSC).
  - NeuroGRID is closely integrated with e-DIAMOND (Core/MRC) and IXI (Core) and has links with PsyGRID (MRC/DH).
  - PsyGRID has links to myGRID (EPSRC), CLEF
### Active Collaborations to other International e-Science Programmes and projects

- (MRC), RealityGRID (EPSRC).
- ANN is tightly linked to GRIDPP (PPARC).
- cancerGRID has extensively engaged with the NCI Centre for Bioinformatics and their recent initiative caBIG (cancer bioinformatics Grid).
- BioCMAT has links to BIRN – resulting in award to implement a BIRN node in Edinburgh and Manchester.
- e-FAMILY is actively collaborating with EMBL-European Bioinformatics Institute.
- CLEF has a major collaboration with Stanford (CO-ODE/HyOntUse, Protégé).
- NeuroGRID will actively engage with BIRN.
- Several investigators are members of the Enabling Grids for e-Science in Europe (EEGE) programme.

### e-Science Programme at NERC

3.3.101 The NERC e-Science Programme was established in 2001 as part of the cross-research council e-Science Programme. The objective has been to support consortia based proposals from partnerships involving environmental scientists and computer scientists to deliver world-class e-Science and environmental science. The NERC e-Science Programme forms only part of NERC’s investment in e-Science, which is now being continued in NERC’s other research programmes, in its Research and Collaborative Centres and in responsive mode grants.

### Background

3.3.102 The NERC e-Science Programme provided £14.2M for research projects and studentships in environmental e-Science as part of the much larger cross-council initiative.

3.3.103 The following eight research projects have been supported following three funding rounds in October 2001, January 2002 and September 2004. Abstracts for these projects can be found at: [http://www.nerc.ac.uk/research/programmes/escience/facts.asp](http://www.nerc.ac.uk/research/programmes/escience/facts.asp).

#### Table 13 NERC supported projects 2001-2004

<table>
<thead>
<tr>
<th>Projects</th>
<th>Rounds 1 and 2</th>
<th>Round 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climateprediction.net</td>
<td>£284k</td>
<td>£435k</td>
</tr>
<tr>
<td>Climateprediction.net used very large ensemble runs to study climate change in the next century and measured the sensitivity of the existing models to small parameter variations like changes in carbon dioxide and the sulphur cycle.</td>
<td></td>
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</tr>
<tr>
<td>Grid for Ocean Diagnostics, Interactive Visualisation and Analysis (GODIVA)</td>
<td>£858k</td>
<td></td>
</tr>
<tr>
<td>The project developed tools to allow very large data sets from ocean and climate models to be visualised and explored collaboratively and remotely. This will support the study of ocean circulation and its impact on climate change.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environment from the molecular level (e-Minerals)</td>
<td>£1,336k</td>
<td>£1,679k</td>
</tr>
<tr>
<td>This project used Grid technologies to push forward the capabilities of molecular-scale simulations for the study of environmental processes.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grid ENabled Integrated Earth systems model (GENIE)</td>
<td>£1,130k</td>
<td>£1,378k</td>
</tr>
<tr>
<td>The GENIE project is delivering long term benefits to the Earth System modelling community by developing a scaleable model using a Grid based architecture to simulate long term climate change.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The NERC DataGrid</td>
<td>£722k</td>
<td>£826k</td>
</tr>
<tr>
<td>This project developed the infrastructure to provide seamless access to data holdings focussing initially on a solution for data discovery and usage in the atmospheric and oceanographic sciences.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Grid for Coupled Ensemble Prediction Studies (GCEPS)
The investigation to predict weather and climate changes for up to 10 years ahead by performing ensemble predictions based on varying the initial ocean, ice and land conditions. £723k

Global coastal ocean modelling (GCOM)
Developed a model for the coastal seas to improve the understanding of shelf sea contribution to the global carbon budget, which can be integrated in to larger earth system simulations. £451k

Creating a taxonomic e-Science (CATE)
Developed web based taxonomy for two groups of plants and one group of animals and made these tools available via the web to encourage take up and use by taxonomists for other groups. £487k

<table>
<thead>
<tr>
<th>Rounds 1, 2 and 3</th>
<th>£5,133k</th>
<th>£5,176k</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rounds 1, 2 and 3</td>
<td>£10,309k</td>
<td></td>
</tr>
</tbody>
</table>

3.3.104 The third round of funding was agreed in April 2005 and showed an increase in both the number and the quality of the proposals submitted compared to the previous two rounds. The following table shows the number of applications, their grades and the number that were awarded.

Table 14 NERC comparison of funding rounds

<table>
<thead>
<tr>
<th>Date</th>
<th>Applications</th>
<th>Rej.</th>
<th>a1</th>
<th>a2</th>
<th>a3</th>
<th>a4</th>
<th>Awards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round 1</td>
<td>Oct 2001</td>
<td>8</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1 3</td>
</tr>
<tr>
<td>Round 2</td>
<td>Jan 2002</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1 2</td>
</tr>
<tr>
<td>Round 3</td>
<td>Sep 2004</td>
<td>22</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>7*</td>
<td>6 7</td>
</tr>
</tbody>
</table>

* In Round 3 one a3 application was partially funded following the resubmission of the strongest part of the bid, which the committee considered to be a4.

Note: The Grading scale ranges from: Reject equals flawed and a5 equals outstanding.

3.3.105 The programme involved approximately 60 scientists as either Principle Investigators or Co-Investigators from 35 different institutions. Of those investigators based in university departments, 94% of them were from 5* or 5 rated departments. 30% of the Principle Investigators and Co-investigators for all the awards are based in computer science related institutions as indicated in figure 7.

Figure 7 NERC proportion of investigators by institution type

3.3.106 NERC’s Research Centres have been active participants in the e-Science Programme. The Centre for Ecology and Hydrology, Proudman Oceanographic Laboratory and National Oceanography Centre - Southampton were all participants in the first two rounds of projects. In addition to these British Antarctic Survey and Plymouth Marine laboratory are co-investigators in the final round.
3.3.107 The programme has funded 17 studentships in two rounds. NERC funded 8 studentships in the financial year 2003/04 and a further 9 studentships in the financial year 2005/06 and one project studentship in the year 2005/06. These are based at 14 different institutions, 12 of which are 5* or 5 rated and of these 3 are based in computer science departments.

3.3.108 NERC places a strong emphasis on knowledge exchange and in 2007 two knowledge exchange grants were funded. The projects were:

- **CSML- Strategic Exploitation and KT (C-SEKT) (e-Science)** - This project aims to evaluate and exploit the Climate Science Modeling Language in several high-profile globally-significant activities. *Lead Contacts*: Dr A Woolf and Dr BN Lawrence (STFC Laboratories, RAL) *Start Date*: 01/04/2008 *End Date*: 31/03/2010 *Grant Value*: £88,693.52.

- **Sharing and visualizing large volume environmental – data (e-Science)** - The main objective of this project was to transfer knowledge and technology from the DEWS project (Delivering Environmental Web Services) into the wider environmental science community. *Lead Contacts*: Dr J Blower and Professor K Haines (University of Reading) *Start Date*: 01/01/2008 *End Date*: 30/04/2009 *Grant Value*: £83,132.77.

3.3.109 **e-Science centres**: NERC funded two e-Science centres: National Institute for Environmental e-Science (NIEsS) and the Reading e-Science Centre (ReSC) (co-funded with the Core Programme).

3.3.110 **National Institute for Environmental e-Science**: The National Institute for Environmental e-Science (NIEeS) was based at the University of Cambridge and ran targeted outreach events and application specific events to promote and support the use of e-Science technologies within the UK environmental science community. These were attended by representatives from environmental non-government agencies and environmental companies. NIEeS ran 60 different events with over 2,500 attendees. NIEeS was involved in a number of demonstrator projects to promote e-Science. For example;

- NIEeS worked closely with the Cambridge e-Science Centre and the eMinerals project which developed a campus grid within Cambridge;
- NIEeS developed Fortran interfaces to help environmental scientists visualise their results in Google Earth;
- NIEeS undertook work to enable the ATHAM (Active Tracer High Resolution Atmospheric Model) and MCHSRM (Monte Carlo Hyperspectral Synthetic Remote Sensing Model) environmental models to be run in a grid environment.

3.3.111 **Reading e-Science Centre**: The Reading e-Science Centre (ReSC) had a more technical focus developing demonstrator projects with collaborators in academia, government agencies (e.g. the Met Office) and industry to showcase the potential of e-Science. ReSC employed two full-time staff with the grant from NERC and has developed numerous open-source tools and services, which have been adopted world-wide by researchers and operational environmental data providers. A further £1.7M has been won from grants from research councils, European framework programmes, industry and other funding bodies, enabling the ReSC to employ a further 4 full-time staff in order to build upon its core work. The ReSC has been very active in engaging with many communities, including scientists, government agencies, industry, the general public and the University of Reading itself.

3.3.112 The Centre will be sustainable for at least the next four years since winning an EPSRC e-Research Platform grant in 2008 in Partnership with Oxford and Southampton e-Science Centres. The aim is to play a more regional role in encouraging e-Research which will go beyond the NERC remit.

3.3.113 **Other outreach activities**: In addition to the e-Science centres the climateprediction.net project developed a short course for the Open University ‘Modelling the climate’ which ran for the first time in September 2005. They have also developed teaching materials for primary schools, key stage 3 / 4 Science, Maths and Geography and A Level Physics. The GENIE project has collaborated with the Open University to produce a user-friendly interface of the GENIE model for use in teaching.

3.3.114 **Achievements to date in Environmental Science**: The NERC e-Science programme aimed to fulfil joint objectives of undertaking excellent e-Science and environmental science. These
have been achieved in NERC’s e-Science Programme and have advanced the major areas of e-Science for the environmental sciences taken from Sir John Taylor’s original definition of e-Science; these areas are:

- **Distributed global collaborations** - examples are climateprediction.net and CATE;
- **Access to very large data sets** - examples are the NERC data Grid and eMinerals;
- **Very large scale computing resources** - examples are eMinerals, GENIE, GCEPS and GCOM;
- **High performance visualisations** - examples are GODIVA and the work of the Reading e-Science Centre.

### Section 3.3.115 Research Outputs:

The programme produced 254 publications to July 2009.

#### Table 15 Research Outputs

<table>
<thead>
<tr>
<th></th>
<th>Refereed journals</th>
<th>Books/ chapters</th>
<th>Multimedia and non refereed</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climateprediction.net</td>
<td>15</td>
<td>1</td>
<td>7</td>
<td>23</td>
</tr>
<tr>
<td>GENIE</td>
<td>43</td>
<td>4</td>
<td>10</td>
<td>51</td>
</tr>
<tr>
<td>GODIVA</td>
<td>10</td>
<td>4</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>e-Minerals</td>
<td>87</td>
<td>4</td>
<td>20</td>
<td>111</td>
</tr>
<tr>
<td>NERC DataGrid</td>
<td>7</td>
<td>2</td>
<td>25</td>
<td>34</td>
</tr>
<tr>
<td>CATE</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>GCEPS</td>
<td>4</td>
<td></td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>GCOM</td>
<td>2</td>
<td></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>174</strong></td>
<td><strong>12</strong></td>
<td><strong>67</strong></td>
<td><strong>254</strong></td>
</tr>
</tbody>
</table>

This includes 12 publications in Nature and 1 in Science.

### Section 3.3.116 e-Science related work being funded by other NERC programmes:

NERC does not formally classify e-Science research. Examples of research with e-Science elements outside the NERC e-Science Programme that have been funded are detailed below:

- **Demonstration of the Tablet Data Recorder used for the Countryside Survey**
  (Centre for Ecology & Hydrology: CEH and Lancaster Environment Centre) - CEH has undertaken the Countryside Survey in Great Britain at regular intervals since 1978. The field survey component involves in-depth recording of nearly six hundred 1x1km survey squares, selected to represent all the major habitat types in the UK. One of the biggest successes of the 2007 survey was the incorporation of digital data capture — the use of portable ‘tablet’ PCs (Itronix Duo-Touch) to record information on site. The use of digital data capture has enabled the data-gathering and capture phase to cut its timescale from 20+ months to nothing.

- **Optimising Antarctic scientific cruises using Google Earth to visualise near real-time data**
  (British Antarctic Survey: BAS) - use of the virtual globe technology provided by Google Earth to visualise complex near real-time data, specifically with reference to data collected as part of multidisciplinary Southern Ocean research cruises. Improving the interaction with near real-time data has enabled it to be used as a decision-making tool, improving the efficiency of the cruise programme by helping to position cruise stations in relation to environmental conditions (sea-ice, frontal zones). It has also allowed remote user interaction by providing a coherent visualisation of the data collected, thus maximising the scope of the science and saving resources.

- **Imperial College Ocean Model (ICOM)**
  Imperial College, London and the National Oceanography Centre, Southampton developed a global ocean circulation model based on an unstructured Grid, allowing variable resolution and self-adaptation to maximise model accuracy.

- **Geology in 3D (British Geological Survey: BGS)**
  The BGS has developed a digital work flow for geological mapping from field capture through to 3D modelling. OneGeology is an international initiative of the geological surveys of the world and a flagship project of the ‘International Year of Planet Earth’, which aims to create dynamic geological map data of the world available via the web allowing greater accessibility of geological information for everyone.
The QUEST (Quantifying and Understanding the Earth System) programme is a large £21M Programme and all the e-Science climate modelling based projects are linked to this Programme. The GENIE model, together with the framework for running the model which the e-Science project developed, is being used by two consortia projects within QUEST.

The Environmental Data Portal (EDP) is an innovative online system funded by NERC to overlay and visualise data from different scientific disciplines, from many sources and in various formats. It works by "harvesting" metadata files from participating organisations by using technology developed by the NERC Data Grid. An operational system will be able to handle, overlay and visualise most environmental datasets and will allow users to see, for example, land cover maps overlaid onto geological data.

3.3.117 Other e-Science grants that have been funded within NERC’s responsive mode funding stream are detailed below:

- **Investigating the dependence of tropical convective system lifecycle on environmental conditions and the implications for global cloud feedback** (Fellowship award). The study proposed to combine satellite observations, re-analysis data, and model simulations to provide an improved understanding of how the lifecycle of tropical convective systems depends on the large-scale environmental conditions. *Lead Contact:* Dr Joanna Futyan (University of Reading) *Start Date:* 01/09/2007 *End Date:* 31/07/2009 *Grant Value:* £234,400.84.

- **Finite eElement Adaptive grid Modelling of Ecosystems and Nutrient Transport (FILAMENT).** The overall objective of the grant is to quantify the role of mesoscale and sub-mesoscale processes in nutrient supply and primary production, in the oligotrophic region of the North Atlantic sub-tropical gyre by developing and applying a novel coupled biological-physical ocean model, which aims to advance ocean ecosystem modelling. *Lead Contact:* Professor Meric Srokosz (NOCS), *Start Date:* 03/06/2008 *End Date:* 02/06/2011 *Grant Value:* £499,390.47.

- **Models and Impact Relevant climate Prediction (MIRP)** (a knowledge exchange grant). The project is about exploiting the BADC (British Atmospheric Data Centre) position as one of three global repositories for model intercomparison data to facilitate information and data flow between the earth system modelling community and the impacts and adaptation communities. The main aim is to have in place the ability for that information flow to be appropriate and available during and soon after the next Intergovernmental Panel on Climate Change assessment phase. *Lead Contact:* Dr BN Lawrence (STFC Laboratories, RAL) *Start Date:* 01/04/2010 *End Date:* 31/03/2013 *Grant Value:* £429,487.85.

- **Public Resource Distributed Modelling.** The approach to climate modelling that has been pioneered by the climateprediction.net/ BBC Climate Change Experiment project has been followed up with two further projects supported by NERC.

- **Climateprediction.net/PRECIS.** Transferring the tools and skills for regional climate prediction is a NERC knowledge transfer grant. It aimed to make the distributed computing facility pioneered by climateprediction.net available to scientists around the world, particularly in the developing world, who will be able to design and carry out climate modelling experiments which will give them unprecedented access to information about how the climate in their local region will change.

- **The Seasonal Attribution Project** studied the extent to which the risk of occurrence of extreme weather events is attributable to human-induced climate change. The focus was on the UK floods of autumn 2000 which occurred during the wettest autumn ever recorded, causing widespread damage and an estimated insured loss of £1.3 billion. This work was funded by WWF International and a NERC studentship.

3.3.118 **End of Programme Event:** The end of programme event was a successful two-day Royal Society discussion meeting entitled: ‘The Environmental e-Science Revolution’.
The meeting was funded by NERC through the e-Science Programme, with support from Microsoft Research. Prominent speakers were invited from both inside and outside the Programme. The meeting also had an extended demonstration and poster session from projects that were funded through the programme.

The meeting was aimed at environmental scientists who are using or are hoping to use e-Science tools and techniques to undertake their research. Following this meeting a volume of Philosophical Transactions A of the Royal Society has been published on this topic containing contributions from key speakers and presenters at the meeting along with those who were funded through the Programme. This is also available online as open source journal: [http://rsta.royalsocietypublishing.org/site/issues/eScience.xhtml](http://rsta.royalsocietypublishing.org/site/issues/eScience.xhtml).

NERC has also produced a 24 page publication demonstrating the key highlights of the NERC e-Science Programme entitled e-Science: Harnessing the power of the internet for environmental research. [http://www.nerc.ac.uk/publications/other/escience.asp](http://www.nerc.ac.uk/publications/other/escience.asp).

NERC e-Science links to Strategy and the Future: The previous NERC strategic plan Science for a Sustainable Future 2002 - 2007 had a key objective to train and develop skilled people. This explicitly identified the need for IT specialists to work with environmental scientists, particularly in relation to Earth System Modelling. The NERC e-Science Programme has already delivered some of these rapid advances.

The NERC e-Science projects are also undertaking research to support NERC’s strategic science priorities from the strategy Next Generation Science for Planet Earth 2007 – 2012. In particular the Technologies theme identifies that ‘Rapid advances in software engineering, and information and communication technologies are revolutionising the way researchers are working, and working together, to use computing power and scientific data repositories’. The Technologies theme in the strategy further emphasises the importance of technologies such as e-Science within NERC.

The CEH Environmental Information Data Centre (EIDC) has been developed as there is a requirement to manage scarce environmental resources in a sustainable and integrated manner. The primary objective of the EIDC is to provide researchers (both internal and external to CEH) with access to the coordinated data resources and informatics tools required to deal with complex, multidisciplinary environmental questions, which has built on e-Science technologies.

As part of LWEC (Living With Environmental Change) the Virtual Observatory programme has been created to define the concepts and methods that will enable a better understanding of the water-soil system of rivers. The Virtual Observatory seeks to capture the opportunity to harness the new technologies and advances in data-mining and high performance computing, as well as in distributed networking and near real-time environmental observations, (which have been developed through the e-Science Programme) to address fundamental science questions across a wide spectrum of the NERC research community.

e-Science Programme at STFC

Background

The Science and Technology Facilities Council was formed as a new Research Council on 1 April 2007 through a merger of the Council for the Central Laboratory of the Research Councils (CCLRC) and the Particle Physics and Astronomy Research Council (PPARC) and the transfer of responsibility for nuclear physics from the Engineering and Physical Sciences Research Council (EPSRC). Funding for e-Science was provided to both CCLRC and PPARC and the following details set out the e-Science Programme of these research councils.

CCLRC

CCLRC received £5M for e-Science in SR2000 and £6M in SR2004, over three years and two years respectively.
3.3.128 CCLRC’s remit to Grid-enable its facilities was tackled in several ways.

- Undertaking basic technology projects;
- Putting grid-enabled infrastructure in place;
- Embedding the developed technology in data taking and analysis via deployment projects with the facility scientists.

3.3.129 In parallel with this, CCLRC collaborated with most other research councils, JISC, and the e-Science Core Programme in their e-Science projects in order to disseminate CCLRC’s experience and to foster common approaches across the community.

3.3.130 The majority of these funds were used to support work through the CCLRC e-Science Centre (see [http://www.e-science.stfc.ac.uk/](http://www.e-science.stfc.ac.uk/)) which also received funding from other UK research councils (BBSRC, EPSRC, NERC and PPARC), government departments (DTI) and the European Union (EGEE). The overall scale of Programme was ~£11M and ~100 people. The e-Science Centre focused on:

- Data storage, management, and curation;
- Data computation, analysis and visualisation.

3.3.131 This has been delivered through:

- Direct contributions to STFC projects and activities, e.g. LHC, ISIS, Diamond Light Source (DLS), Central Laser Facility (CLF):
  - Initially a series of deployment projects were undertaken with the facilities to investigate enhancements in data-taking, metadata capture, near real-time analysis, visualisation, and instrument control. By the end of this period, CCLRC had started second generation projects integrating several basic technologies into facility applications. Examples included a proposal management system, data catalogue, the EVE project (Excitations Visualisation Environments) for ISIS and the data catalogue and storage facility for DLS. The development of the second target station for ISIS included significant investment in integrated analysis software;
  - Infrastructure investments in data storage, computational facilities and networking.
- Developing technologies and infrastructure for current and future programmes in partnership with other stakeholders:
  - Grid infrastructures for the UK and Europe (UK NGS, EGEE);
  - Information management in a distributed heterogeneous environment (collaborative work on Storage Resource Broker, the NERC Data Grid);
  - Long term data curation (UK Digital Curation Centre and the European CASPAR project);
  - Advanced analysis and visualisation (Godiva, Integrative Biology).
- Leveraging STFC investment and expertise through provision of services to partner organisations:
  - Data storage services for PPARC, AHRC, BBSRC;
  - JISCMAIL and NGS for JISC;
  - VizNet training;
  - UK e-Science Certification Authority.

3.3.132 The majority of projects undertaken were collaborative (both with other STFC departments and with other institutions in the UK and internationally). The terms "collaborative" and "co-funded" are much more applicable as a metric to those research councils with a strong focus on providing funding via grants. For these research councils, these terms have very specific definitions. It is not straightforward to apply these metrics to the funding provided by PPARC and, particularly, to CCLRC where a significant proportion of funding was provided through routes other than grants. One example is that CCLRC provided the additional 20% of the Full Economic Costs required for the CCLRC components of projects awarded by other research councils (examples include e-Minerals and e-Materials) or provided funding for additional staff effort on funded projects (for example, Integrative Biology). This type of funding does not comply with the grant-related definition but instead reflects the different nature of the funding provided by CCLRC compared to other research councils. Some projects were co-funded, GridPP, for example, has been funded by PPARC, the Higher Education Funding

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6 These include ISIS spallation neutron source, Diamond Light Source, RAL Central Laser Facility, Synchrotron Radiation Source at Daresbury, LHC Tier 1, British Atmospheric Data Centre.
Council for England (HEFCE), the Scottish Funding Council (SFC) and the European Union. Examples of collaborative projects include:

- The e-Science Centre contributed to the completed GODIVA project, a NERC funded Web Portal, with collaboration with National Oceanography Centre, Southampton, and ESSC at the University of Reading, The University of Manchester and Imperial College;
- CCLRC participated in iAstro, European COST Action 283, Computational and information infrastructure in the Astronomical DataGrid;
- The e-Science Centre was a collaborative partner in NERC’s largest e-Science project, Environment from the Molecular Level (e-Minerals) (http://www.eminerals.org/). Other partners included the Universities of Cambridge, Bath, Reading and UCL (both Earth and Computer Sciences). The project brought together simulation scientists, applications developers and computer scientists to develop UK e-Science Grid capabilities for molecular simulations of environmental issues;
- The e-Science Centre was involved in the NERC Data Grid project. This flagship project remains key to NERC’s data aspirations. The original scope of the project was to provide a common data sharing environment for all of the NERC Data Centres, starting as demonstrators with the British Atmospheric Data Centre (BADC) and the British Oceanographic Data Centre (BODC). Through continued NERC funding, the existing infrastructure has been strengthened and expanded to encompass the National Oceanographic Centre - Southampton and the Plymouth Marine Laboratory;
- Independently of (and in parallel with) the NERC e-Science Programme, the e-Science Centre worked with the Centre for Hydrology and Ecology (CEH) at Lancaster (another NERC Data Centre) on the Ecological Data Grid project. The aim of this project was to provide the CEH-specific developments needed for them to join the NERC Data Grid;
- The JISC and Core Programme funded Digital Curation Centre provided advice and tools to the UK scientific and Library communities on the active preservation of data. The CCLRC e-Science Centre has been a key partner contributing a significant research effort in collaboration with the three other centre partners, the Universities of Edinburgh, Glasgow and Bath;
- The Integrative Biology project funded by EPSRC to investigate the causes of cardiovascular problems and cancer using numerical modelling, has involved collaboration with a large number of organisations. CCLRC provided the data management infrastructure for the project and led the work on the Grid for tumour modelling, visualization and interactive services.
- The e-Science Centre collaborated with the UCL Chemistry and Computer Science departments and the Royal Institution on e-Science Technologies for the Simulation of Complex Materials, part of the e-Science Core Programme. The project supported the production and sharing of combinatorial chemistry and complex material science results.
- Large scale computer simulation of physical properties of materials was a DTI funded project to create a dynamic pilot database of materials properties (such as elastic stiffness, dielectric constants, optical properties, heat capacity, electronic band gap) based on quantum mechanical simulations run within Grid computing environments, thereby creating a new industry service. Partners in the project included the Universities of Cambridge and Frankfurt, IBM and the bioinformatic software company, Accelrys.

3.3.133 Highlights from the CCLRC programme include:

**Grid Computing**

The computing Grid project for the Large Hadron Collider (LHC) has been one of the highest priority activities for PPARC, CCLRC and STFC. The e-Science Centre led the deployment and operation of the UK Tier-1 centre, coordinated the technical operation of the national GridPP Grid and continues to play a leading role in the deployment of the worldwide LHC Grid project. Without the infrastructure deployed by GridPP and LCG (LHC Computing Grid), it would not be possible to effectively use the distributed computing resources required to fully exploit the data from the LHC. The UK is recognised as leading the way in deployment and operation of Grid computing infrastructure. The e-Science Centre led the UK involvement in the European Grid infrastructure project (EGEE) and represented the UK in the Design Study for a European Grid Infrastructure. In the UK, the e-Science Centre has coordinated the deployment and operation of the National Grid Service infrastructure for support of Research.
Data and Information Management
CCLRC pioneered a range of technologies to facilitate the management, exploitation and curation of scientific data. These are now being exploited through the STFC facilities and their user communities. The technologies include:

- The Core Scientific Metadata Model (CSMD) and its implementation as an Information Catalogue System (ICAT) which gives a common schema for representing scientific data across domains;
- The DataPortal software which enables scientists to search in parallel across distributed, heterogeneous metadata catalogues and give easy access to the data;
- Systems which support the automatic collection of metadata from both computational and experimental processes;
- Ontology management tools to support communities in maintaining their own semantic infrastructure;
- The e-Pubs Institutional Repository (IR) which holds records of over 30,000 ex-CCLRC publications spanning 20 years and is the 3rd largest IR in the UK;
- The cost effective storage and management of multi-petabyte data volumes, including development of standards based Grid interfaces to the data (SRM).

Data Analysis and Visualisation
CCLRC developed data analysis and visualisation systems which provide scientists with effective tools for Grid-enabled access to HPC and high-end visualization resources for large scale computational problems. Working in close collaboration with application scientists, leading edge user interface and parallelisation and visualization software has been developed to improve researcher effectiveness. Examples of the technologies developed include:

- The Integrative Biology Grid Interface which is being exploited by users in Oxford and in the USA to enable them to use Grid resources to perform in-silico experiments of heart and cancer models from their desktops;
- The Tobyfit software described above which is now able to cope with the vast data sets generated by the new generation instruments such as MERLIN and is being adopted by other groups in the Universities of Bristol and Cambridge and in the USA;
- Distributed visualisation technology which allows users to exploit remote high-end visualization resources and display results on their desktops. This is of major importance to data analysis in the facilities and to computational biologists in the Integrative Biology project.

Digital Preservation and Curation
CCLRC is known world wide as a key player in the development of long term data curation technologies. It has been leading the development of policy and technology in this area. For example:

- The e-Science Centre has been one of the four partners in the national Digital Curation Centre (DCC) which provides expertise, advice and tools for the UK community;
- The e-Science Centre is leading the EU project, CASPAR, which is developing tools and infrastructure components to support digital preservation for any and all digital objects;
- Dr David Giaretta, an astronomer at the CCLRC Rutherford Appleton Laboratory, was one of the principle authors of the Open Archival Information System (OAIS) Reference Model (ISO 14721) which defines a framework for digital preservation and now forms the basis of much work in this area;
- Dr Giaretta has also been a main contributor to the Audit and Certification checklist, and leads the ISO standardisation work, as a follow-on to the OAIS standard;
- The e-Science Centre is a member of the Digital Preservation Coalition and founding member of the European Alliance for Permanent Access.

The expertise and tools developed in these activities are used across the operations of STFC to improve the services provided to the research community and securing the valuable data produced at its facilities for the future. Externally, IBM, are planning to incorporate digital preservation functions developed in CASPAR into their next generation storage devices.

Security and Trust
e-Science research on trust and security has focused on STFC Grid developments, tackling current challenges in Grid security as well as security issues for next generation Grids. This included the development of approaches to create high-level trust in virtual organisations. Examples include:
ShibGrid, a Shibboleth based access method for the National Grid Service (NGS);
- Novel techniques for authentication and authorisation in Grids for Virtual Organizations and distributed mobile services developed by the XtreamOS and the Akogrimo projects;
- Usability issues of the UK e-Science Certification Authority;
- Modelling and enforcing general virtual organization agreements as developed in the TrustCoM project;
- Improvements to requirements-engineering methodologies for dealing with security requirements for e-Science applications.

**Semantic Web**
The e-Science Centre has had a significant impact on the development of some semantic web technologies which have now become international standards. The research focused on retrieval of scientific and technical information in open information systems such as the Web, and on using the Web as a platform for sharing and linking scientific data in "data webs". For example:

- The Simple Knowledge Organisation System (SKOS) a new technology for information retrieval was initially developed by e-Science staff in research funded by the EU-IST programme (SWAD-Europe). SKOS is now under development as an international Web standard;
- Development of best practices for publishing data on the Web. This work has had a wide impact in the development of information management technologies for science, media, government and cultural heritage. NASA and Dow Jones, for example, use SKOS as a key standard in the information systems.

**Climate Science Modelling Language**
The e-Science Centre developed techniques for integrating a wide range of information in the atmospheric and oceanographic sciences within global-scale infrastructures. This enabled interoperability with a range of other information including biodiversity, resource management and emergency response. The Climate Science Modelling Language (CSML) was a conceptual model and XML encoding for this type of data. It was a pioneering application of emerging ISO and web service standards and attracted attention from universities and agencies worldwide, including the UN World Meteorological Organisation. While being deployed operationally in NERC, it continued to be developed and promoted for use in a range of international initiatives (EU INSPIRE Directive, Global Earth Observing System of Systems, EC-ESA's Global Monitoring for Environment and Security, WMO Information System).

**PPARC**

3.3.134 The PPARC e-Science Programme focussed on funding computational and data Grid applications, middleware development and essential hardware to develop resources for data and information management and processing across local, national and global networks. Such resources were essential for the delivery of PPARC’s future Programme, for example, facilities such as the LHC (Large Hadron Collider) experiments and the UKIRT WFCAM (Wide Field Camera) will generate massive quantities of data that must be made available in a seamless way to scientists across the research communities.

3.3.135 PPARC received a total of £57.6M from the Spending Reviews in 2000 and 2002 to support developments in e-Science.

3.3.136 The SR 2000 Settlement provided £26M. This was used to support the following:
- **GridPP** ([http://www.gridpp.ac.uk/](http://www.gridpp.ac.uk/)) - a collaboration of physicists and computer scientists in the UK and at CERN to develop the grid computing technologies to meet the computing challenge of the Large Hadron Collider (LHC), the world’s largest particle accelerator based at CERN. This included the UK contribution for the EU-DataGrid (EDG) project and implemented the UK components of the EDG test bed. Approximately 30% of the GridPP resources were invested directly at CERN as the UK contribution to the CERN LHC Computing Project (£5.6M);
- **AstroGrid/VISTA** ([http://www.astrogrid.org/](http://www.astrogrid.org/)) – development and deployment of a working UK Virtual Observatory for a number of key UK astronomical data sets and for the development of a data flow system for the VISTA telescope. The AstroGrid consortium collaborated with two EU-funded Grid projects; AVO and EGSO (£5M);
Grid OneD – development of a Grid based analysis framework for gravitational wave data analysis;

Collaborative projects in Biology and Medicine;

Contributions to the e-Science Core Programme (eSCP) including support for the UK Grid Support Centre and joint funding of computer science groups contributing to the EU DataGrid project;

A collaborative project with the eSCP, CISCO and UKERNA to look at Multi Protocol Label Switching (MPLS) for the development of managed bandwidth and Quality of Service (QoS) in high speed networking;

e-Science Studentships - 10 per annum (£1.5M).

3.3.137 The SR2002 Settlement provided a further £31.6M. Following a call for proposals, this was used to support the following:

GridPP Phase 2 – continuation of support to build on the prototype developments in Phase 1 to deploy the computing Grid required for full UK exploitation of the LHC. A collaboration between 19 UK universities and CERN, GridPP was part of the follow-on project to the EU DataGrid project, Enabling Grids for e-Science in Europe (EGEE), which aims to support the European Research Area by bringing together Grids from different countries and different disciplines (£15.9M);

AstroGrid Phase 2 – support to develop further the infrastructure of the UK Virtual Observatory. The second phase extended the deployed tools to support new areas of science such as solar-terrestrial physics. A collaboration of 11 UK universities (£4M);

Virtual Universe (VirtU) – a project to make the results of cosmological simulations more widely available and integrated with the developing standards for the Virtual Observatory (£150k);

ATLAS computing project - part of the UK ATLAS project which will meet the UK software and computing commitments to the ATLAS experiment at the LHC in CERN in preparation for full exploitation in 2007 (£2.45M);

CMS computing project - to construct and support the CMS UK computing system, including developing a Grid monitoring system and tools for exploitation of the CMS tracker, Endcap Calorimeter and trigger systems at the CMS experiment at the LHC at CERN (£1.1M);

Large Hadron Collider beauty computing project – to develop and deliver the computational infrastructure required to underpin the physics programme at the LHCb experiment at the LHC in CERN (£1.12M);

Combined e-Science Data Analysis Resource for high energy physics (CEDAR) (http://www.cedar.ac.uk/) - develop an e-Science resource for particle physics with a Grid-based archive of measurements made at existing and past experiments and calculations and phenomenological models of relevance to high energy physics (HEP) providing easy, automatic comparisons between them. A key motivation of CEDAR is to provide a set of services to the HEP community which will be the standard way for recording reaction data and tuning Monte Carlo programs. (£300k);

Enabling Virtual Observatory Access to ALMA Data - develop the data archive of the Atacama Large Millimetre Array (ALMA) (http://www.eso.org/sci/facilities/alma/) as an integral and inter-operable component of the Virtual Observatory. This gave the UK a leading role in the handling of ALMA data when it came on stream in 2007 (£300k);

VEGA - to develop astronomical data pipelines and archives for new astronomical facilities and missions. The VEGA programme deployed the data processing pipeline and archive for the VISTA telescope (http://www.vista.ac.uk/) and carried out preparatory similar developments for the GAIA mission (http://sci.esa.int/science-e/www/area/index.cfm?areaid=26) (£2.26M);

UK Swift Data Centre (http://www.swift.ac.uk/swift_live/) – to provide the UK astronomical community with rapid data services from the Swift space-based X-ray and optical/UV observatory (http://www.swift.ac.uk/) and spectroscopic data from the Faulkes Telescopes (£512k);

Making SDO (NASA Solar Dynamics Observatory) data available to the Virtual Observatory - to develop and deploy data processing for the SDO (http://sdo.gsfc.nasa.gov/) and fully interface the SDO data with the UK Virtual Observatory (£500k);

e-Star - to develop and deploy software infrastructure to support robotic telescope control for time-critical and time-dependent astronomy (£250k);
GridOneD – continued support of the Grid-based analysis framework for gravitational wave data analysis (£350k);

Gamma Grid - to develop and support the “mass modeling” data processing for the Swift data centre (£190k);

Designer Algorithms for Astronomical Data Mining - to deploy virtual observatory tools for automated classification and extraction of key physical quantities for large data sets (£150k);

Contribution to the funding of the National e-Science Centre Training Team for the Europe-wide EGEE project (£100k);

Astronomy Software Support Group at CCLRC (£250k);

The remaining e-Science funds supported PPARC e-Science studentships, e-Science summer schools and related training.

3.3.138 Some selected highlights include:

AstroGrid

- Leading development of vital international standards through the International Virtual Observatory Alliance (IVOA) which will support truly pervasively globally inter-operating VO systems, including those in the areas of authorisation, virtual storage and application execution architectures;

- A developmental Virtual Observatory System transitioned to an operational system for UK astronomical science research;

- Over 300 registered users;

- Core infrastructure has been deployed in Russia, and will soon be deployed in South Africa (providing seamless UK access to key South African Large Telescope data sets); Japan is also interested in deploying key components.

GridPP

- GridPP is closely involved in two major international projects EGEE co-ordinates regional and disciplinary Grids to form the largest multi-science Grid in the world:
  - GridPP contributed substantially to EGEE’s first biomedical data challenge WISDOM (Wide in Silico Docking on Malaria). The Franco-German led challenge saw production of over 46 million docked ligands - this would have taken over 80 years on a single PC, when in fact it took six weeks. Overall, the UK processed the second highest number of biomedical jobs of any country, with GridPP contributing approximately 100,000 kSI2k-hours of CPU time;
  - There are around 150,000 CPU in the EGEE Grid, spread over 280 sites in more than 50 countries. In the year to July 2009, GridPP provided 19% of EGEE’s computer time and contributed nearly 90 million CPU hours (KSI2K hours) to more than 30 EGEE virtual organisations, including for biomedical research, geoscience and fusion research.

VEGA

This project supports the reduction of the data flow from the UKIRT (UK Infrared Telescope) WFCAM (Wide-Field Camera) instrument and the processing and archiving needs of the VISTA telescope instruments. The data flow system was used for processing other priority European instrument data e.g. European Southern Observatory's Very Large Telescope Survey Telescope Omegacam data in support of their public survey programme. The project played a lead role in the definition of the European-wide data reduction and science analysis system for the European Space Agency Global Astrometric Interferometer for Astrophysics mission. Key elements of the VISTA pipeline were adapted for use in the processing system to handle the GAIA mission data flow (photometric and spectroscopic data).

The UK Swift Data Centre

Operating since the launch of Swift in November 2004. The Swift science team received a Group Achievement and the 2005 Exceptional Achievement Awards from NASA.

The NASA Swift gamma-ray mission makes prompt multi-wavelength observations of gamma-ray bursts (GRB) and their associated afterglows. UK astronomers were part of an international team that used the Swift satellite to observe the first moments of a supernova explosion as it happened. This extraordinarily fortunate discovery led to multiple observations with other telescopes and allowed the totality of a supernova explosion to be observed for the first time. Researchers have also used the satellite to track comets as they close in on Earth.
Virtual Universe
The project developed software and middleware to incorporate data from the Millennium Simulation into a Theoretical Virtual Observatory.

Designer Algorithms
The project developed tools for convenient visualisation in two dimensions of high dimensional data, using latent variable techniques, with special emphasis on finding clusters and outliers. It has used genetic algorithms, which allow models themselves to evolve, in a fashion modelled on biological evolution, to provide a more flexible and sophisticated suite of models for the density distribution in galaxies and clusters.

e-Star
The project enabled the Liverpool & Faulkes Telescopes to inter-operate. Intelligent Agents were developed to carry out a number of science programmes on these telescopes, including gamma ray burst follow-up and Dwarf nova outburst monitoring. GRB reaction time of less than 3 minutes on the Liverpool and Faulkes Telescopes resulted in the FIRST multicolour early time gamma ray burst optical light curve.

3.3.139 Future plans - During the next (exploitation) phase, support continues for e-Science activities within the research programmes rather than as a discrete e-Science programme. GridPP is now in its third phase (~£16M), which will run until April 2011. Continuing support was provided for Astrogrid (£1.2M) until June 2009.

e-Science Programme at AHRC

3.3.140 e-Science in the Arts and Humanities (A&H) may sound like a contradiction in terms, but there should be no doubt about the potentially transforming impact on the A&H of the e-Science technologies that have been used across the range of other disciplines.

3.3.141 The most obvious application, though not the only one, is in data Grid and related applications; the ‘data deluge’ in the A&H is as much of a problem in the A&H as in other domains. A&H data exists in a large variety of technical forms, and each collection, sometimes each item, can typically only be accessed on its own. Yet the usefulness of data grows in proportion to the ability to connect it with other data; not just one text to another, for instance, but texts to images, historical to geographical data, and so on. e-Science data technology offers ways of making far more powerful use of the electronic resources that are already possessed.

3.3.142 Other Grid technologies associated with e-Science also have significant potential for the A&H. The high-performance computing resources of the computational Grid are beginning to show their value for processing large volumes of A&H data, often fuzzy or unstructured, including visual and sound resources as well as text. The video-conferencing facilities provided by the Access Grid are becoming increasingly important with the spread of collaborative research in the A&H, and also provide exciting new opportunities for sharing performance and creative interaction in the arts. In practice, however, e-Science in the A&H has not only involved the development of Grid and related technologies; its scope has been broader, and is best understood as enabling all sorts of advanced research and development collaborations between computer scientists and arts and humanities scholars. E-Science is now considered simply as the advanced end of e-Research in the A&H.

3.3.143 The A&H did not benefit from the ear-marked funding for the national e-Science Programme, mainly because the AHRC did not exist as a research council when the Programme was established. Instead a separate A&H e-Science Initiative was launched by the AHRC in 2005, with support first from JISC and then from EPSRC. Total funding from all three bodies was approximately £3.2m.

3.3.144 The Initiative has funded the following activities:
- An e-Science Scoping Survey by Sheila Anderson, King’s College London, on ‘Scoping e-Science and e-social science developments and their value to the arts and humanities’. See http://www.ahe ss.ac.uk/scoping-survey/ for details of the survey, and access to its reports.
A JISC-funded e-Science Support Centre (AHESSC) at King’s College London: see http://www.ahessc.ac.uk/. This is now funded until August 2010, and exists to support projects awarded by the Initiative, to support and promote e-Science in all arts and humanities disciplines, and to liaise across the e-Science, e-social science, computing and information sciences communities.

A series of e-Science Workshops and Demonstrators. These explored the application of a wide range of ICT technologies, including all three types of Grid technology, to research across a range of A&H disciplines. They helped to set the agenda for the research grants and studentships call that followed, and have all been now completed: details are available at http://www.ahessc.ac.uk/workshops-demonstrators2.

Table 16 AHRC funded workshops and demonstrations

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<th>Name</th>
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<td>PF Ainsworth</td>
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<td>Virtual Vellum: Online Viewing Environment for the Grid and Live Audiences</td>
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<tr>
<td>Alan Bowman</td>
<td>University of Oxford</td>
<td>User Requirements Gathering for the Humanities</td>
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<td>CV Crowther</td>
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<td>Paul Ell</td>
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<td>Geographical Information System e-Science: developing a roadmap</td>
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<td>SJ Norman</td>
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<td>Motion Capture Data Services for Multiple User Categories</td>
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</tr>
<tr>
<td>David Shepherd</td>
<td>University of Sheffield</td>
<td>The Access Grid in Collaborative Arts and Humanities Research</td>
</tr>
<tr>
<td>Gregory Sporton</td>
<td>University of Central England</td>
<td>Building the Wireframe: e-Science for the Arts Infrastructure</td>
</tr>
<tr>
<td>Melissa Terras</td>
<td>University College London</td>
<td>ReACH: Researching e-Science Analysis of Census Holdings</td>
</tr>
</tbody>
</table>

A series of e-Science research grants and postgraduate studentships, to a total value of over £2m, awarded in May 2007. Seven awards were made across a wide range of e-Science technologies, and a wide range of subjects in both the arts and the humanities, from dance and music to museum studies, archaeology, classics and Byzantine history. These projects are all still in progress; details are as follows:

Table 17 AHRC e-Science research grants and postgraduate studentships

<table>
<thead>
<tr>
<th>Name</th>
<th>University</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helen Bailey</td>
<td>University of Bedfordshire</td>
<td>Relocating Choreographic Process: The impact of Grid technologies and collaborative memory on the documentation of practice-led research in dance</td>
</tr>
<tr>
<td>Alan Bowman</td>
<td>University of Oxford</td>
<td>Image, Text, Interpretation: e-Science, Technology and Documents</td>
</tr>
<tr>
<td>Tim Crawford</td>
<td>Goldsmiths College, University of London</td>
<td>Purcell Plus: Exploring an e-Science Methodology for Musicologists</td>
</tr>
<tr>
<td>Vincent Gaffney</td>
<td>University of Birmingham</td>
<td>Medieval Warfare on the Grid: The Case of Manzikert</td>
</tr>
<tr>
<td>Sally MacDonald</td>
<td>University College London</td>
<td>e-Curator: 3D colour scans for remote object identification and assessment</td>
</tr>
<tr>
<td>Julian Richards</td>
<td>University of York</td>
<td>Archaeotools: Data mining, faceted classification and e-archaeology</td>
</tr>
<tr>
<td>Monica Schraefel</td>
<td>University of Southampton</td>
<td>musicSpace: Using and Evaluating e-Science Design Methods and Technologies to Improve Access to Heterogeneous Music Resources for Musicology</td>
</tr>
</tbody>
</table>

3.3.145 From its beginnings as the AHRB (Research Board), the AHRC has funded and continues to fund a large number of projects producing digital outputs. Almost all of the now-terminated...
Resource Enhancement Scheme fell into this category; the proportion of standard research grants that do so has risen from 31% in 2000 to well over 40% in 2006-8. These outputs have in virtually all cases taken the form of digital content resources, rather than tools, and have generally not involved the development of new or advanced methods and technologies. Digital outputs under the standard research grants must also be integrally linked to research findings. The advantage of the separate e-Science Initiative is to have allowed the funding of cutting-edge technological and methodological developments, which have not necessarily been required to generate significant and immediate research findings, only to demonstrate their potential for doing so.

3.3.146 The initiative is run as an integrated programme under the leadership of David Robey, as Director of the AHRC ICT in Arts and Humanities Research Programme. For more details, see http://www.ahrcict.rdg.ac.uk/activities/e-science/.

### Statistical overview of the UK e-Science Programme

3.3.147 Research grants provide financial support to research organisations for specific research projects. A project may consist of more than one research grant. Although people often refer to a “standard grant” there is in fact no such thing. Grants range from a few thousand pounds to several millions and from a few months to more than 5 years. There is a distinct trend for longer and larger grants, driven by trends to be more transformative and collaborative. In addition to these mechanisms for funding, research councils may provide funds via a contract with an institution.

3.3.148 The total number and value of e-Science research projects/contracts funded by all research councils is shown in Figure 8. This includes projects funded from individual research council’s budgets after the ring-fenced funding ended in 2005/06. As shown in the figures below, some research councils did not capture whether a project was related to e-Science after 2005/06, and hence no data could be provided. STFC provided funding to CERN as part of the GridPP project in the form of a contract.

![Figure 8: e-Science research projects/contracts funded by all research councils 2001-09](image-url)
The number and value of research projects/contracts funded in e-Science by each research council are shown in figures 9, 10, 11, 12, 13, 14 and 15. Please see section 3.3.5 on research council spend profiles for e-Science funding for an explanation on how the funding was distributed.

Figure 9  e-Science research projects funded by the Core Programme 2001-09

![Figure 9](image1.png)

Figure 10  e-Science research projects funded by BBSRC 2001-09

![Figure 10](image2.png)
### Figure 11  e-Science research projects funded by EPSRC 2001-09

The number and value of all e-Science projects supported by EPSRC during the last 8 years to 2008/2009.

<table>
<thead>
<tr>
<th>Financial Year</th>
<th>Value (£M)</th>
<th>Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001/02</td>
<td>21</td>
<td>6</td>
</tr>
<tr>
<td>2002/03</td>
<td>14</td>
<td>21</td>
</tr>
<tr>
<td>2003/04</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>2004/05</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>2005/06</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>2006/07</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>2007/08</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>2008/09</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

Note: EPSRC continues to support e-Science projects through their standard research programmes. However, as e-Science is not a research topic code these grants cannot be identified. See section 3.8 for examples of further related funding.

### Figure 12  e-Science research projects funded by ESRC 2001-09

The number and value of all e-Science projects supported by ESRC during the last 8 years to 2008/2009.

<table>
<thead>
<tr>
<th>Financial Year</th>
<th>Value (£M)</th>
<th>Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001/02</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2002/03</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>2003/04</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>2004/05</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>2005/06</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>2006/07</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>2007/08</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>2008/09</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>
Figure 13  e-Science research projects funded by MRC 2001-09

The number and value of all e-Science projects supported by MRC during the last 8 years to 2008/2009

<table>
<thead>
<tr>
<th>Financial Year</th>
<th>Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001/02</td>
<td>4</td>
</tr>
<tr>
<td>2002/03</td>
<td>4</td>
</tr>
<tr>
<td>2003/04</td>
<td>4</td>
</tr>
<tr>
<td>2004/05</td>
<td>1</td>
</tr>
<tr>
<td>2005/06</td>
<td>1</td>
</tr>
<tr>
<td>2006/07</td>
<td>1</td>
</tr>
<tr>
<td>2007/08</td>
<td>1</td>
</tr>
<tr>
<td>2008/09</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 14  e-Science research projects funded by NERC 2001-09

The number and value of all e-Science projects supported by NERC during the last 8 years to 2008/2009

<table>
<thead>
<tr>
<th>Financial Year</th>
<th>Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001/02</td>
<td>5</td>
</tr>
<tr>
<td>2002/03</td>
<td>2</td>
</tr>
<tr>
<td>2003/04</td>
<td>1</td>
</tr>
<tr>
<td>2004/05</td>
<td>7</td>
</tr>
<tr>
<td>2005/06</td>
<td>2</td>
</tr>
<tr>
<td>2006/07</td>
<td>1</td>
</tr>
<tr>
<td>2007/08</td>
<td>2</td>
</tr>
<tr>
<td>2008/09</td>
<td>2</td>
</tr>
</tbody>
</table>

Note: NERC continues to support e-Science projects through their standard research programmes. However, as e-Science is not a research topic code these grants cannot be identified. See section 3.8 for examples of further related funding.
Co-funding to e-Science projects (2001-2008)

3.3.150 Additional funding into the e-Science Programme has been received from a number of sources. Co-funding occurs when one organisation is the lead funder, but the remit of the project falls within the scope of another organisation, and so they provide a proportion of the total funding for the project/contract. The distribution of this co-funding received on e-Science projects/contracts is shown in Figure 17 below, and shows that MRC is the most frequent co-funder to e-Science projects that they do not lead on. The Core Programme is the largest co-funder by value; this is because they co-funded e-infrastructure, such as Digital Curation Centre and National Grid Service, with JISC.

3.3.151 Figure 16 shows the co-funding received from other organisations to e-Science projects/contracts from 2001-2008 (please note that the organisations listed below as co-funder were not the lead funder who provided the contract for research). The total value of co-funding provided was £13,256M from 72 contributions.

7 This data does not include co-funding with the DTI Programme. It also does not include collaborative work carried out by CCLRC as CCLRC did not co-fund in the same way as the other research councils. CCLRC would collaborate with projects by providing the additional 20% FEC funds required for the CCLRC components of projects awarded by other research councils (examples include e-Minerals and e-Materials) or funding additional staff effort on funded projects (e.g. Integrative Biology). The strategic justifications were based on an assessment of the technological relevance to CCLRC, combined with the scientific excellence implied by the funding awarded by other councils.
3.3.152 Table 18 shows the 15 institutions with the largest e-Science portfolios; this totals £209,696K out of a total portfolio of £214,783K covering 63 institutions.

Table 18  Top fifteen Institutions by value

<table>
<thead>
<tr>
<th>Institution</th>
<th>Value of Projects/Contracts (£)</th>
<th>Number of Projects/Contracts</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Glasgow</td>
<td>61,593,382</td>
<td>8</td>
</tr>
<tr>
<td>University of Edinburgh</td>
<td>25,553,095</td>
<td>27</td>
</tr>
<tr>
<td>The University of Manchester</td>
<td>23,427,392</td>
<td>41</td>
</tr>
<tr>
<td>University of Southampton</td>
<td>22,365,584</td>
<td>20</td>
</tr>
<tr>
<td>Oxford University</td>
<td>17,566,285</td>
<td>28</td>
</tr>
<tr>
<td>CCLRC</td>
<td>11,000,000</td>
<td>*</td>
</tr>
<tr>
<td>University of Cambridge</td>
<td>10,380,582</td>
<td>19</td>
</tr>
<tr>
<td>Newcastle University</td>
<td>10,077,545</td>
<td>15</td>
</tr>
<tr>
<td>Imperial College London</td>
<td>7,533,231</td>
<td>16</td>
</tr>
<tr>
<td>University College London</td>
<td>6,020,099</td>
<td>20</td>
</tr>
<tr>
<td>CERN</td>
<td>5,670,000</td>
<td>3</td>
</tr>
<tr>
<td>University of Bristol</td>
<td>4,660,037</td>
<td>15</td>
</tr>
<tr>
<td>University of York</td>
<td>4,135,388</td>
<td>6</td>
</tr>
<tr>
<td>University of Leeds</td>
<td>3,735,494</td>
<td>15</td>
</tr>
<tr>
<td>University of Nottingham</td>
<td>3,536,899</td>
<td>14</td>
</tr>
</tbody>
</table>

Note: *CCLRC - The majority of these funds were used to support work through the CCLRC e-Science Centre (see [http://www.e-science.stfc.ac.uk/](http://www.e-science.stfc.ac.uk/)) which also received funding from other UK research councils (BBSRC, EPSRC, NERC and PPARC), Government departments (DTI) and the European Union (EGEE). The overall scale of the CCLRC programme was ~£11M and ~100 people. The e-Science Centre focused on: data storage, management, and curation; data computation, analysis and visualisation. This money was not issued through the grants mechanism.
3.3.153 Figure 17 shows the distribution of funding for e-Science over the past eight years, with a significant proportion of the funds going to the Universities of Glasgow, Edinburgh, Manchester and Southampton.

### Figure 17  Distribution of funding for e-Science 2001-09

**Top Fifteen Institutions by Value and Number**

<table>
<thead>
<tr>
<th>Institution</th>
<th>Value of Funding (£)</th>
<th>Number of Projects/Contracts</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Glasgow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Edinburgh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The University of Manchester</td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Southampton</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imperial College London</td>
<td></td>
<td></td>
</tr>
<tr>
<td>University College London</td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of York</td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Leeds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Huddersham</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxford University</td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Cambridge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCLRC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EPSRC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EPSRC Computational system for the Minerals and Ceramics Consortium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EPSRC National Service for Computational Chemistry Software (NSCSS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GridSphere Portal Software</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Globus 2 software</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HECToR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HPCx (UK National Super-computing Service prior to HECToR)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EPSRC Computational system for the Minerals and Ceramics Consortium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EPSRC National Service for Computational Chemistry Software (NSCSS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GridSphere Portal Software</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Globus 2 software</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Values are based on the Principal Investigator’s institution. £32.9M of University of Glasgow’s funding is for the GridPP project. See Table 18 above for explanation of CCLRC funding.

### National and International Facilities and Services

3.3.154 Access to research facilities is essential for e-Science researchers. Some of these are provided internationally or nationally and some are administered by the Science and Technology Facilities Council (STFC). The facilities listed below were used by e-Science projects/contracts funded through the UK e-Science Programme:

- Access Grid
- Atlas Data Store (ADS) at RAL
- BioPerl/BioJava
- Brain imaging machines and software
- Cancer patient record data at the Royal Marsden Hospital National Centre for Electron
- CERN
- CSAR (Computer Services for Academic Research)
- EPSRC Computational system for the Minerals and Ceramics Consortium
- EPSRC National Service for Computational Chemistry Software (NSCSS)
- GridSphere Portal Software
- Globus 2 software
- HECToR
- HPCx (UK National Super-computing Service prior to HECToR)
- HPC service at RAL (SCARF)
- III-V Materials, University of Sheffield
- Information and Statistics division (NHS Scotland)
- Diamond Light Source at RAL
- National Grid Service
- NERC Data Centre at RAL (British Atmospheric Data Centre)
- NEODAAS- Remote Sensing Data Analysis Service
- Neutron Source at RAL (ISIS)
- Ontology support including OWL
- Open Middleware Infrastructure Institute (OMII)
- Spectroscopy and Surface Analysis, STFC
- Synchrotron at Daresbury Laboratory (now closed) (SRS)
3.4 Bibliometric Evidence

3.4.1 Panel members are asked to form a view on the quality of e-Science research in the UK in comparison to the rest of the world. It is expected that much of the evidence will be gathered during the institution visits to the Panel.

3.4.2 In this section quantitative data is provided on the key outputs from research council funded e-Science research, such as: publications, citations, prizes, key-note addresses, spin out companies.

3.4.3 As e-Science is not a traditional discipline data could not be collected from the normal sources, such as HESA (Higher Education Statistics Agency). In addition, as some of the projects/contracts funded through the UK e-Science Programme finished several years ago, it was felt that data contained within the research council Final Report databases would not be sufficiently up-to-date to enable an accurate assessment of the full impact of these projects/contracts (with the exception of NERC who collects information from their Principle Investigators (PIs) on a yearly basis). Therefore the PIs who were awarded funding through the e-Science Programme were asked to provide data on the outputs which have resulted from their projects/contracts to date. Tables 19 and 20 show the collated bibliometric data which the P.Is provided.

3.4.4 STFC received an 84% response rate. BBSRC obtained a 51% response rate, see footnote 8 for an explanation of this return rate. ESRC was able to supply data on 41% of their projects and MRC received an 86% response rate. As EPSRC managed the Core Programme the EPSRC and Core data is combined, and had an 80% response rate. As NERC requires their P.Is to provide data on a yearly basis they already held this information.

Table 19  Bibliometric data for e-Science projects/contracts

<table>
<thead>
<tr>
<th>Research Council</th>
<th>Number Journal Publications</th>
<th>Number Conference Papers</th>
<th>Number Software Publications</th>
<th>Number Books/ Book Chapters</th>
<th>No. Citations From Top 5 Publications</th>
<th>No. Key Note Addresses</th>
</tr>
</thead>
<tbody>
<tr>
<td>BBSRC(^8)</td>
<td>171</td>
<td>104</td>
<td>11</td>
<td>11</td>
<td>1762</td>
<td>44</td>
</tr>
<tr>
<td>ESRC</td>
<td>73</td>
<td>327</td>
<td>13</td>
<td>25</td>
<td>299</td>
<td>27</td>
</tr>
<tr>
<td>EPSRC/Core</td>
<td>251</td>
<td>957</td>
<td>102</td>
<td>53</td>
<td>3542</td>
<td>249</td>
</tr>
<tr>
<td>MRC</td>
<td>69</td>
<td>79</td>
<td>8</td>
<td>2</td>
<td>Not Available</td>
<td>4</td>
</tr>
<tr>
<td>NERC(^10)</td>
<td>174</td>
<td>35</td>
<td>2</td>
<td>12</td>
<td>1958</td>
<td>7</td>
</tr>
<tr>
<td>STFC</td>
<td>228</td>
<td>552</td>
<td>45</td>
<td>0</td>
<td>3649</td>
<td>41</td>
</tr>
</tbody>
</table>

\(^8\) As the volume of publications from the UK e-Science programme was so high, the Principle Investigators were only asked to provide citation rates for their five most significant publications. As e-Science is not a traditional discipline, citation rates for e-Science publications are difficult to collect, for example a number of the journals are relatively new and are not captured by traditional citation search engines. Therefore the citation data can only be viewed as indicative.

\(^9\) BBSRC funded a number of summer schools/workshops through the Bioinformatics and e-Science Programme and the e-Science Development Fund, including five summer schools funded through the PeST initiative. In all, nine were funded and these projects were not intended to generate publications. One BBSRC project focussed on GRID support, again no publication returns expected. Bibliometric Data for one project has been submitted to NERC as part of a wider project and one project (comprising two applications) reported they had no publications arising from the project. A project with the Institute of Animal Health was funded too recently to produce publications. In addition, the e-Science Development Fund supported short term, low pump-priming or software development projects, limited to one year and £80K in funds.

\(^10\) The information provided is taken from NERC’s Final Reporting mechanism. This may not be a complete record of projects funded by NERC that have had key research results taken up by industry or those that have produced spin off companies.
3.4.5 The raw data provided by the P.Is can be found in the spreadsheet ‘Publications Data’ on the Panel ftp site and this contains full details of the evidence provided.

3.4.6 As a result of the enabling nature of many of the projects/contracts funded through the e-Science Programme, the collection of bibliographic data in Tables 19 and 20 does not amply demonstrate the contribution of these projects to e-Science. For example, the most heavily funded project, GridPP, was established to build a distributed computing Grid across the UK for particle physicists. When the Large Hadron Collider, the world’s largest particle accelerator, opens at CERN the Grid will be used to process the accompanying data deluge. At this time, there will be a significant number of publications amply detailing the science GridPP has been built to serve. Current publications relating to the establishment of this infrastructure simply do not provide any measure of the project or its significance to science. In addition, although projects such as GridPP do have significant synergy with industry, they were not specifically designed to generate licenses, patents or spin-off-companies.

3.4.7 However, a number of projects have already demonstrated their global impact. One of the products of Professor Carole Goble’s MyGrid project was the Taverna Management System which has been downloaded more than 69,500 times, has 361 organisation users in 35 countries, 10 third party plug-ins and over 3,000 services available. In recognition of her achievements in the application of computing technology to scientific insight and innovation, Professor Goble was awarded the Inaugural Microsoft Research Jim Gray e-Science Award, December 2008. Taverna has significantly influenced Microsoft Corporation’s Trident scientific workflow management system and they have adopted myExperiment as its workflow repository.

3.4.8 The UK e-Science community have been invited to provide keynote addresses at prestigious conferences throughout the world and they have been awarded many prizes. These include:

- The Mobile Data Association Green Award for the most innovative use of mobile technology in reducing carbon emissions for Professor John Polak’s MESSAGE project;
- The Sun Hardware Award for academic excellence for Professor Richard Sinnott;
- The EuroSys Roger Needham Award for Dr Nick Cook for his PhD work on the Gold project (this is an annual prize awarded to a PhD student from a European university whose thesis is regarded to be an exceptional, innovative contribution to knowledge in the systems area);
- The Robot Scientist project, led by Professor Ross King from Aberystwyth University, generated a number of high quality publications as well as significant media interest, culminating in being shortlisted for the World Technology Award (software category).

3.4.9 Outputs from the projects have been used in a variety of settings. For example:

- The outputs from Professor Alan Rector’s Hybrid User-Oriented Ontology Tools project are known to be used by numerous industrial groups including Ordnance Survey, Astra Zeneca and BT.
- Professor Jim Austin’s DAME project developed distributed technology for aircraft diagnostics and was further developed (in collaboration with Rolls-Royce Marine) to construct a prototype demonstrated in the marine environment for health monitoring of ships. The DAME technology is also being used by the EPSRC-funded WICAS and SWIFT projects, in collaboration with Airbus, for advanced health monitoring on future, wirelessly interconnected Active Aircraft. This future Active Aircraft will feature complex "Smart Skin" technology for reduced drag and increased fuel-efficiency.
Dr Steven Hand from the University of Cambridge established the start-up company XenSource in 2005, which was bought by Citrix Systems in late 2007. He has been involved in the ongoing development of the Xen virtual monitor, which has been instrumental in virtual data centres, virtual workspaces, and in the emerging ‘cloud’ (Amazon's EC2 is based on Xen).

The software which was produced from the AXIOPE project is used in 100 neuroanatomy laboratories worldwide. The software tools and computational modelling will increase the understanding of basic neuro-scientific processes; in particular, the software will increase the productivity of neuroscientist in generating new knowledge that may suggest new ways of treating disorders, through specific surgical or pharmacological interventions.

The CLEF repository is now available and contains data on more than 22,000 cancer cases. It is an interactive knowledge source for academic researchers and clinicians to access the latest medical information. The CLEF project also influenced international standards for Electronic Health Records.

The data portal from the GODIVA project contains real time meteorological ocean data from the UK Met Office and the European Centre for Medium-range Weather Forecasts. They have collaborated with British Maritime Technology and the UK Coastguard to link an operational search and rescue tool to this data portal using web service technology. This has been interfaced into the Reading Grid Access Data Service (GADS) Web Service allowing real-time Met Office wind and current data to be picked up online. It is used in forecasting surface objects drifting at sea.

The DEWS project is being deployed by the Met Office, IBM, British Maritime Technology and Lost Wax. It has benefited the Marine and Health sectors to aid with rescue at sea and is helpful for mitigating the effects of diseases made worse by specific weather conditions.

3.4.10 The e-Science programme produced many highly cited, high quality publications, including in books, software publications and some of the top refereed journal papers:

- Nucleic Acids Research (6)
- Proceedings of the National Academy of Sciences, USA (3)
- Science (3)
- Journal of the American Chemical Society (2)
- Cell (1)

All projects from the NERC e-Science Programme participated in an end of programme discussion and most have published in the *Philosophical Transactions of the Royal Society A*.

3.4.11 The iSPIDER project led by Dr Simon Hubbard, The University of Manchester, generated a portfolio of high quality, well-cited publications and created the PRIDE data repository for proteomic data. The iSPIDER team was also central to the development of minimum reporting standards for proteomics experiments, which have been accepted by the broader research community.

3.4.12 The e-Science Programme has allowed the development of enabling bioinformatic resources, including the highly cited protein structure prediction servers based at University College London (led by Professor David Jones), and the ONDEX data visualisation programme (led by Professor Chris Rawlings, Rothamsted Research) which underpins a significant recent systems biology project funded by BBSRC core funds.

3.4.13 Two patents have arisen from the climateprediction.net project, which have been granted both in the UK and in the US to Dr Myles Allen *et al*. These are titled: ‘Customized Seasonal Weather and Climate Forecasting’ and ‘Method and System for Producing a Weather Forecast’.

3.4.14 The BBC Climate Change project was a result of the climateprediction.net experiment, which developed an innovative new methodology for the quantification of uncertainty in climate model predictions. The GENIEfy project achieved the first large ensemble runs of a fully 3D Earth system model on the National Grid Service and other computer clusters and ‘Condor pools’ of PCs in UK universities. This project also produced the first coupled carbon cycle and climate change projections to the year 3000 with a comprehensive Earth system model, the results...
received widespread publicity including BBC 6 o'clock news, The Times, New Scientist, and international media. The Stern Review and IPCC Working Group II both asked to see the results.

3.4.15 There is a wealth of evidence of the high productivity of the e-social science projects in terms of number and quality of presentations and publications. The following examples are a few of those where the nodes are seeking to embed their emerging activities in the social science community:

- The first phase of the NCeSS 'Understanding New Forms of Digital Records' (DReSS) research node which has resulted in over 70 publications, presentations and demonstrations of the Digital Replay System (DRS) in international conferences and workshops. The Release of DRS, which provides new tools and services for qualitative research, has resulted in a growing user community. The ESRC funded Computer Assisted Qualitative Data Analysis (CAQDAS) networking project makes DRS available to the wider qualitative research community.

- The NCeSS node 'Modelling and Simulation for e-Social Science' (MoSeS) has made presentations on dynamic microsimulation at a number of international conferences (Institute of British Geographers, London; Geocomputation, Maynooth; International Microsimulation Association, Vienna) and was invited to make a submission to the journal *Computers Environment and Urban Systems*.

- The 'Generative e-Social Science for Socio-Spatial Simulation' research node (GeNeSIS) produced the 'Digital Geography: Geographic Visualisation for Urban Environments' [http://digitalurban.blogspot.com/2008/03/buy-booklet-digital-geography.html](http://digitalurban.blogspot.com/2008/03/buy-booklet-digital-geography.html) and their multimedia and Virtual London work was featured in the Cities theme of *Science* magazine.

- The 'Data Management through e-Social Science' (DAMES) node prepared a Journal article for the *International Journal of Sociology and Social Policy*. Their most recent technical paper is a note on 'Logistic Regression Models in Sociological Research'.
3.5 International Engagement

Introduction

3.5.1 e-Science research is international. While the priority as a country (and the research councils’ as a national agency) is to support UK e-Science, international collaboration is also supported and want to make it as easy as possible for researchers to work with each other. This allows ‘best with best’ collaborations which help ensure the UK is able to benefit from expertise as it develops, wherever it is in the world.

International Collaboration with e-Science Researchers

3.5.2 Over the past eight years 27 e-Science projects funded through the e-Science Programme have included overseas collaborations. There was an exchange of personnel at all levels delivering benefit to UK researchers through access to both expertise and equipment. The majority of these were with researchers in the USA and Europe. Please note that this information has been gathered from research council data and it has been difficult to capture the entire breadth of international collaboration, some of which will have taken place during the life-time of the project (after initial applications were made for funding) and is therefore not available in this document. However, the Review Panel will be able to draw on additional evidence from those presenting during the Review week.

3.5.3 The Core Programme provided support for e-Scientists to be involved in international activities which ensured that the UK was actively communicating and collaborating with the international community. Support was provided in several ways:

- Funding for members of the community to play an active role in the development of internationally agreed Grid protocols through the Global Grid Forum (GGF). UK researchers were involved in 20 Working Groups at GGF and 23 Research Groups, leading several of the activities;
- The Core Programme funded a booth each year at the US Supercomputing Conference between 2002 and 2006, to enable researchers to demonstrate activities from the UK Programme;
- During the Programme there were international meetings with China, USA, Australia, Singapore, Japan and Korea. The Core Programme Directorate provided support and guidance on many international strategies including in Europe, Australia, China, and Singapore (amongst many others);
- The e-Science centres and researchers within the Core Programme were involved in the major EU Grid initiatives. The National e-Science Centre led the training element of the EGEE and many sites within the UK are partners. (EGEE is Europe’s leading Grid computing project which provides a computing support infrastructure for over 10,000 researchers world wide);
- The Core Programme held three calls for networking activities to collaborate with international projects which had common interests (either in an application area or in the technologies used). They funded 11 ‘sister’ projects, with most of the collaborations being with US-based projects. The total cost of this activity was £400,000, and although the grants awarded were relatively small (max £41,200), these projects produced a number of joint papers between the UK researchers and their international partners.

3.5.4 In addition to the e-Science projects which had overseas collaboration, PPARC and CCLRC provided (and STFC continues to provide) the UK’s contribution to the LHC (Large Hadron Collider) Computing Grid. The LHC Computing Grid is a global collaboration of more than 170 computing centres in 34 countries. The mission of the Grid project is to build and maintain a global resource to store and analyse the huge amounts of data recorded by the LHC experiments for the entire high energy physics community that will use the Large Hadron Collider at CERN. It will thus give the UK unprecedented access to the data arising from the LHC based at CERN in Geneva. CERN is the European Organisation for Nuclear Research.
and is run by 20 European Member States with many non-European countries also involved. The current Member States are: Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, the Netherlands, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland and the United Kingdom. Some 8,000 visiting scientists (half of the world’s particle physicists), come to CERN for their research. Scientists from some 580 institutes and universities from 85 nationalities use CERN’s facilities. The funding of the CERN computing grid is thus an outstanding example of real international collaboration.

3.5.5 CERN has also led the pan-European consortium to Enabling Grids for E-sciencE (EGEE). This Grid infrastructure will extend beyond particle physics to fields such as biomedical and geological applications. The National Grid Service (NGS), based at the STFC’s Rutherford Appleton Laboratory (RAL), has provided the EGEE helpdesk and user support in the UK. The NGS has provided access to research resources outside the UK through partnership arrangements with organisations such as EGEE and Teragrid in the US. The NGS has provided the EGEE helpdesk and user support in the UK. The two organisations have also collaborated on training and outreach to the UK community.

3.5.6 The UK e-Science Programme provided support for UK e-Science researchers to collaborate internationally. However, this was not the only funding mechanism available to them. Each research council provides support for international engagement and delivers this via a number of schemes such as:

**EPSRC**

- *Overseas Travel Grants*, which allow researchers to apply for travel and subsistence, salary costs of the Principal Investigator for time spent on the grant, and indirect costs. They can apply for funding to visit one centre or several centres. There is no limit on the amount of funding available;
- *Responsive Mode* research grants can be used to support international collaboration. Researchers can include the costs of collaboration, for example, travel and subsistence for research staff to work in a partner’s laboratory overseas, as well as the usual UK-based costs like staff, equipment, UK travel and subsistence, and consumables. They can also use funding flexibly, for example, to fill postdoctoral researcher and project student places with candidates from a partner’s laboratory;
- *Visiting Researcher*, which enables visits by scientists and engineers of acknowledged standing from within the UK or abroad to the investigator’s organisation for periods of up to a year;
- *Networks*, which allow the creation of new interdisciplinary research communities and topics, by developing interaction between the research community and appropriate science, technology and industrial groups. The aims are to transfer experimental techniques, models and scientific insights, and promote mobility between academe, universities and industry. Networks can include overseas partners;
- *Bilateral Research Workshops (N + N meetings)* can be held to exchange ideas and expertise internationally, with the objective of exploring the possibility of more substantial future collaboration. Roughly equal numbers attend from each side. EPSRC will fund travel and accommodation expenses of UK participants and, for meetings in the UK, core meeting costs.
- *Specific calls for internationally collaborative proposals* are held in most EPSRC programmes. For example, Chemistry and Materials both have long-established annual joint calls with NSF (USA).

**NERC**

- NERC does not run specific international schemes and instead their international collaboration is done on a wider scale i.e. through centres and international project offices. Occasionally, they run joint schemes with other countries such as ‘Call for

---

11 Observer states currently involved in CERN programmes are: the European Commission, India, Israel, Japan, the Russian Federation, Turkey, UNESCO and the USA. Non-member states currently involved in CERN programmes are: Algeria, Argentina, Armenia, Australia, Azerbaijan, Belarus, Brazil, Canada, Chile, China, Colombia, Croatia, Cuba, Cyprus, Estonia, Georgia, Iceland, Iran, Ireland, Lithuania, Mexico, Montenegro, Morocco, New Zealand, Pakistan, Peru, Romania, Serbia, Slovenia, South Africa, South Korea, Taiwan, Thailand, Ukraine and Vietnam.
Proposals to the UK-US Environmental Nanoscience Initiative-2:
http://www.nerc.ac.uk/research/programmes/nanoscience/events/ao.asp

- The international collaboration that NERC runs through all grants allows distinguished researchers from the UK or overseas to be funded to visit the Investigator's institution in order to give full time advice and assistance in research in a particular field for up to 12 months. In addition NERC Research Grants allow UK PIs to collaborate with named senior international academics in an overseas research organisation as Project Partners. Partners are not funded by NERC.

**MRC**

- **UK Collaborative on Development Sciences (UKCDS)** - MRC is a founding member of the UK Collaborative on Development Sciences. UKCDS brings together key UK funders and stakeholders who provide support for the development sciences research base. Members of UKCDS work together to establish a framework for co-ordinating development sciences research in the UK. Its aim is to provide sustainable improvements and benefits for the lives of the world's poorest people. For further information please visit the UKCDS website (www.ukcds.org.uk) or download the UKCDS brochure.

- **Including overseas co-applicants and collaborators on MRC Grants** - International collaboration in medical research is facilitated by MRC grant terms and conditions, which permit co-applicants and collaborators on MRC grants to be based overseas where the nature of the research makes this necessary. Grants may include the costs of research being undertaken at overseas research organisations. Costs for international collaborations may be funded through the new investigator research grants (formerly career establishment grants and new investigator awards) and senior fellowships.

- **Working at an overseas research organisation as part of an MRC fellowship** - MRC’s research is conducted at a globally competitive level. In order to allow researchers to benefit from working in another country, MRC will support the costs of up to one year of an MRC fellowship spent overseas for the purpose of research training (up to two years in the case of career development awards).

- **EuroHORCS ‘Money Follows Researcher’ Scheme** - MRC recognises the importance of enabling UK researchers to increase their knowledge and experience by working overseas, and also the importance of promoting the UK as partner of choice for overseas researchers. For this reason MRC has signed up to the European Heads of Research Councils (EuroHORCS) Money Follows Researcher Scheme. The scheme allows researchers funded by an MRC grant to continue their funded research upon moving to another participating European country.

**ESRC**

- ESRC has a dedicated International Office Group headed by an Associate Director; but all ESRC Boards and Committees help to identify and make use of opportunities to enhance international working, and all sections of the Office help to implement activities with an international dimension.

- During the past year ESRC have signed bilateral agreements with several funding agencies around the world, and are working on several more. These provide for collaborative grant applications under responsive mode. ESRC are co-funders of a major initiative to foster collaboration among funding agencies around the world, which will lead to co-ordinated action in areas such as data resources; North-South and South-South academic exchanges; and capacity-building in resource-poor countries.

- The £11M ESRC-DfID joint initiative on poverty alleviation is pioneering new ways to commission excellent research with partners in other countries, including (for the first time) provision for co-investigators not based in the UK.

- In 2005 ESRC co-funded a series collaborative projects aiming to establish collaboration on global or large-scale problems that require efforts of international research in the area of cyber-infrastructure. The call was for two distinct activities: (1) Agenda-setting Workshops; (2) Collaborative Exchange Visits. The scheme open only to holders of a current NSF or an ESRC e-Science award funded a total of six workshops and three collaborative exchanges.

**BBSRC**
### 3.5.7 Numerous sources of funding (in addition to the research councils) are available to support the international flow of people through travel grants and visiting fellowships. These alternative schemes are typically run by major organisations such as: the British Council; the Royal Society; the British Academy; the Wellcome trust; the Royal Academy of Engineering; the Leverhulme Trust; Cancer Research UK; the Nuffield Foundation; and the Royal Society of Edinburgh.

- **Human Frontier Science Program** supports novel, innovative and interdisciplinary basic research focused on the complex mechanisms of living organisms by awarding research grants and fellowships. The UK contribution to HFSP’s budget is paid through MRC and BBSRC.

- **Japan, China, India and United States Partnering Awards** - The Partnering awards are intended to set up partnership links between UK and overseas laboratories, to promote the exchange of scientists, particularly early career scientists and to promote access to facilities in their respective areas.

- **International Workshops** aim to stimulate joint working in topics important to BBSRC’s strategy, to match numbers of scientists from the UK with other countries to identify areas of commonality and explore the potential for international collaboration. Applications involving collaborations with any other country are accepted, although the USA, Canada, Brazil, EU Member States, Japan, China and India are encouraged.

- **International Scientific Interchange Scheme (ISIS)** allows researchers to travel outside the UK to initiate collaboration or prepare proposals with partners for international programmes (e.g. EU Framework, Human Frontier Science Program). Funding is available for either short term or long term travel for researchers to travel outside the UK for periods of up to 12 months. The scheme also supports access awards, for stays of up to one month in another country to undertake a specific piece of work, access facilities not available in the UK or gain access to new techniques or materials, which would be of benefit to the BBSRC project or the UK research team. Funding is limited to travel and subsistence costs only, and does not usually exceed ~£5k.
3.6 Support for People

Introduction

3.6.1 This section provides data about people working in, and who trained in, e-Science research. Data is drawn from research councils awarded and project Students\(^\text{12}\); it is important to bear in mind the caveats noted in section 3.2.15.

Research Council Support for e-Science Postgraduate Training

3.6.2 Over the seven year period from 2001 to 2008, there were at least 162 postgraduate students in the e-Science area registered at UK institutions. Table 21 shows the destinations of awarded/project student's post-qualification, by all research councils and is based on data obtained from the research councils.

### Table 21 The destinations of awarded/project students, by all research councils

<table>
<thead>
<tr>
<th>Destination</th>
<th>CORE</th>
<th>EPSRC</th>
<th>BBSRC</th>
<th>MRC</th>
<th>NERC</th>
<th>STFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Sector/Industry/Commerce - Research</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Private Sector/Industry/Commerce - Not Research</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not known</td>
<td>8</td>
<td>54</td>
<td>4</td>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not employed</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Higher Education - Research</td>
<td>8</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Higher Education - Other</td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Higher Education - Academic</td>
<td>12</td>
<td>2</td>
<td>1</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government/Other Public Sector - Research</td>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Further Training</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Yet Complete</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2</td>
<td>33</td>
<td>58</td>
<td>6</td>
<td>18</td>
<td>43</td>
</tr>
</tbody>
</table>

Note: EPSRC and the Core Programme could only provide data on their number of Project Studentships. Whilst EPSRC have supported e-Science Awarded Students through the Doctoral Training mechanism, e-Science is not a code used through their management information system, therefore this data could not be collected. All other research councils only have awarded students. ESRC do not have any data. BBSRC does not retain student destination data, instead collecting student destination data from questionnaires sent out by HESA (the Higher Education Statistics Agency). This data depends on current addresses of former students being available and the addressees completing them and sending them back with accurate and usable information. While this can give statistically useful information regarding large numbers of students, it can be difficult to trace individual students, as in this case.

3.6.3 Figure 19 shows the destinations of students by all research councils.

\(^{12}\) The research councils provide awards to eligible research training institutions, which are then responsible for selecting students for these awards who meet the research council's eligibility criteria. These students are known as Awarded Students, whereas project students are funded through research grants.
3.6.4 Figure 20 shows the ten institutions which have attracted the greatest number of students. The panel will meet with all of these institutions.

Figure 20 Top ten institutions by registered students

3.6.5 Figure 21 gives a breakdown of the student effort funded through the e-Science Programme. The figures are derived from research council data. The male:female gender balance is approximately 4:1.
Additional Support for e-Science Training

3.6.6 The number of awarded/project students funded through the Programme does not provide the complete picture of training in the UK. For example, the National e-Science Centre at Glasgow ran a course in Grid computing for MSc students at the University of Glasgow. In the first year 16 students undertook this extensive course (which included 20 lectures, 10 tutorials, 3 minor programming assignments and one major programming assignment).\(^\text{13}\) Also, in 2005 Cranfield University launched the first UK MSc in Grid Computing.

3.6.7 The National e-Science Centres were also entrusted with a role to establish an appropriate regional outreach programme. This took various forms from a seminar series to joint projects and/or visits to relevant organisations in the region. The National Centre in Edinburgh (NeSC) was funded more substantially for such activities, which included running training courses and a national seminar series. The training, outreach and education division of NeSC is led by Dr David Ferguson, please see [http://www.nesc.ac.uk/training/](http://www.nesc.ac.uk/training/) for full details.

3.6.8 The e-Science Institute also runs a programme of workshops, lectures, conferences and tutorials with hands-on training. The institute hosts international visitors and e-researchers were able to share knowledge and ideas about their particular research projects, forge new interdisciplinary activities and investigate ways in which distributed computing can advance their research.

3.6.9 The e-Science Envoy, Professor Malcolm Atkinson, has taken a leading role in establishing the International Summer School on Grid Computing (ISSGC), which was first held in 2003. In 2005 Professor Atkinson played a leading role in a consortium bid for the project 'International Collaboration to Extend and Advance Grid Education' (ICEAGE) ([http://www.iceage-eu.org/v2/index.cfm](http://www.iceage-eu.org/v2/index.cfm)) which now provides funding for ISSGC. Prof Atkinson has chaired the ISSGC Programme Committee since this time. Approximately 400 students have attended the two-week ISSGCs, and the graduates are already very active in scientific computing throughout the world. It has seeded a significant collaborative network (students come from approx 25 countries each year).

\(^{13}\) The NeSC at Glasgow was not funded by the research councils to undertake this activity.
Trained Researchers

3.6.10 Research assistants are typically junior researchers, PhD-qualified, who are employed on temporary contracts by universities, occasionally with teaching responsibilities, though their employment conditions have been evolving over recent years. They are often funded on grants and supervised by more senior academics. Figure 22 shows the number of research assistants employed by the councils through the e-Science Programme.

**Figure 22** Numbers of research assistants by research council

![Number of Research Assistants by Research Council](image)

3.6.11 Research council data records 1,516 research assistants funded through the e-Science Programme working in UK institutions. However, since the ring-fenced Programme has ended, it is not possible to calculate how many are now active in this field.

Demographics of grant/contract holders

3.6.12 Figures 23 and 24 show the number and value of e-Science projects/contracts announced by gender of Principal Investigator from 2001 – 2008.
3.6.13 There are proportionately more female doctoral students than there are female e-Science Principal Investigators. As noted in 3.6.5, male doctoral students outnumber females by approximately 4:1. This figure is 15:1 for those applying for research grants. However, as the Programme has only been operating for a short period of time, it is not possible to draw a comparison between the number of students going through to becoming grant holders.
3.7 Knowledge Transfer

The Challenges of measuring Knowledge Transfer (KT)

3.7.1 The exploitation of academic research and its economic impact is subject to increased attention within the UK (see ‘Support for Science and Innovation in the UK’ section 2). As a consequence KT is a central element of the review. Obtaining reliable quantitative evidence on KT effectiveness and economic impact which can be directly linked to specific funding interventions is notoriously difficult. A recently published report about the economic impacts of the research councils' work underlines these difficulties and provides a detailed analysis of the key issues.14

3.7.2 To assist the Panel, the universities participating in the review will provide examples of their KT activities during the review week. In addition, collaborators from industry will be participating in the visits and Panel members are encouraged to make the most of these opportunities to explore the effectiveness of knowledge exchange between the research base and industry.

Grid Computing Now! Knowledge Transfer Network (KTN)

3.7.3 Grid Computing Now! KTN is a government based knowledge transfer network, set up in 2005 with initial funding for three years. Grid computing is concerned with the development of computer systems that allow organisations to use their available processing power more efficiently and to access and use data held in different formats on different systems. The Grid allows local or distributed networks of computers to be linked together, thus providing an opportunity to recognise and make use of the full potential of the various components.

3.7.4 The purpose of Grid Computing Now! KTN is to accelerate the adoption of Grid computing and other modern distributed computing technologies. This has proven successful and, over the past four years, Grid computing has escalated from being an item of general technical interest, to being a fundamental element for the next generation of service-based infrastructures. Grid Computing Now! KTN aims to meet the needs of both the public and private sectors for business orientated, efficient and sustainable computing infrastructures through creating awareness, providing background education and connecting prospective users with experts and suppliers. As a result of this, Grid Computing Now! KTN has ensured that many companies are familiar with the opportunities that Grid computing can offer, and has therefore greatly assisted in creating a more competitive industrial base that is ready to respond more readily and economically to new market opportunities.

3.7.5 Membership of Grid Computing Now! KTN had increased in number to 1331 at the end of March 2009 and is still rising, with 56% of members coming from business and 19% from academia. The Grid Computing Now! KTN website www.gridcomputingnow.org has received over 10,000 visits in the last year and the five webinars, which are designed to provide members with the opportunity to listen and learn from experienced users and industry experts, have generated over 1500 downloads. The fifteen case studies that Grid Computing Now! KTN have published in 2008-2009 illustrate success stories over a range of critical business issues including Green IT, Healthcare, Transport and other sectors.

3.7.6 Further details of these activities are available in Annex K, which can be found in the Panel ftp site.

The Technology Strategy Board

3.7.7 The role of the Technology Strategy Board is to stimulate technology-enabled innovation in the areas which offer the greatest scope for boosting UK growth and productivity. The Technology Strategy Board promotes, supports and invests in technology research, development and commercialisation. It also spreads knowledge and brings people together to solve major technological problems or make new advances. Collaborative R&D is a primary mechanism of the Technology Strategy Board’s strategy and is designed to assist the industrial and research communities to work together on R&D projects in strategically important areas of science, engineering and technology. Successful applications are funded by the Technology Strategy Board with contributions from industry and the research councils.

14 http://www.rcuk.ac.uk/news/warry.htm
Collaborative Research in the e-Science Programme

3.7.8 Collaborative research is a key element of the knowledge transfer activities of the e-Science research portfolio. Collaboration with users (largely but not exclusively industry) routinely takes place within research grants, centres and consortia.

3.7.9 A key indicator of the value that industry places on e-Science research is the extent to which it is prepared to co-fund and collaborate with the researchers. The DTI jointly supported the e-Science Core Programme to the tune of £20M, with matching contributions from industry of over £20M in cash and resources. In addition to this activity the research council funded Programme also secured industrial collaboration. Over the past eight years 138 collaborations have been recorded on e-Science projects. The collaborators on these projects are shown in Figure 25 by sector.

Figure 25 Collaboration by sector for all research councils projects/contracts

3.7.10 Figure 26 shows the top ten industrial collaborators to EPSRC grants, by value of contributions (this is the only Council with data containing values).
3.7.11 Figure 27 shows the industrial collaborative funding of EPSRC e-Science grants by financial year. No industrial collaboration was funded through research grants in the financial years 2002/03 and 2004/05 and there was a general reduction in collaborative funding after the initial programme was launched. This was due to the nature of the Programme and how the funding was allocated, namely the launching of major pilot projects in the first phase of the Programme.
3.7.12 In addition to high quality conference papers and journal articles, research council supported projects often demonstrate knowledge transfer through a range of outputs including new licences or patents, spin off companies and software. See section 3.4 for bibliometric evidence. Table 20 is reproduced below for ease of reference.

Table 20    Bibliometric data for e-Science projects/contracts continued

<table>
<thead>
<tr>
<th>Research council</th>
<th>No. awards</th>
<th>Total no. patents</th>
<th>No. spin off companies</th>
<th>No. key research results taken up by industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>BBSRC</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>ESRC</td>
<td>12</td>
<td>0</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>EPSRC/Core</td>
<td>25</td>
<td>1</td>
<td>8</td>
<td>58</td>
</tr>
<tr>
<td>MRC</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>NERC</td>
<td>11</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>STFC</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>
Further Related Funding

3.8.1 EPSRC continues to manage and fund the Core e-Science portfolio, on behalf of all the research councils, through its Infrastructure Programme. In March 2008, EPSRC provided underpinning flexible support to four centres at a total cost of £3.4M. This funding was provided to help embed e-Science Centres in their institutions and regions across the breadth of the research councils’ remits. In March 2008, the Core portfolio also funded four networking grants at a total cost of £1M in order to provide opportunities for researchers to meet and share experiences and best practice both in the UK and internationally. In 2009, EPSRC and JISC funded the National Grid Service to run until March 2011 at a cost of £1M to EPSRC and £2M to JISC. In 2009, EPSRC granted additional funding to OMII-UK to enable all three sites to continue until March 2010. Please see section 3.3.50 for further details of these activities.

3.8.2 In 2009, EPSRC consulted with the e-Science community (covering all RC remits) to identify the e-infrastructure facilities and services which are required to conduct high quality research. This highlighted the management, curation and development of robust software as being a key area to support. As a result, EPSRC has recently released a £5M call to provide underpinning, flexible support to a research infrastructure which will aid the long term sustainability of software which in turn enables high quality research. The outcome of this call will be known in February 2010.

3.8.3 In addition to continuing to support the Core portfolio, EPSRC’s specific e-Science Programme has now become embedded within its other Programmes. Researchers wishing to apply for funding for e-Science research within EPSRC’s remit can do so at any time through EPSRC’s Responsive Mode funding mechanism. Professor Peter Coveney, University College London, and Professor Carole Goble, The University of Manchester hold EPSRC Platform Grant funding for their RealityGrid (£424,909) and MyGrid (£1,154,681) e-Science projects respectively.

3.8.4 STFC has continued to provide support for e-Science activities within the research programmes rather than as a discrete e-Science programme. It is an element of STFC’s mission to spearhead the exploitation of e-Science technologies throughout their programmes, the research communities they support and the national science and engineering base.

- GridPP - Support has continued for GridPP, a collaboration of particle physicists and computer scientists from the UK and CERN. The consortium has built a working particle physics Grid across 17 UK institutions as part of the LHC (Large Hadron Collider) Computing Grid. The Grid Tier-1 computer is housed in a newly established computing room at the Rutherford Appleton Laboratory (RAL). This facility was highly praised when a robust test of all international Grid infrastructures was recently undertaken on all participating tier-1 centres. GridPP is currently in its third phase of operation, where funding has concentrated on UK-based hardware and system management, Grid support, operations support and dissemination, outreach and project management. This funding will continue until April 2011. The STFC Oversight Committee for GridPP is currently liaising with the project team to develop the case for the fourth phase of funding.

- NGS – The National Grid Service (NGS) provides access to compute, storage and software resources for UK and international academic collaborators. The NGS is funded by JISC and EPSRC, however the STFC Scientific Computing Technology group is a core site for the National Grid Service (NGS). STFC staff participate at all levels of management of the NGS.

- e-Science Centre - The e-Science team at RAL provide the hardware support for the Silicon Graphics Implementation (SGI) cluster. This cluster is operated for the National Service for Computational Chemistry Software (NSCCS) by the Cluster Computing Group. The NSCCS provides access to software packages, computing resources, specialist scientific consultation and software training for UK academics working across all fields of chemistry. The NSCCS is now based on a 224 core SGI Altix 4700 server with 896GB memory and 15TB disk storage.

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15 Further information on EPSRC’s Responsive Mode funding mechanism can be found at: http://www.epsrc.ac.uk/ResearchFunding/Opportunities/ResponsiveMode/default.htm.
Information for the Panel

Further Related Funding

- **AstroGrid** - STFC provided support for the Astrogrid project until June 2009. AstroGrid, which was guided by an STFC Oversight Committee, is the doorway to the Virtual Observatory (VO). It provides a suite of desktop applications to enable astronomers to explore and bookmark resources from around the world, find data, store and share files in VOSpace, query databases, plot and manipulate tables, cross-match catalogues, and build and run scripts to automate sequences of tasks. Tools from other Euro-VO projects inter-operate with AstroGrid software, so users can also view and analyse images and spectra located in the VO. AstroGrid produced web pages that hold software for downloading. The latest version of the VODesktop was released in July 2009. The developers of the AstroGrid project are in the process of applying for funding for a new project that will build on the success of AstroGrid.

3.8.5 ESRC has invested considerable funds to support the development of a portfolio of e-social science activities. The National Centre for e-Social Science (NCeSS) continues to be the focal point through which the council delivers its strategy, to develop and promote the use of e-Science, to benefit social science research.

3.8.6 The NCeSS node research programme has been a key driver behind the development of e-social science. It is the single largest investment in e-social science anywhere in the world. The nodes were re-commissioned in 2008. Continued funding of the research programme gave existing nodes the opportunity to build on their achievements and provide the opportunity to establish new nodes, to address the gaps in the current research portfolio. A further £6.8M was committed, spread over three years, to support seven nodes until 2012.

3.8.7 A further node ‘e-Stat’ directed by Professor William Browne (Bristol) was commissioned in 2008, to address the gap in quantitative e-social science, an important area for NCeSS. The node which started Sept 2009, at a total cost of £890K, aims to develop a mix of advanced computational tools and techniques which, in combination with quantitative data and quantitative methods, to support social science research.

3.8.8 Each node currently devotes at least one third of the funding provided by ESRC to training and capacity building activities. The Centre’s Training and Capacity Building (TCB) programme ranges from dissemination of information about how new e-social science tools and techniques are able to advance methodological and substantive social science research, through encouragement and support for the take-up of e-Infrastructure among the wider social research community, to direct training in the application of e-social science within methodological and substantive research projects. In pursuit of this last objective, during commissioning in 2008 nodes were encouraged to link studentship and postdoctoral fellowships to their research programme. Three students were attached to the nodes, funded within the total node budgets. Two started in 2008 and the third October 2009.

3.8.9 To maximise the impact of the research programme and the UK’s international reputation in e-social science, in early 2009 ESRC started the commissioning for a National Strategic Director for e-Social Science, the overall aim of the post being to develop a coherent inter-agency approach, drawing upon various national and international e-social science initiatives to maximise the uptake, use and impact of new e-technologies across the social science community.

3.8.10 Professor David De Roure (Southampton) was recently appointed as the new National Strategic Director for e-Social Science, with Dr Marina Jirotka (Oxford) as co-director. The appointments started on 1 October 2009. Funding for the posts totals £650K. Further funding will be made available to support a range of strategic activities to be identified by the Director. The Director will be expected to have developed a draft national strategy and implementation plan for discussion with the ESRC’s Research Resources Board (RRB) in March 2010.

3.8.11 In addition to the students funded and discussed in section 3.6, EPSRC have recently funded 44 new doctoral training centres (7 of these are Digital Economy centres and 1 is an Information and Communications Technologies centre) with an investment in excess of £250M. This followed numerous evaluations and built on the success of existing centres. These will each take in around ten students per year for five years starting in 2009. Whilst none of these

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16 DEC’s were funded through the DE Programme, which is a cross-council programme between the EPSRC, MRC, AHRC, and ESRC, and managed by the EPSRC.
centres are specifically carrying out e-Science research, there is a degree of overlap between e-Science and Digital Economy. The difference is in the potential beneficiaries; e-Science aimed to benefit scientific researchers, whereas Digital Economy research aims to benefit society, government and business.

3.8.12 The doctoral training centre students will receive a formal programme of taught coursework and undertake a challenging and original research project at PhD level. The seven Digital Economy centres and one ICT centre are listed below:

- **Centre for Digital Engagement, University of Bath and Bournemouth University**
  http://www.digital-entertainment.org/
  Visual effects, computer animation, digital film and computer games companies are driven by highly skilled people who are fully up-to-date in the latest technology and have design and management skills. Bringing together Bath’s Media Technology Research Centre, Bournemouth’s National Centre for Computer Animation and world-leading companies, this centre offers students the chance to gain a fully-funded doctorate while being immersed in the most dynamic, creative industry in the world.

- **Centre for Doctoral training in Healthcare Innovation, University of Oxford**
  http://www.ibme.ox.ac.uk/centre-for-doctoral-training
  This programme concerns engineering in healthcare innovation. Students will gain first-hand experience of how technologies they develop have potential clinical impact via a hospital internship, will develop translational research skills to both accelerate clinical uptake of technologies, and take inventions through the first steps of commercialisation. Students will learn how to design clinical trials, and about innovation/entrepreneurship and will conduct a PhD in information-driven healthcare, personalized modelling in healthcare, or cancer therapeutics and delivery.

- **HighWire, Lancaster University**
  http://highwire.lancaster.ac.uk/
  HighWire is a world class, cross-disciplinary and user-centric initiative with innovation at the heart of its curriculum and ethos. Seeking a creative fusion between computer science, management and design, it aims to produce a new breed of innovative people who understand and are able to advance the state of the art in technical, design and business innovation: innovative people prepared to work in challenging roles in organisations and ready to drive radical change in the digital economy.

- **Horizon DTC for the Digital Society, University of Nottingham**
  http://www.horizon.ac.uk/phd/
  Ubiquitous Computing, in which millions of computers become embedded into the world, promises to transform the ways in which people work, shop, travel, learn, socialise and play, and will drive the growth of the digital economy in the 21st century. Supported by £8 million investment from EPSRC, the University, and over 30 industry partners, they will recruit more than 50 PhD students over the next five years. These students will experience an innovative PhD programme that combines a PhD research project with training in interdisciplinary research and innovation skills and an industrial internship.

- **Media and Arts Technology Programme, Queen Mary University of London**
  http://www.mat.qmul.ac.uk/
  This programme provides an innovative, inter-disciplinary training in the science and technologies that are transforming the creative sector. It is led by internationally recognised experts in digital music, digital video, human interaction, performance, live art and digital media law. The centre aims to produce postgraduates who combine world-class technical and creative skills and who have a unique vision of how digital technology transforms creative possibilities and social economies.

- **UK PhD Centre in Financial Computing, UCL, London School of Economics and London Business School**
  http://www.financialcomputing.org/
  This centre covers financial IT, computational finance and financial engineering, software engineering, computational statistics and machine learning, network, high performance computing, mathematical modelling, statistical and signal processing.
8

Web Science DTC, University of Southampton  
http://webscience.ecs.soton.ac.uk/dtc/  
Web science is a multi-disciplinary approach to a technical understanding of the construction and analysis of the web as a distributed global information system, and a qualitative examination of the social impact of the web on human society. Web scientists will develop an understanding of the web’s development and growth, its capacity for furthering global knowledge and communication, and its inherent values of trustworthiness, privacy and respect for social boundaries.

Security Science DTC, UCL (this is an ICT DTC)  
http://www.ucl.ac.uk/secret/homepage/  
This centre will train and shape a generation of thought leaders in integrated and socially sensitive security; this will encompass not only future academics but also the policy makers and industrialists with whom they interact during and after their training. Supported by £7M investment by EPSRC and £10M of cash and in-kind from industrial, academic and public sector partners, they plan to establish Europe’s largest centre for doctoral training in security science. The centre is a world-class interdisciplinary centre applying the latest techniques in a variety of disciplines to problems in the crime and security domain.

3.8.4 The Digital Economy Programme is a cross-council Programme managed by EPSRC working closely with MRC, AHRC and ESRC (http://www.epsrc.ac.uk/ResearchFunding/Programmes/DE/Introduction.htm). The Programme has a research budget of £83M between 2008 and 2011. A significant part of the Digital Economy portfolio is the DE Research Hubs which are also closely linked to the e-Science community (e.g. Paul Watson, Director of the Newcastle Hub is also the Director of the North East Regional e-Science Centre).  
http://www.epsrc.ac.uk/ResearchFunding/Programmes/DE/CurrentProjects/dehubs.htm. The three DE Hubs are listed below:

Horizon, University of Nottingham  
The Horizon Digital Economy Research Hub is helping to connect people with digital technology to radically improve the way they live, work, play, and travel. The centre is developing new ways to use the electronic ‘footprints’ left behind whenever mobile, internet and other digital technologies are used, and new ways to use digital technologies to help business and stimulate economic growth.

Focusing on ‘always on, always with you’ technology, the hub will promote creative industries such as internet and mobile phone gaming as well as online smart marketing tools for retailers. The centre will also help reduce carbon levels by developing communication tools to encourage more car sharing — by combining global positioning systems (GPS), social networking sites and mobile digital technologies.

Inclusion through the Digital Economy, Newcastle University and University of Dundee  
Poor health, disability, family breakdown, poverty and unemployment are just some of the reasons why people of all ages may become marginalised from society and may lack the skills, confidence or opportunities to access and benefit from digital technologies that have the potential to transform their lives.

The Digital Economy Research Hub aims to tackle social exclusion by making it easier for people to access the life-changing benefits offered by digital technologies. Research will address four fields where digital technologies and the building of a truly inclusive digital economy could deliver major social benefits: connected home and community, accessibility, inclusive transport services; and creative industries.

Rural Digital Economy, University of Aberdeen  
The Rural Digital Economy hub is exploring the contribution digital technologies can make to enhancing key services, generating business opportunities, boosting quality of life and promoting the economic, social and environmental sustainability of rural areas across the UK.

Research is based around four themes: access and mobilities, healthcare, enterprise
3.8.5 Much of BBSRC’s e-Science activities have been continued via investment in Systems Biology, a quantitative approach to studying animals, plants and microbes that combines theory, computer modelling and experiments.

3.8.6 Two large tranches of investment have been made. The first was when BBSRC, in collaboration with EPSRC, established six Centres for Integrative Systems Biology (3 in 2005, and 3 in 2006) at a total investment of over £40M.

3.8.7 These Centres are shown in table 22.

Table 22  Centres for Systems Biology funded by BBSRC and EPSRC

<table>
<thead>
<tr>
<th>PI</th>
<th>Institution</th>
<th>Title</th>
<th>Funds (£M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Millar AJ</td>
<td>University of Edinburgh</td>
<td>Centre for Systems Biology at Edinburgh (CSBE)</td>
<td>9.2</td>
</tr>
<tr>
<td>Hodgman TC</td>
<td>University of Nottingham</td>
<td>Centre for Plant Integrative Biology (CPIB)</td>
<td>9.2</td>
</tr>
<tr>
<td>Armitage J</td>
<td>Oxford University</td>
<td>From Bacterial Chemotaxis to the Prediction of Complex Networks: The Oxford Integrative Systems Biology Centre</td>
<td>9.0</td>
</tr>
<tr>
<td>Stark J</td>
<td>Imperial College, London</td>
<td>A centre for integrative systems biology at Imperial College London (CISBIC)</td>
<td>6.5</td>
</tr>
<tr>
<td>Kirkwood T</td>
<td>Newcastle University</td>
<td>Centre for Integrated Systems Biology of Ageing and Nutrition (CSBAN)</td>
<td>6.45</td>
</tr>
<tr>
<td>Westerhoff HV</td>
<td>The University of Manchester</td>
<td>The Manchester Centre for Integrative Systems Biology (MCISB)</td>
<td>6.3</td>
</tr>
</tbody>
</table>

3.8.8 The second large funding stream was the Systems Approaches to Biological Research initiative (SABR). The aim of the SABR initiative was to work in partnership with relevant UK universities and research institutes to establish a range of systems biology research projects. The objectives of this initiative were to:
- Support a range of high quality systems biology projects, thereby further establishing systems biology research in UK universities and research institutes;
- Encourage cross-disciplinary interactions between the biosciences and the physical sciences, mathematical/computational sciences and engineering;
- Contribute to the training of postdoctoral staff and postgraduate students in systems biology research in the UK;
- Contribute to improved interactions between the science base and industry.

3.8.9 Six projects were funded through this initiative, shown in table 23.

Table 23  Funding provided through the BBSRC Systems Approaches to Biological Research Fund (SABR)

<table>
<thead>
<tr>
<th>PI</th>
<th>Institution</th>
<th>Title</th>
<th>Funds (£M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coen E</td>
<td>John Innes Centre (JIC)</td>
<td>A Multiscale Approach to Genes, Growth and Geometry</td>
<td>1.9</td>
</tr>
<tr>
<td>Bangham JA</td>
<td>University of East Anglia</td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>Brown AJP</td>
<td>University of Aberdeen</td>
<td>Combinatorial responses of fungal pathogens to their human hosts: an Integrative Systems Biology approach</td>
<td>2.55</td>
</tr>
<tr>
<td>Stark J</td>
<td>Imperial College London</td>
<td></td>
<td>2.1</td>
</tr>
<tr>
<td>Jackson D</td>
<td>The University of Manchester</td>
<td>Dynamics and function of the NF-kappaB signalling system</td>
<td>1.0</td>
</tr>
<tr>
<td>White MRH</td>
<td>University of Liverpool</td>
<td></td>
<td>3.3</td>
</tr>
</tbody>
</table>
An associated project was the Exploiting Systems Biology-LINK project (ESB-LINK), a BBSRC initiative open to named investigators associated with the BBSRC/EPSRC Centres for Integrative Systems Biology. One project was funded through this mechanism, shown in table 24.

**Table 24: Project funded through the Exploiting Systems Biology LINK initiative (ESB-LINK)**

<table>
<thead>
<tr>
<th>PI</th>
<th>Institution</th>
<th>Title</th>
<th>Funds (£M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hodgman TC</td>
<td>University of Nottingham</td>
<td>The Regulatory Network Controlling Tomato Ripening</td>
<td>0.22</td>
</tr>
</tbody>
</table>

**3.8.11** NERC’s strategic science priorities from the strategy *Next Generation Science for Planet Earth 2007 – 2012* allows e-Science to be embedded within the science research themes. In particular the Technologies theme identifies that ‘Rapid advances in software engineering, and information and communication technologies are revolutionising the way researchers are working, and working together, to use computing power and scientific data repositories’. The Technologies theme in the strategy further emphasises the importance of technologies such as e-Science within NERC.

**3.8.12** MRC is part of an initiative led by the Wellcome Trust, in association with a number of other UK biomedical funders, to establish a UK version of PubMedCentral (UKPMC). The contract to run UKPMC has been awarded to a partnership of the British Library, The University of Manchester and the European Bioinformatics Institute. MRC is a major funder of UKPMC. The aim of this initiative is to create a stable, permanent and free-to-access digital archive of the full text, peer-reviewed research publications (and datasets) that arise from research funded by MRC, the Wellcome Trust and other members of the UKPMC Funders Group. UKPMC will comprise three key systems:

- A mirror of the data held in PMC, subject to permission from those publishers that participate in PMC;
- An author manuscript submission and tracking system, with supporting document conversion services;
- A system to provide authenticated login services to the submission system. Further details of the proposed system can be found on the UKPMC project pages of the Wellcome Trust website.

**3.8.13** In response to demand from the scientific community the MRC Strategy Board has launched an initiative to strengthen UK-wide capability and expertise in high-throughput (HTP) sequencing. The investment will facilitate access to cutting-edge equipment and dedicated technical and bioinformatics expertise to allow biomedical and clinical researchers to fully realise the potential of these approaches. MRC sees a need for regional hubs with sufficient critical mass to allow:

- The provision of dedicated expert support staff;
- An environment which enables close working with and expert advice to the scientists applying these techniques to a wide variety of areas;
- Direct interaction with manufacturers in order to facilitate the iterative improvement of HTP sequencing technologies;
- Efficient and effective use of the equipment.
£7.5 Million funding is available to help develop and consolidate three to five regional hubs for three years initially (with a possibility of two further years support at a lower level). The hubs are expected to become self-sustaining thereafter.

3.8.14 In 2008, MRC contributed £1.5M to a £10M call with the Wellcome Trust for proposals maximising the use of electronic databases for health research. Together MRC, EPSRC and ESRC have funded four awards arising from this call. With EPSRC, MRC also funded a joint initiative, with a total value of £2.3M, in information driven healthcare.

3.8.15 MRC is a funding partner of the National Cancer Research Institute Initiative which has funded:

- **The NCRI Informatics Oncology Information Exchange (ONIX).** This was developed as part of the answer to how the cancer research community could make more effective use of the vast amounts of information that is generated in this field. ONIX aims to achieve this by making the discovery of information easier, quicker and more efficient by connecting to and cataloguing useful cancer-related resources. In addition to providing a resource discovery function, in the future ONIX will also act as a data discovery tool by enabling structured targeted searches to be performed simultaneously across multiple diverse resources so that data can be found in a timely manner. ONIX will bring together a range of resources, which will include biomedical data, data analysis tools, research publications, information about new research technologies and projects developing community standards to facilitate information sharing and re-use. This will ensure that scientists have access to a comprehensive and diverse range of information on which to further their research.

- **Cancer InfoMatrix.** This is an online tool that provides links, information and monitors informatics activity across the spectrum of biomedical cancer research. It is an up-to-date and dynamic resource that aims at promoting adoption of standards, data sharing and data integration within and between biomedical cancer research domains. It is generic in its applicability and can be applied to any major area of biomedical research (e.g. cardiovascular disease). In addition to displaying information, it also aims to identify areas of commonality between projects.

3.8.16 Capacity building:

- **Bioinformatics** - MRC support special training fellowships in biomedical informatics which aim at creating a research workforce able to take forward new developments in the fields of bioinformatics, neuroinformatics, health informatics and computational biology. This special training fellowship is aimed at individuals from non-biological as well as biological, non-clinical and clinical backgrounds. The special fellowship is awarded at the post-doctoral entry level only and includes a well-specified formal training element in addition to a research project. Total investment for these fellowships is £1.7M - £2M per year.

- **Advanced course in Masters Studentships** - The MRC advanced course Masters Scheme aims to assist universities to make a significant impact on unmet national needs for advanced biomedical and health research skills. These are skills that have been identified by MRC and other partners as critical to the success of the UK if it is to meet national goals for better healthcare and improved human, social and economic health.

3.8.17 The Capacity Building Studentship Scheme aims to assist UK Research Organisations to make a significant impact on unmet national needs for advanced biomedical and health research skills by funding targeted 3, 4 or 1+ 3 year PhD courses. These are skills that have been identified by MRC and other partners as critical to the success of the UK if it is to meet national goals for better healthcare and improved human, social and economic health.

3.8.18 This year’s priorities of the courses were:

- **Biological and medical imaging (£1.46M)** - Training in a range of advanced imaging research methods relevant to human health and disease, such as imaging physics, radiochemistry and tracer development, biomarker characterisation, data acquisition, computation and analysis.

- **Mathematical and statistical research (£1.24M)** - Training in advanced mathematical and statistical research methods as applied to population health sciences including
epidemiology, genetic and pharmaco-epidemiology, biostatistics, bio-informatics and e-health; and to basic sciences such as pharmacology and physiology.

3.8.19 During 2009/10 MRC will support a number of new and ongoing initiatives designed to enhance existing investment in the research data sets and stimulate innovative research using research data sources and routinely collected data sets.

- The MRC Data Support Service is a new initiative that will provide tools and support for scientists to work across diverse population data sources and types. During the first year it will deliver a needs assessment for four of the six MRC exemplar studies and a prototype web-based directory of MRC population data sets.

- Initiatives led by the Department of Health in England through the Research Capability Programme and analogous programmes in Scotland and Wales will soon enable unparalleled access to electronic health records and other routinely collected health data. During the coming year MRC will develop and implement a strategic plan to exploit linkage to the previously unavailable health data sets and to maximise investment in existing research data and resources.

- As part of its commitment to e-health, MRC will work with other funders to develop a ‘strategic framework for health informatics for research’. The framework will provide a means to facilitate alignments between existing activities and new plans aimed at realising the research potential offered by e-health and NHS data sets. MRC is committed to playing a leading role in the co-ordination and strategic oversight of these activities.
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RCUK REVIEW OF e-SCIENCE IN THE UNITED KINGDOM

SECTION 4 - EVIDENCE TO THE PANEL

NOVEMBER 2009

Research Councils UK (RCUK)
Polaris House, North Star Avenue
Swindon, SN2 1ET
Wiltshire, UK

http://www.rcuk.ac.uk
4. The Institution Perspective

EVIDENCE SUBMITTED TO THE E-SCIENCE REVIEW

Arranged in sections by the Evidence Framework high level questions A-E

Each section is preceded by a single page summary of the key points made. This summary is reproduced in full at the end of the chapter.

This is followed be a single page with links to each response submitted to facilitate easy navigation through the document.

INDEX

A. Did the UK e-Science Programme build a Platform which enables e-Science tools, infrastructure and practises to become incorporated into mainstream research in the UK?

B. How does UK e-Science activity compare globally?

C. What has been the impact (accomplished and potential) of the UK e-Science Programme?

D. What are the future opportunities for UK e-Science?

E. How did the Programme Strategy (having a Core and individual Research Council Programmes, developing tools and applications in parallel) affect the outputs from UK e-Science?

F. Other comments

Response Key Point Summaries

A  B
C  D
E
A. Did the UK e-Science Programme build a Platform which enables e-Science tools, infrastructure and practises to become incorporated into mainstream research in the UK?

The following key points were highlighted:

- There is broad agreement that the programme allowed the development of software tools and technologies, but penetration and adoption of those tools is considered to vary according to discipline area. Some multi-disciplinary collaborations have been enabled and standards have been disseminated, but significant barriers still exist and the general perception is that there is still potential in e-Science to be tapped.

- The e-Science programme enabled three broad types of platform: centres (discussed by the universities of Glasgow, Manchester and Newcastle), the Grid, and major facilitation projects, particularly the Open Middleware Infrastructure Institute (OMII). The Grid is a distributed HPC project, supported by the programme at different organisational levels from the National Grid Service to regional services (the White Rose Grid) and local campus Grids. Barriers to widespread usage of the Grid still exist, for example the digital certificates used to access the service are perceived as being too difficult to use and manage. Distributed HPC is not seen as a major output of the e-Science Programme to the biosciences, mentioned by Rothamsted Research. OMII is based at the Universities of Manchester and Southampton and is a widely used workflow system operating across the sciences (cited in the evidence from the Universities of Newcastle and Oxford). The diverse nature of the platforms can be a hindrance: Newcastle University’s submission described the lack of integrated e-Science platforms as a barrier to wider impact, and the Anatomical Society said that no coherent body of work has been produced. Additionally, there are concerns over long-term sustainability of some platforms (for example the National e-Science Centre at Glasgow). This is also reflected in submissions from the Universities of Glasgow (related to training) and Stirling.

- While it is noted (by the University of Glasgow) that there are few disciplines that have not been touched by the Programme in some way, the penetration of the projects into the research community vary according to the disciplines. There remains a perception that the major end-users of the tools are researchers who were primarily funded to work on or with e-science tools, cited by the University of Glasgow.

- While cross disciplinary projects do appear to have been enabled (University of Southampton), other submissions reported disappointing engagement. Barriers to engagement in cross-disciplinary programmes were discussed broadly by Newcastle University and in relation to work between biological and computing sciences by the University of Reading. Despite this, significant biological and life science projects were widely cited (Universities of Manchester, Edinburgh, Imperial College London), noting the observation from Rothamsted Research that e-Science projects are mainly in the data access and manipulation fields. The biodiversity community (University of Reading, Natural History Museum, Linnean Society) used the e-Science Programme to develop tools that underpin some of the major biodiversity databases, and biomedical researchers have additional work on visualisation tools. The biomedical sciences are considered to yet to fully benefit from the e-Science Programme (discussed by the University of Glasgow).

- In physics, remote access to large infrastructure projects (e-HTPx enabling access to Diamond, Grid-PP/LHC Grid for access to the LHC) were enabled and widely used. In astrophysics, Liverpool John Moores indicated that e-Science is considered as the province of software engineers, despite multiple astrophysics projects existing at Edinburgh, and the submission from Oxford indicating that astronomers and other physics-related projects were both easily integrated into the e-Science Programme and willing to use new technologies. Evidence presented from engineering (Dame Anne Dowling, Engineering Chair for the RAE) indicates that uptake and provision of tools by researchers is low.

- Social Sciences have benefited from collaborative tools and visualisation (University of Stirling, Southampton) as well as data integration and visual media annotation (King’s College). King’s College London cites numerous projects, in the Arts and Humanities for example, The Arts and Humanities e-Science Initiative.
Follow the links below to view the responses

Visiting Panel:
- Aberystwyth University (no response against individual framework questions)
- Liverpool John Moores University
- Newcastle University
- Rothamsted Research
- University of Aberdeen
- University of Bristol (no response against individual framework questions)
- University of Cambridge
- University of Edinburgh
- University of Glasgow
- University of Manchester (The) (2 submissions)
- University of Nottingham (no response against individual framework questions)
- University of Oxford (2 submissions)
- University of Southampton
- University of Stirling
- Wellcome Trust Sanger Institute (no response against individual framework questions)
- White Rose Universities (Leeds, Sheffield and York)

Panel Visits:
- University of Reading
- Proudman Oceanographic Laboratory (no response against individual framework questions)

- Imperial College London (2 submissions)
- King’s College London
- Natural History Museum, London
- University College London (no response against individual framework questions)
- Rutherford Appleton Laboratory (RAL), STFC (a combined submission from all the projects being reviewed during the visit to RAL)

Others:
- Anatomical Society of Great Britain & Northern Ireland
- Diamond Light Source
- Institute of Physics (IoP) (no response against individual framework questions – please see Section F - Other Comments below)
- Isaac Newton Institute for Mathematical Sciences, Cambridge
- Linnean Society of London
- The UK Computing Research Committee (UKCRC)
- Professor Dame Ann Dowling, Chair, Engineering Panel in RAE 2008
- Professor Nigel Hitchin, Panel Chair of last RAE exercise (no response against individual framework questions – please see Section F - Other Comments below)
Response by Liverpool John Moores University

- In my area (observational astronomy) it has remained a tool for software engineers to develop solutions for certain specific problems in time domain astrophysics rather than being adopted by the day-to-day academic researcher.

End of response by Liverpool John Moores University  (return to ‘A’ response list)

Response by Newcastle University

- At Newcastle, the Programme funded the North East Regional e-Science Centre (NEReSC) which created a local critical mass. We were then able to build on this by successfully bidding for 25 e-Science projects, involving a wide variety of disciplines, including: Bioinformatics, Ageing & Health, Neuroscience, Chemical Engineering, Transport, Geomatics, Video Analysis, Artistic Performance and Computer Science. The key to this was that the NEReSC funding enabled us to employ 1-2 people over a sustained period who were not specifically associated with any one research project. Instead, they were able to identify high-quality research groups from across the University who might benefit from e-Science, build a relationship with them, develop a joint vision for how e-science might transform their research, help write grant proposals and then (when successful) ensure that the projects followed best practice and were integrated into the local, national and international e-Science communities. Building new multi-disciplinary groups takes significant effort, and so I do not believe that e-Science would have anywhere near such a wide impact across the University without NEReSC’s dedicated funding from the core programme.

Over time, many of the research groups came to see exploiting e-Science as being just their normal way of working, e.g. the tools, techniques and approaches had been completely embedded in the way they approached their research.

The ending of funding for NEReSC in 2009 did carry the risk that such techniques would not be spread to other research areas. However, in 2009, the Director of NEReSC was asked to take over the University’s Informatics Research Institute, and funds were provided to ensure that the approach taken by NEReSC could continue, and be extended more widely across Newcastle.

In general, e-Science technologies and practices have changed the way researchers at Newcastle store, share and analyse data. This has allowed them to do their research faster and/or better and/or more cheaply.

The main issues preventing e-Science having an even wider impact are:

- the lack of integrated e-Science platforms. There are many good e-Science technologies available (e.g. from OMII) and we use several of them, but there is a lack of integrated solutions that combine the store, share and analyse functions. Consequently, integration and configuration of software is usually required, and this takes expertise and effort.

- the manageability of the infrastructure. Most e-Science software has to be locally installed, configured and managed. This requires dedicated local effort and expertise. A move to e-Science delivered over the web through a “Software as a Service” approach could reduce the need for this local effort and expertise, and widen the base of users. However, I appreciate that this requires further research, and won’t be appropriate in all cases. It also requires a different funding (or a business) model.

The main barrier to multi-disciplinary research is the effort needed by each party to understand the others’ work and approach. This includes the science, the terminology, how people are rewarded and how impact is measured (e.g. is producing novel, high quality data a good output, or do only papers in Nature count?). The UK programme built a community, and provided the effort needed to facilitate such multi-disciplinary engagement. I have been in CS research since the mid 1980s, but I’d not seen anything like this happening before the e-Science Programme. Before the Programme
I, like many other computer scientists, often struggled to find real application challenges to drive and evaluate my computing research – I now have regular interactions with researchers from a wide variety of disciplines, and many potential collaborations that can drive our research in a mutually beneficial way.

The Programme built a large, but close, e-Science community in the UK, and linked it to the rest of the world. One key plank was the All Hands Meeting which, now in its eighth year, can still attract over 500 delegates. The combination of talks, demonstrations, workshops and international keynotes was vital to create and sustain the community.

The Edinburgh National e-Science Centre has been vital for education and training. Its innovative and energetic leadership ensured that a wide range of training events and workshops spread best practise across the community. Almost all of those involved in e-Science at Newcastle have benefited from this at some time.

Locally NEReSC has run many local events for academics (e.g. regular PhD summer schools) and industry (as described in Section C below).

End of response by Newcastle University

Response by Rothamsted Research

- Within UK bioscience research, which is the community relevant to Rothamsted Research, the e-Science programme has been successful in helping deliver infrastructure and research tools into mainstream research.

The most recognisable impact has been the increasing number of e-science software tools in Bioinformatics that exploit Web Services. The BBSRC e-science programme, as well as core funding of OMII and MyGRID, provided the impetus for many bioinformatics groups to develop web service resources that enabled their databases and algorithms to be accessed using Grid techniques. For many research groups (particularly in the biomedical sciences), the Taverna workbench and associated tools (MyExperiment, BioCatalogue) have become important parts of their routine bioinformatics toolkit. A number of MSc courses in Bioinformatics teach the concept of workflows and data integration using Taverna and MyExperiment.

The predominant use (from my experience) of the UK e-Science infrastructure by the biological science community has been in the access to data resources and integration of data; not in the area of high performance distributed computing.

End of response by Rothamsted Research

Response by University of Aberdeen

- The Programme has clearly created a new community of technology researchers and end-user researchers with a capability in areas such as e-Science tool development, deployment and evaluation. What is less clear is the future of this community.

We have direct experience of e-Science technologies changing how researchers work. Our collaborators at the Macaulay Land Use Research Institute have adapted their social simulation models to use semantic technologies and to operate in a Grid environment. These changes are as a direct result of their engagement with the e-Science programme.

Training of researchers in use of e-Science tools must become fully embedded in undergraduate and postgraduate programmes if the technologies are to become part of mainstream research practice. We have begun to work closely with MRes and research student training programmes at Aberdeen to introduce some of our locally developed tools.

End of response by University of Aberdeen
Response by University of Cambridge

- I believe the primary major outcome of the eScience programme was to show that scientific computing is about more than HPC. High throughput computing, visualisation, collaborative tools (i.e. social networking for scientists) and data management are now taken more seriously and their relevance to mainstream research is better understood than previously. The projects funded by the eScience programme produced a critical mass of PhD graduates and young postdocs with skills in these areas that they will carry forward into mainstream research and industry.

Multi-disciplinary research is nothing new, though the regional eScience centres often acted as a focus within their institutions for multi-disciplinary projects. This may have been merely as a ‘directory’ or ‘match-making’ service to put researchers from different disciplines in touch with each other, although this is a service often not provided in any other meaningful way.

The other critical role the eScience programme played was to provide a focus for experimentation with new technologies that could enable new science. In that respect, it was an unqualified success: one need only look at the publication list for projects such as MyGrid, RealityGrid and campus grids such as CamGrid. JISC now appears to have taken on the role of funding innovative technology development that does not obviously fit the remit of any other research council. As far as I can tell they have successfully identified the major themes of current interest and are spending their funds wisely.

It would be a pity if the communication channels provided by the network of regional eScience centres were to disappear with the end of the core eScience Programme. Some vestiges remain such as the Campus Grids Special Interest Group, the eScience Directors’ Forum and the annual All Hands meeting. There may be scope for increasing the number of Special Interest Groups with support from the research councils or JISC. Perhaps the All Hands meeting could evolve into a showcase event of new scientific computing technologies in general such as multi-core computing and Open Data, rather than just those traditionally associated with eScience.

End of response by University of Cambridge (return to ‘A’ response list)

Response by University of Edinburgh

- We have achieved a critical mass of capability in e-Science worldwide for: analysing LHC data (GridPP); establishing and leading the International Virtual Observatory Association to integrate astronomy data from multiple observatories and wavelengths (Euro-VO, AstroGrid); creating and supporting standards and middleware for distributed data integration (OGSA-DAI); defining an international standard for QCD simulation data and middleware for shared use (ILDG); facilitating multidisciplinary communities and establishing consensus on e-Science strategies (NeSC); stimulating long-term collaborative research in new areas of e-Science (eSI); using brain-image analysis to predict psychotic episodes in schizophrenia and bi-polar patients and revising diagnostic criteria (NeuroGrid, NeuroPsyGrid); and computational steering of multi-scale materials simulations using distributed HPC resources (RealityGrid).

All of the above have changed radically the way research is conducted in those fields. Gene expression studies within developmental biology now use internationally shared data and tools (e-MouseAtlas, DGEMap, Next Generation Embryology). 450 biologists per day are using GridQTL to analyse shared quantitative trait data. Computational and data resources on a much bigger scale have enabled neuroscientists to plan a complete model of the fly brain from genes to behaviour (eSI theme). Both within and across disciplines only a small proportion of the potential has been realised (to quote the BBSRC CEO, 7% of biologists benefit from computational methods, 95% should). Sustained support for software and services is needed.

The eSI research themes directly addressed the multidisciplinary barriers by providing a forum for crossing boundaries, leading to transfer of workflows from biology to astronomy, and pooling of scientific gateways across computational chemistry,
seismology and cell biology. Thirteen themes in the last five years show the value of this approach, but only begin to address the potential opportunities.

Five international summer schools and two web-enabled winter schools have introduced 350 doctoral and post-doctoral students to grid computing. Our MSc programmes in HPC and e-Science graduate around 30 students per year. Thirteen PhD students have completed e-Science theses and a further 10 are underway. We have led 2,000 training events delivering 10,000 trainee days across industry and academia worldwide. Our training is just beginning to address the scale of cultural change that is needed in tertiary education.

End of response by University of Edinburgh

Response by University of Glasgow

- Did the Programme create a critical mass of capability in developing and exploiting e-Science tools and techniques? Is this capacity being sustained?

  - The programme as a whole had elements tools and techniques that could in principle be used to support a critical mass of capabilities, but it is fair to say that this critical mass has not yet truly materialised. The primary end users of e-Science tools and techniques are those that have been funded directly to work and engage in e-Science research techniques. It is noted, that pockets of engaged researchers do exist, and certain tools and techniques are being used to support a wide range of researchers. One example of this is the security expertise and technologies developed and applied at NeSC Glasgow which are used in a portfolio of projects from the clinical sciences, social sciences, electronics, arts and humanities amongst others.

  - The long terms sustainability of these efforts is difficult to accurately predict. The NeSC at Glasgow is primarily funded through research grants (although all NeSC personnel are now on open-ended contracts as part of IT Services at the university). These grants cover all UK research councils and include significant EU and industrial collaborations. It is hoped that this spread of domain of application will ensure that NeSC Glasgow is not pigeon-holed into one research area/funding stream. Nevertheless, grant funding remains a fickle model for long term sustainability. A further review of the business case for e-Science is currently on-going at the university and will be presented to the Senior Management Group (SMG) in due course. (The last review / business case presented to SMG resulted in NeSC Glasgow staff being placed on open-ended contracts.) It is hoped that key positions will be made permanent to support the establishment of the University of Glasgow Research Infrastructure and wider support of researchers on campus.

To what extent have the e-Science technologies developed through the Programme changed the way researchers in other disciplines work? Are there new areas of research that have been enabled by the e-Science programme? What can be done to increase this happening? Are the present infrastructure and communication channels sufficient?

- There have been a variety of technologies that have been put forward and used through the e-Science Programme – possibly too many! As identified previously, it is still the case that the vast majority of researchers using e-Science technologies are funded to do so.

- At the risk of stating the obvious - successful e-Infrastructures must meet researcher needs and address their requirements. For many domains this means making e-Infrastructures with minimal Grid exposed, e.g. through portals such as DAMES, NeISS, and clinical projects like EuroDSD. For others who prefer Unix command lines and are more HPC savvy, then they should be offered such interfaces and environments. Thus Prof. Asenov from the nanoCMOS project expressed that he wants to do what he can do now, but on the Grid where codes compiled with a "-g flag".

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Many new areas are now supported and many others will no doubt be supported in the future. It is noted that many new domains at NeSC Glasgow are atypical of the classic Grid end user (ala running jobs on HPC facilities like the NGS), e.g. supporting researchers conducting clinical trials; social simulations; language and literature domains.

There remain vast areas that could benefit from e-Science expertise. The biomedical domain is one example where a multitude of research areas could benefit from e-Science technologies and expertise, e.g. to cope with the data deluge associated with high throughput post-genomic facilities. One challenge in this and with regard to the whole e-Science Programme is that typically projects are funded to support a given collaboration of individuals and organisations. The key question is how to support other researchers facing similar collaborative issues or indeed addressing similar research questions. Most projects are not typically funded to support other groups/researchers. However it is the case at NeSC in Glasgow through grants such as the NeSC Research Platform that we have attempted to support such technology transfer and hands-on support for other non-funded research communities. This altruistic approach has lead to several major grants, e.g. AvertIT and EuroDSD were both based upon initial early prototypes undertaken by NeSC staff with no direct project funding. Similarly, we support the storage and processing of a wide range of biomedical data to a variety of research groups at the university at no cost.

It is noted that the funding received for NeSC itself at Glasgow from EPSRC (including funding for the NeSC, NeSC-II, NeSC-III and now NRP and NIN grants) corresponds to less than 1FTE per year from 2001-2013.

To what extent did the e-Science Programme contribute to and benefit from multi-disciplinary research? What barriers to such research did the Programme overcome and what opportunities did it enable?

The e-Science Programme contributed greatly to supporting a range of multi-disciplinary research. Indeed it could be argued that there are few areas of research that have not been impacted in some way by the programme. Given this it would be expected and hoped that different disciplines would have learnt from each other. Whilst some cross discipline success stories have occurred, e.g. the security story at NeSC Glasgow, I believe that much more could and should have been done in this regard.

From a technology/software perspective, many projects have developed the proof of concept, but not been able to translate this into a robust product used by a community of researchers in anger. Case in point, the currently running ESRC DAMES project involving NeSC Glasgow has developed a software e-Infrastructure that couples clinical, social and geospatial data sets and services through a seamless, secure environment. Moving from proof of concept as exists right now to a robust infrastructure remains a challenge (and one that the project is not sufficiently resourced to fully achieve).

Many opportunities exist in this space still, however it is also noted that many barriers still exist to successful collaborations. Cultural, economic and political consequences of collaborating through e-Science solutions remain an issue. Thus collaborators are also often competitors and are thus sceptical of data sharing and the ramifications of sharing data. Reports on these and various related issues in the life sciences were documented in the JDSS report (available from [http://labserv.nesc.gla.ac.uk/projects/jdss/index.html](http://labserv.nesc.gla.ac.uk/projects/jdss/index.html)).

Through a body of completed projects and expertise garnered at NeSC Glasgow, it is now possible to address far more complex research questions. As one example, research in the area of public health can require heterogeneous software systems incorporating a wide and complex set of data resources and support for a variety of experts covering clinical, social, environmental, geospatial areas etc. Work through projects such as the Scottish Health Informatics Platform, DAMES and various others now make such research viable. (Current work is exploring research questions in depression, self-harm and suicide).
Further cross council funding streams to leverage these kinds of developments is needed. (SHIP is funded through the Wellcome Trust, EPSRC, ESRC and the MRC).

How effective is the education/training of e-Science practises and techniques at ensuring sufficient take up and adoption? What barriers to effective knowledge exchange and information flow remain and how can they be overcome? What are the barriers to the uptake of these tools and techniques?

I would argue that we have barely scratched the surface of what is needed in terms of education and training: how to support data curation; support data provenance; how to write optimised codes for execution on heterogeneous HPC facilities; how to build secure systems for short-lived collaborations crossing institutional boundaries; etc etc; all represent on-going challenges facing the e-Science community. All too often research communities and projects have developed their own ad hoc and hence non-interoperable and/or non-optimal solutions.

A major issue is the complexity of technologies coupled with overall complexity of research requirements which themselves often evolve. It is often the case that documentation is paramount to solving software complexity issues: documenting what works and what doesn’t work so others can learn from the experiences should have had a far greater focus. At NeSC through efforts such as the Engineering Task Force we have attempted to address this directly. We also note that the level of expertise and complexity of software and its configuration is often non-trivial even for competent developers (see http://labserv.nesc.gla.ac.uk/projects/etf/).

The domain-level immersion needed to understand the domain level terminology and ultimately the software requirements continues to be a non-trivial issue. Given that domains such as bioinformatics (as one example) are expanding rapidly both in terms of the tools, science and data sets that are being generated, an e-Scientist can only realistically support these communities by continued involvement in bioinformatics. This model does not typically fit with existing project-oriented funding models.

Training on how to acquire and manage an X509 certificate is not what is needed for most researchers – indeed it is now widely recognised that this should be hidden completely from end users. Similarly from experiences in numerous projects at NeSC Glasgow, many (most!) researchers don’t want access to a HPC facility like ScotGrid or the NGS. (There are communities where this is not the case of course, e.g. nanoCMOS). Rather many communities need help with data management, data processing tasks etc as well as advice and support on building secure systems.

NeSC Glasgow established the first Grid Computing course in the UK (for advanced MSc students) and focused explicitly on challenges of large scale distributed systems. Many graduates now work at NeSC. We were not funded to undertake this teaching effort. Numerous PhDs are also currently being supervised at NeSC Glasgow. All of the lecture materials associated with the Grid Computing courses have been made freely available and have been used by many others, e.g. at Grid Summer schools.

End of response by University of Glasgow

Response by The University of Manchester (1)

The UK’s infrastructure-Science Programme provided a platform – comprising resources, infrastructure, software and people – for major interdisciplinary projects that have global impact.

The Programme established a range of centres (e.g. the eScience Centres, the Digital Curation Centre (DCC), the National Grid Service (NGS), the Open Middleware Infrastructure Institute (OMII-UK), the National eScience Centre (NeSC)), discipline specialist centres (ESRC’s NCeSS and NERC’s eScience Centre) and initiatives (e.g.
the eScience Institute) to build general infrastructure, specific software for applications and capacity through training. Both the NGS and OMII-UK have major nodes at Manchester. The NCeSS Hub, responsible for developing the e-Social Science research programme and coordinating the work of its research groups ('Nodes'), is based in Manchester, as is one of the Nodes.

The UK maintained an open view of services, pioneering the concept that e-Science could be built on current standards for Web Services without needing to wait for special extensions to WS- standards (myGrid, Newcastle eScience Centre). This has ensured that the UK’s infrastructure is robust, flexible and relevant. We also focused more on data which has proven to be the right call for the demands of UK science. In addition, we recognised the importance of supporting not just “heroic” or “big” science tackling the “grand challenges” but also the individual scientist working on problems at all scales, and the social sciences and humanities where “big” has less relevance.

The UK e-Science Programme established a stack for support and integration of e-Science tools and methods that is internationally leading. The UK National Grid Service is a highly successful distributed computational and data research infrastructure that has participated in leading-edge collaborations with other infrastructures on a global scale used by large UK projects such as nanoCMOS, RealityGrid and NaCTeM. NGS is a key component of GridPP and the forthcoming EGI European e-Infrastructure. NGS crucially recognises the need to support secure access over multiple platforms.

The Open Middleware Infrastructure Institute provides software that is used across the full range of research projects on scales ranging from the desktop to the global internet. NGS and OMII-UK work together to deliver a heterogeneous, holistic platform that serves both big science and the solo scientist; for example in data access (OGSA-DAI), job submission (GridSAM) and Grid programming (SAGA), application hosting (AHE) and workflow (BPEL, Taverna).

Higher up the middleware stack, the Taverna workflow system developed by the EPSRC’s myGrid pilot project and OMII-UK at Manchester is the most adopted open source workflow system in the sciences with over 69,500 downloads and 361 organisation users in the public and private sector (details in the submission “myGrid: an OMII-UK node”). Taverna is widely used by the UK and international Life Sciences community to investigate fundamental questions into systems biology, ‘omics, pharmacogenomics, cheminformatics and the mechanisms of life and how they relate to disease and well being. Although developed for the Life Sciences, the software has been adopted by astronomy (AstroGrid), climate modelling (RENCI), engineering (JPL) and the social sciences (FLOSS) among others. The UK has led the way in developing high level middleware for integration such as workflows (Taverna, but also P-GRADE, BPEL, Triana) and distributed querying (OGSA-DQP). Workflows are now recognised by the EU (e.g. in the ESFRI projects) and NSF as fundamental e-infrastructure.

The Programme also produced a range of specialist platforms. For example, the open Clinical Data Management System (openCDMS) developed by the MRC PsyGrid project has been adopted by the UK’s Mental Health Research Network to manage studies and clinical trials in the NHS. The handling of sensitive data is a fundamental problem in the use of clinical data in medical research. UTOPIA, first funded through ESNW, is a platform for integrated scientific data visualisation with over 2,000 registered users. The e-Social Science programme has produced a tool to map and analyse childhood obesity data that is being adopted by NHS Primary Care Trusts. myGrid’s system biology asset elab has been adopted and fielded by the EU Systems Biology programme SysMO.

The Programme has impacted on the research infrastructure at Manchester in several ways. A Campus Cloud Infrastructure has been recommended by M’s cross-faculty review as the basis for a University strategy for computational research. The Manchester Interdisciplinary Biocentre runs a Condor pool to support its “dry lab” scientists. Taverna is used on a regular production basis in the MIB, NIBHI and MCISB. ESNW co-built an e-Science infrastructure across the North-West (NWGRID) funded by the NWDA, supporting research that featured in the popular media and in Nature. The
NGS links this with other regional Grids, such as the White Rose Grid, to form a national resource. Grid computing forms part of the Computer Science curriculum. e-Science infrastructure was used, for example, in the e-Fungi project to carry out comparative genomic studies on the fungi; this includes the most comprehensive analysis of specialization and diversification in the fungi, which was followed up by a focused study on the genomics of pathogenicity.

The Programme has successfully stimulated scientists to become e-infrastructure aware and trained a new generation of scientists and infrastructure developers through the institutes and centres and through a programme of schools and workshops.

Response by The University of Manchester (2)

- Most certainly, yes. The main successes of the ISPIDER pilot project were arguably the contributions made to repositories in this area of proteomics, key areas of e-Science infrastructure which enabled interoperability between them, and core technologies which support more general integration of web services into pipelines/workflows. The proteomics repositories developed with ISPIDER are still being developed and maintained. In particular PRIDE (www.ebi.ac.uk/pride) has become the chief proteomics data repository in Europe. PRIDE has gone on to receive wider funding from Wellcome trust and the EU and now contains almost 10,000 experiments, with data captured in PRIDE’s XML format based around community-driven data standards. Indeed, ISPIDER team members have been integral to the Proteomics Standards Initiative (PSI), notably Paton and Hermjakob, which has developed standards in this area for mass spectrometry based peptide and protein identifications and the attendant mass spectrometry data from which it is derived. This also includes data capture tools for cutting edge areas of the proteomics field, such as the PRIDE Wizard (http://www.mcisb.org/resources/PrideWizard/, Siepen et al., 2007, Proteome Sci, 5:4) which introduced extensions to the underlying data model for quantitative data – one of the outputs of the project. Further data capture tools have been built on this beyond ISPIDER by the PRIDE team, using principles originating from the ISPIDER e-Science project.

Further evidence is provided by the large number of published outputs from this particular project either relating to, or using, proteome informatics tools developed within or from ISPIDER. To date, we estimate this is 24 journal articles, 10 conference papers, 3 book chapters and also software releases. These include papers published as primary research articles (which have direct impact on the proteomics field) and those describing e-Science infrastructure that raise awareness of technological developments which underpin the computational tools used in the science. For the former, five selected papers which are representative of research impact are shown below:


A particularly apposite example of new tools and technology is the web-service enable PICR tool (www.ebi.ac.uk/picr) which enables protein identifiers to be cross-referenced across different resources and has been used by several projects subsequently. Within ISPIDER, it was used to enable linking of proteomics data across multiple repositories (see www.ispider.manchester.ac.uk). This helps resolve one of the long-standing problems for protein informatics in that primary accessions had hitherto been linked only by static cross-references in flat files between various databases (or in some cases, not at all). PICR allows one to compare the biological entity which has been labelled differently by two independent resources and therefore is a key component for pipelines and workflows in protein informatics.

A similar example of core technology supporting further e-Science development is provided by the Ontology Lookup Service (OLS), developed at the EBI as part of ISPIDER. PRIDE makes intensive use of controlled vocabularies/Ontologies in OBO format. To manage efficient search, retrieval, and application of OBO terms, we needed a strong ontology management module. This has been developed as an independent, open source module, with both an interactive HTML interface and GRID-enabled access via web services. The OLS (http://www.ebi.ac.uk/ontology-lookup/) provides a programmatic SOAP (Simple Object Access Protocol) interface for ontology and controlled-vocabulary queries. While many of the ontologies available via the OLS are found elsewhere online, each has its own query interface and output format. The OLS provides a platform-independent web service interface to query multiple ontologies from a single location with a unified output format. The OLS can integrate any ontology available in the Open Biomedical Ontology (OBO) format and contains over 45 distinct ontologies and 470,000 terms. The open source OLS components have already been included into multiple third party projects and is used by the PRIDEwizard and ProteomeHarvest tools developed for proteomic data capture in this project.

A further example of the more generic technology developed includes QuASAR (http://img.cs.man.ac.uk/quasar/index.php). This work on semantic annotation verification for web services has been released as freely available software called QuASAR and provides the generic tools for resolving mismatching issues between web services. Specifically, the QuASAR project provides a toolkit to assist in the cost-effective creation and evolution of reliable semantic annotations Web services. In particular, we have developed tools to assist human annotators in verifying the annotations they develop before they are deployed into public repositories, and to gain maximum value from manually created annotations, by using them as the starting point from which to infer new annotations.

End of response by
Professor Simon Hubbard, The University of Manchester  (return to ‘A’ response list)

Response by University of Oxford (1)

- The research infrastructure developed by the Programme has provided the basis for collaborative research. Within Oxford the NGS has been particularly important and we
have worked to integrate our own grid computing systems into the NGS. We have also benefitted from the OMII particularly through the Engage programme.

It is clear however that to incorporate these tools and technologies into mainstream research is a challenge that varies across communities and disciplines. Clearly the astronomers and other physics-related activities are easily integrated and the community is sufficiently aware of the new technologies, and willing to invest and take a risk on less mature tools and infrastructure. This is naturally not the case with the social sciences, arts and humanities. We believe that the future of many research challenges and questions in all of these disciplines relies on the capability and capacity of researchers at Oxford to be able to deal with digital assets be they images of classical artefacts or simulation or observational data. We have therefore invested in the OeRC to help achieve the embedding of new technologies. We believe there is much still to be done and this should not be assumed a completed task.

End of response by University of Oxford (return to ‘A’ response list)

Response by University of Oxford (2)

- There is no doubt that the Internet and Web have provided a platform for bottom-up innovation across the disciplines. In my view, the major role of the e-Science Programme has been to show how advances in the Internet, Web (such as Semantic Web), and related ICTs, such as sensor networks, can be used to advance research in the sciences and humanities. The two major areas of application have been to support collaboration, and to strengthen the role of computation in solving research problems, such as in modelling and simulation. This is not in the mainstream, but on the leading edge of applying advances in ICTs to support, extend, and otherwise enhance the quality of research.

End of response by Professor William Dutton, Oxford Internet Institute, University of Oxford (return to ‘A’ response list)

Response by University of Southampton

- Southampton is contributing to software and to standards which form part of the e-Science platform used nationally and internationally. First we provide an overview of some of these activities and then we review them against the evidence framework.

The first phase of the Open Middleware Institute (OMII) was hosted in Southampton, in conjunction with IBM as an industrial partner. With the creation of OMII-UK in 2006 we were pleased to join forces with the Universities of Manchester and Edinburgh to support a national institute. Under the leadership of Prof David De Roure, who has chaired OMII-UK since 2007, the institute also obtained funding from JISC to operate a significant community programme (the ENGAGE project). OMII-UK has an international reputation and is currently informing a significant US software sustainability investment.

OMII-UK in Southampton has provided the central support for the operation, including a software engineering team, marketing and administration of the projects commissioned in the community. The community software developed in this way includes: the Application Hosting Environment, originally developed at UCL, which enables scientists to use grid resources transparently using unmodified scientific applications; OMII-SAGA, principally developed at Louisiana State University, which provides a standard interface to distributed computation that makes applications portable from Grid and web services to cloud computing; GridSAM (Imperial College) provides a uniform interface using the JSDL standard to submit and manage compute jobs on many scheduling systems; Portlet Access Grid (Manchester) which enables access through a web-browser to the Access Grid collaboration network; and Rapid (Edinburgh), a unique way of quickly designing and delivering web portal interfaces to applications that require computational resources, including utility computing infrastructures and high-performance computing facilities.
The CombeChem pilot project, which continues today as a platform grant and associated JISC-funded activities, has generated the eCrystals Web interface to the EPSRC National Crystallographic Service as well as two Electronic Lab book solutions (Semantic ELN and the Lab-Blog) which are currently in use in several departments in Southampton, Bangor and STFC (with further deployment planned in other institutions). Led by Prof Jeremy Frey, Dr Simon Coles and Dr Cameron Neylon, the original concept of “publication at source” and the adoption of Semantic Web, Web 2.0 and open repositories technologies have made CombeChem an exemplar in the Semantic e-Science, Science 2.0 and Open Science movements, as well as engaging in schools (e-Malaria). This work has been conducted with the School of Electronics and Computer Science, which produces the widely used EPrints open repository software, as well as the School of Mathematics, and is an important theme in e-Research South. This activity is partly sustained through funding from Microsoft under the oreChem project, a collaboration between chemistry scholars and information scientists to develop and deploy the infrastructure, services, and applications to enable new models for research and dissemination of scholarly materials. A key aspect of this work is the design and implementation of an interoperability infrastructure based on Semantic Web principles that will allow chemistry scholars to share, reuse, manipulate and enhance data that are located in repositories, databases and web services.

The myExperiment project, joint with The University of Manchester, has had a tremendous impact in demonstrating the successful use of Web 2.0 in scientific collaboration. Funded by the myGrid platform grant, by JISC and by Microsoft, myExperiment is led in Southampton by Prof David De Roure and in its current phase is integrating with the Institutional repositories in Southampton and in Manchester. It has thousands of users and contains the largest public collection of scientific workflows. myExperiment is supporting a new generation of e-Science projects ranging from social statistics to neuroscience.

The e-Social Science programme has enabled Southampton to build on existing relationships between Computer Science and Social Statistics, and to forge new relationships with other schools, to further contribute to the national platform. In Psychology, the LifeGuide node of the National Centre for e-Social Science is helping deliver new behavioural interventions on the internet, and as a key partner in Bristol's e-Stat node we are contributing to the national capability in quantitative social science.

Under the leadership of Prof Luc Moreau, an international community has participated in three “Provenance Challenges”, the Open Provenance Model has been developed and there has been an article in CACM. Some twenty teams have been involved in these activities seeking to make their systems interoperate (participants include Harvard, ISI, NCSA, Microsoft, Indiana, Chicago, Rensselaer, Amsterdam). This work is now impacting international standards activity through the creation of a W3C Incubator Group on provenance, with international membership including industry.

In addition to W3C activities, Southampton has had extensive participation in the Global Grid Forum and subsequently the Open Grid Forum. Prof David De Roure is on the Steering Group and has been Area Director for e-Science as well as chair of the Semantic Grid working group.

The Southampton Regional e-Science Centre was distinctive for its extensive engagement with industrial users, with a mission to support the development of e-Science and to demonstrate the applicability of Grid technologies to engineering and science problems. Through a series of projects (GEM, G-Civil, G-Ship, G-Yacht, G-Hydroflex, G-Markets) it extended Grid to the users and made several public contributions of software; it also participated in GENIE (Grid ENabled Integrated Earth system model), developing data and computational modelling methods for earth systems science, with collaborators including Southampton’s National Oceanography Centre. The creation in 2005 of the Microsoft Institute for High Performance Computing continued this emphasis on the engineering design process under the leadership of Prof Simon Cox.
As a research-led university Southampton continues to make significant investment in computational infrastructure. The £3M Iridis3 HPC is currently the largest university-funded HPC in UK Higher Education (i.e. excluding Hector), with 1008 compute nodes (8000 cores) delivering ~74Tf peak. Major Iridis users are engineering, including the University Technology Centre for Computational Engineering led by Prof Andy Keane, Electronics and Computer Science (ECS) and Chemistry. Chemistry and ECS also lead the new Doctoral Training Centre in Complex Systems Simulation and Modelling which will use this facility. We also provide a Condor Pool (Windows/1400 nodes) a 1.4Tflops postgraduate and undergrad facility (which runs Taverna), participation in the UKQCD grid for particle physicists and a windows HPC cluster which contributes to the National Grid Service.

With respect to the evidence framework:

*Did the Programme create a critical mass of capability in developing and exploiting e-Science tools and techniques? Is this capacity being sustained?*

All of the above e-Science projects have demonstrated capability in developing and exploiting e-Science tools and techniques. We strongly welcome the EPSRC’s recent move to regard Software Sustainability as a national facility but note that the overall reduction in spend nationally will result in a downsizing of the current sustainability operation. CombeChem is sustained through diverse funding routes including EPSRC, JISC and Microsoft. Our diverse regional exploitation of e-Science tools and techniques is partially sustained through the e-Research South activities which are facilitating new collaborations and developing new funding streams.

*To what extent have the e-Science technologies developed through the Programme changed the way researchers in other disciplines work? Are there new areas of research that have been enabled by the e-Science programme?*

The “blogging the lab” work and myExperiment are exemplars of changing practice. The projects with Psychology, Music and the School of Nursing and Midwifery have brought new computing expertise to significantly enhance established research areas which did not previously enjoy an engagement of this sort and have generated new avenues of research.

*To what extent did the e-Science Programme contribute to and benefit from multidisciplinary research? What barriers to such research did the Programme overcome and what opportunities did it enable?*

The e-Science programme provided the basis of multidisciplinary work between Electronics and Computer Science, Engineering Sciences and a great many other schools notably Chemistry, Mathematics, Social Statistics, Psychology, Nursing and Midwifery, Music, Geography and Biological Sciences, as well as the School of Ocean and Earth Science at the National Oceanography Centre. The interdisciplinary mandate of e-Science funding has kick-started these collaborations. The challenge is to find ongoing support for these multidisciplinary collaborations so that the new research opportunities may be fully exploited.

*How effective is the education/training of e-Science practices and techniques at ensuring sufficient take up and adoption? What barriers to effective knowledge exchange and information flow remain and how can they be overcome? What are the barriers to the uptake of these tools and techniques?*

e-Science at Southampton has been user-centric from the outset and this is an important distinctive of our approach, tackling barriers. The projects are focused on users and make extensive use of workshops, trials and training. For example, CombeChem introduced the “Smart tea” design method, OMII-UK Engage conducted large numbers of interviews across the community, the Regional Centre focused on “Making the Useful Usable” and myExperiment follows a Web 2 agile development methodology (the subject of a paper in IEEE Software this year on designing software
for adoption by scientists). Our approach to shifting research practice is one of co-evolution of researcher and technologist, not “build it and they will come”.

We believe that the most significant roll-out of new methods will be in the next generation of researchers and accordingly we have focused on our Doctoral Training Centres. For e-Social Science methods we are pleased to have an engagement between the new National Strategic Director for e-Social Science post and the ESRC National Centre for Research Methods.

End of response by University of Southampton (return to ‘A’ response list)

Response by University of Stirling

- Institutional evidence from the University of Stirling

The application-driven nature of e-Science projects at Stirling means that our institutional response is weighted to issues of supporting mainstream research. Activities at the University of Stirling reflect two types of contribution to mainstream research which are typical examples of how the UK e-Science Programme has contributed to the national research infrastructure:

- e-Science projects have generated new and original infrastructural resources which contribute to wider research communities (cf. examples 1, 2, 3 and 4 below, contributing to the social and medical sciences).

- e-Science projects have served to develop and sustain clusters of expertise in specialist research topics (cf. example 5 below, pertaining to the social sciences).

1. Development of major national/international resources in specialist data domains. The DAMES Node features a set of data provisions (‘Grid Enabled Specialist Data Environments’, GESDE) which act as unique archives of research data associated with specialist topics (on occupations, educational qualifications, and ethnicity). These services are provisioned by using metadata and data storage standards from e-Science, and secure portals for access to data. These services are still in production but offer relevant resources to large user communities (those working with such types of data). One route to sustainability in these services is a planned long-term coordination with the EU-funded CESSDA PPP project.

2. Generic training and capacity building in data management. The DAMES Node provides training and generic resources in the domain of ‘data management’. This is an otherwise neglected methodological niche where the DAMES Node has leveraged e-Science approaches to facilitate effective data services and research capacity building.

3. Research tools for simulation analysis of social care and other data. Initiatives at Stirling associated with DAMES and with NeISS have built data analysis and management resources to support micro-simulation research on social care requirements. These resources have already contributed to internal research projects, and are being prepared to support access for social scientists across the UK.

4. Portal for access to neuroinformatics databases. The University of Stirling also has an input on the EPSRC-funded CARMEN project, which has prepared a portal for access to neurological databases (Stirling research contributes to overall management, and to the development of publicly available services for processing raw neurophysiological datasets. This project spans 11 institutions (see the institutional submission of the PI’s institution, Univ. Newcastle).

5. A critical mass in quantitative social science research at the University of Stirling. The DAMES, GEODE, NeISS and e-Stat projects at Stirling have involved social
science research in the domain of large scale quantitative data resources (usually social surveys). The University has developed a small centre of expertise in this research methodology which integrates these initiatives with several other major projects in the analysis of quantitative data hosted wholly or partly at Stirling. These include the Scottish Social Survey Network (ESRC, 2007-2010); the Lancaster-Warwick-Stirling Node (ESRC, 2008-2012); two ESRC training programmes in the topic of ‘Longitudinal Data Analysis for Social Science Research’ (ESRC, 2004-2005 and 2005-2008); the Scottish Institute for Research in Economics (SFC, 2007-2012); and the Applied Quantitative Methods network (ESRC/Scottish Government, 2008-2012). The University also benefits from 9 ESRC-funded PhD studentships in the domain of quantitative methods for large scale survey research (8 in the Department of Applied Social Science and 1 in the Department of Economics), and one ESRC PostDoctoral fellowship (in the Department of Applied Social Science). The e-Science projects hosted at Stirling make a significant contribution to this productive empirical research cluster.

**Contributions to mainstream research: Responses relevant to questions posed by the e-Science Review framework**

In many institutions, including the University of Stirling, e-Science contributions to the development of new research resources are still ‘immature’: they are works in progress which have not yet been in place long enough to establish themselves as dominant resources in their fields. As recognised by the questions raised by the e-Science Review, establishing a critical mass of users, and long-term sustainability, are important challenges which have only sometimes been achieved to completion. The funding of application-driven e-Science projects, led by researchers in the relevant disciplines, raises the chances of successful research contributions emerging and being sustained. In the domain of quantitative methods applications in the social sciences, the University of Stirling represents a promising model for prospective contributions to mainstream research.

**End of response by University of Stirling**

**Response by White Rose Universities (Leeds, Sheffield and York)**

- There is little doubt that the UK e-Science Programme has had a significant impact on e-Research developments in the UK, and beyond that internationally. This large and coordinated initiative influenced the establishment of the White Rose Grid (WRG) in 2002. The WRG integrates central computational and data storage resources at the three major research Universities in Yorkshire – the University of Leeds, the University of Sheffield and the University of York. The WRG has been established and enhanced continuously through generous funding from the three Universities which recognised the importance of supporting a collaborative platform for high performance computing (HPC) research and e-Science developments. The WRG advanced multi-campus facilities underpin substantial research utilising HPC and e-Research methods, techniques and technologies. It provides a host environment for developing proof of concepts and novel technology demonstrators. Our distinct approach to building the White Rose Grid was to bring together the provision of HPC services and e-Science technologies. All WRG computational resources are divided into two pools: at each campus 20% resources are available for cross-site collaborative usage and development of e-Science technologies; whereas the remaining 80% are used to support more traditional local high performance computing research.

The unique pioneering work of the WRG was formally recognised in 2003 by the UK e-Science Core Programme through the award of the status of a UK e-Science Centre of Excellence in visualisation and distributed diagnostics, and later supported through funding of the next stages of the WRG e-Science Centre (stage II: 2006-2008 and stage III: 2008-2013).

The WRG supports intensively activities of the National Grid Service (NGS) which has been established to pioneer use of novel e-Science technologies in UK research. The University of Leeds is one of the co-funding members of the NGS and it hosts one of
the NGS nodes on the Leeds campus. Both the University of Sheffield and the University of York are NGS affiliate sites.

The e-Science Programme has enabled the development of the three generic e-Science expertise areas of our WRG e-Science Centre. These are:

i) distributed diagnostics and optimisation (e.g. the EPSRC project DAME and the DTI/EPSRC project BROADEN, and the EPSRC demonstrator HYDRA)

ii) distributed data mining for support of decision making processes (e.g. DAME, BROADEN, the EPSRC project CARMEN, ESRC projects MoSeS and GEneSIS)

iii) grid security systems and visualisation (e.g. the EPSRC/BAE project NECTISE, the EPSRC project CoLaB, EPSRC projects gViz and eViz, the DTI project ADVISE)

A spectrum of applications have benefited to a different degree from our e-Science expertise developed through the e-Science Programme. In some disciplines such as atmospheric chemistry or transport studies by working together with scientists and PhD students from these areas we have seeded the use of e-Science technologies in their research. Through collaboration with social scientists in developing e-Science tools we have influenced fruitfully research in social science. The ERSC multi-disciplinary project MoSeS used e-Science techniques to develop a national demographic model and simulation of the UK population, specified at the levels of individuals and households. We have worked effectively with arts and humanities researchers (e.g. the EPSRC and Arts & Humanities e-Science Support Centre project Virtual Vellum) who have developed a set of generic e-Science tools that may be applied to view rare manuscripts and thus to advance understanding of complex issues in their domain.

In other areas we have built strongly on our early e-Science achievements and used e-Science technologies matured through a series of our e-Science projects, most notably the DAME and BROADEN projects, to demonstrate successfully how these technologies are able to advance research. One example is the EPSRC CARMEN project, which is building a framework for neurophysiology. This project addresses a large scale neuroinformatics challenge and it will provide methods to integrate data, analysis code and expertise that will accelerate understanding of the Central Nervous System.

We have found numerous benefits to operating a multi-campus grid. This initiative has bridged the gap between researchers and operational staff as both these groups have been involved in building the WRG. The benefits include skills enhancement through sharing knowledge and experience, much increased ease of collaboration, a larger resource pool, good system back up facilities, and the flexibility to stagger usage and continuity of service.

With support from the e-Science Programme we have developed e-Science tools, complex frameworks and expertise in e-Science technologies. We are confident that many disciplines will benefit fully from e-Science technologies in the future providing that more effort and investment will be made over the next 5 to 10 years so e-Science results can be transferred to new disciplines. We need to capitalize on our achievements by applying these new transferable e-Science technologies/frameworks to new disciplines. This process will take at least another 5 years, and only then will we be able to claim that e-Science technologies have changed the way researchers are working in other applications areas. This additional period will allow not only e-Science technologies to mature but also to build trust in e-Science amongst application scientists. e-Science technologies will then become widespread and thus sustainable.

It is essential to revise mechanisms for dissemination of e-Science knowledge and community support. In particular there is a clear need for support of technical networking across current e-Science Centres and other interested groups such as that which was previously (up to 2008) provided by the UK Grid Engineering Task Force. This is no longer sustained in the same form and open to all for sharing e-Science knowledge.
One of the very important achievements of the e-Science Programme was the creation of a large multi-disciplinary collaborative community engaged in development and deployment of novel methods and tools. The Programme initiated an exciting portfolio of multi-disciplinary projects spanning many disciplines and engaging jointly computer scientists and some application researchers. It supported to some degree the transfer of knowledge from the computing domain to other domains. Support of video-conferencing facilities (Access Grid), a variety of frequent training events, seminars, presentations and a large number of meetings involving researchers from different domains enabled multi-disciplinary research. The Programme formed, facilitated, stimulated and inspired the multi-disciplinary user community.

The e-Science Programme has opened a new avenue for collaboration within the White Rose Universities. Application scientists, e.g. from the Department of Automatic Control and Systems Engineering in Sheffield, computer officers and computer scientists worked jointly to establish the White Rose Grid. Many complexities have had to be overcome in order to successfully complete a very large procurement process, establish WRG facilities, deploy and operate grid services, as well as to firmly establish and support a considerable White Rose e-Science community. Over the last 8 years a vast and unique experience has been built up in e-Science technologies. Importantly, the Programme has enabled White Rose computer specialists to work together with groups of application scientists on joint multi-disciplinary projects.

The e-Science education/training programme had been an essential means in ensuring good uptake of e-Science technologies. It has informed the community about rapid technological changes and the current best practice in using complicated and often not reliable middleware and other software and tools. This active and comprehensive programme assisted researchers with dissemination of the outcomes of their research and promoted the developed tools and techniques. It has helped researchers to overcome many challenges of new technologies. These problems were often due to the innovative nature of e-Science, and slowly maturing software, which required continuous updates of documentation and training materials. To ensure that new researchers gain full confidence in using new e-Science technologies it is essential to continue the training programme.

The White Rose Grid training team has organised a number of promotional and training events ranging from regional conferences with business partners (each time with over 140 participants), through regular e-Science workshops, seminars, and meetings to regular presentations and training courses for the White Rose user community and their collaborators. For example, the team provided courses as part of the ADVICT (Advanced Information and Computer Technology) project funded by the Learning and Skills Council (North Yorkshire) to the bio-Science community, Grid Special Interest Group of Digital South Yorkshire and Information Studies Instructors from Sheffield Hallam University.

To overcome barriers to the use of e-Science tools access to all e-Science resources and services need to be simplified. Many users require easy to use and instinctive interfaces to all resources and services which need to have the capability for seamless integration across regional, national and international boundaries. For example digital certificates commonly used for access to e-Science resources, e.g. on the NGS, are perceived by many users as too difficult to use and manage and because of this some users are reluctant to use the national e-Science infrastructure. The introduction of a Shibboleth technological solution, which enables users to authenticate transparently using local mechanisms, might address this issue.

End of response by
White Rose Universities (Leeds, Sheffield and York) (return to ‘A’ response list)

Response by University of Reading

- The e-Science programme has achieved its objectives to a good degree. It has created an important body of knowledge across the academic sector in the area of the application of technology to research by successfully bringing together computer science
groups with other research groups. As a result, there are now many projects that have benefited specific communities as well as many good generic services. Projects like Silchester/VERA project in Reading, have enabled new ways of working through developing technological solutions.

There are projects which have benefited certain communities and there are good generic services (e.g. NGS and the local Campus Grid/HPC), but for many there is a gap between the two - the projects do not fit their way of working and the services are too generic to be useful without specific individual support. There is expertise within the remaining e-Science centres and in Computer Science departments, but often there is not the funding to provide adequate support to enable researchers new to e-research methods to use the locally or nationally provided resources.

Although the programme succeeded in bringing together computer science groups with other research groups, the collaboration between the two groups led sometimes to misunderstandings: scientists often looked to computer scientists to perform the jobs of software engineers and develop robust tools to order; conversely, computer scientists often – quite reasonably - wished to focus on the latest techniques as part of their own research agenda. The “software engineering gap” continues to be a problem in research computing – who will engineer and maintain the necessary tools? This is an expensive task, and engineering work can be seen as taking money away from research.

Within Reading, the expertise built up through the programme combined with the interaction with the US and the resulting benefits from these two have influenced the University’s strategies for e-Research. Knowledge gained through the Reading e-Science Centre, the NGS and the Oxford e-Research Centre has been instrumental in the development of our Campus Grid. The Programme has also helped to identify Computational Science as strategic research theme across the University. E-Research South is playing a central role in raising awareness of e-Research, building communities around it and promoting e-research.

**End of response by University of Reading**

**Response by Imperial College London (1)**

- Definitely yes, but the outcome is more sophisticated that just the building of single platforms for an application. New collaborations were established and new directions for research established. And the results have also had impact in fields wider than academic science research – e.g. commercial and public internet and mobile applications.

  The mode of working, mandatory collaboration between applied and computing groups, fostered a way of working that persists to this day and has been invaluable.

  There are many instances of projects building platforms that have been incorporated into mainstream research. From our own experience, we would cite Discovery Net (PI: Professor Guo) that had practical use in predicting the mutation patterns of the SARS Virus and is now in commercial use via the Inforsense’s Advanced Analytics platforms.

  The e-Protein bioinformatics project exploited a light-weight and flexible approach to link disparate bioinformatics databases at different locations. The integrated approach has continued via the EU BioSapiens project (12M Euro) whilst the component databases and programs are a major resource for the international community with over 1M web hits / month (CATH/3D-GENE) and a paper (3D-GENOMICS) with over 1,000 citations. The collaborative BBSRC Microarray Management project produced an integrated workbench for the organisation and analysis of MicroArray data and experiments that is in practical use today, supported by the Imperial College Bioinformatics Support Service. Work on combining probability with logic-based machine learning developed an approach which is central to the drug discovery strategy of an Imperial spin-out Equinox Pharma.
Through projects such as MESSAGE (PI: Professor Polak), the programme produced real world demonstration of how e-Science concepts can be used to support research into important scientific and practical problems (such as traffic and urban air pollution) through the creation of an architecture and platform for real-time data collection from heterogeneous and mobile sensor devices. The MESSAGE architecture can be used for a much wider range of research problems where collection and management of data is a major challenge.

The MRC Votes project fostered an on-going collaboration with Professor Azeem Majeed of the Department of Primary Care and Social Medicine at Imperial College that led to the development of information and data analysis platforms for PCTs and practicing GPs. This development work is continuing in the NW London NHS CLARCH and EU projects.

Our OMII GridSAM project built a Grid Job Submission and Monitoring Web Service that is now in practical, everyday, use beyond the initial e-Science community. For example the UCL Theoretical Chemistry group led by Professor Price uses GridSAM to provide the web service job execution interface to run the extensive polymorph simulations that are needed to understand the different possible crystal structures that a complex molecule can adopt.

The NERC GENIE project built a platform that enabled several instances of a new modular Earth System Model, at different levels of process complexity and spatial resolution and supported extensive exploration of the parameter space of a 3D ESM.

It is also clear that NGS is providing a platform that supports mainstream computational science and that the LHC Grid will provide a working infrastructure when experiments commence at CERN.

End of response by Imperial College London

Response by Imperial College London (2)

- Definitely yes, but the outcome is a little more sophisticated that just the building of single Platform and the results have also had impact in fields wider than academic science research – e.g. commercial and public internet and mobile applications.

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It is also clear that NGS is providing a platform that supports mainstream computational science and that the LHC Grid will provide a working infrastructure when experiments commence at CERN.

End of response by 
Professor John Darlington, Imperial College London  (return to ‘A’ response list)

Response by King’s College London

- KCL has found that one of the key strengths of the e-Science programme is its ability to stimulate research activity beyond the formal boundaries of its funding. The Arts and Humanities e-Science Initiative (http://www.ahrcict.rdg.ac.uk/activities/e-science/) is a perfect example of this. Partly through its stewardship of the AHeSSC (run by Drs. Stuart Dunn and Tobias Blanke, under the auspices of CeRch, which is directed by Sheila Anderson), and through promoting and supporting cross-departmental dialogue and collaboration, KCL has an established programme of research fundamentally related to esicence, developing research programmes which use e-science tools and methods to respond to research questions in new areas, rather than (necessarily) focusing on developing large-scale computational e-science infrastructure. This is highlighted in particular by the institutional place e-science has achieved within in the Digital Humanities. AHeSSC has a close collaborative relationship with the Centre for Computing in the Humanities (http://www.kcl.ac.uk/cch). This relationship, based on contributions of equal value between technical researchers and domain experts has allowed KCL to embed e-science within the digital humanities, which is reflected in AHeSSC’s publication list (http://ahessc.ac.uk/publications).

One example of institutional development to which e-science has contributed in a key way is the development of the College’s Anatomy Theatre and Museum as a research and innovation space. This venue was long disused, but KCL, has recently invested heavily in renovating it and fitting it with state of the art research and performance technologies. These include two Access Grid venues, theatrical spotlights, recording equipment, and interactive smart boards; and funding is currently being sought to expand the facilities available. In collaboration with the Department of English Studies, CeRch (respectively Alan Read and Sheila Anderson) is developing an ambitious interdisciplinary programme of teaching, research and networking activities in areas including performance, intangible cultural heritage and innovative research practice. This will complement and develop the arts and humanities e-science research programme established at KCL by AHeSSC in the last three years. An outline proposal to the AHRC/EPSRC Science and Heritage programme for an interdisciplinary research project to use the space to create and curate a digital exhibition of Roman inscriptions was successful, and we are awaiting a decision on the full proposal (due February 2010).

A number of other networking activities have been undertaken at KCL which have provided opportunities for collaboration. For example, the Service-Oriented Software Research Network (SOSoRNet) began in December 2005 as an EPSRC-funded network project (EP/D036852/1), was run by Dr Nicolas Gold. The funded period finishing in November 2008. SOSoRNet grew from the Pennine Group’s Research Forum series. The network organised workshops and supported the organisation of other events relating to the development and application of service-oriented software, with the aim of sharing problems and solutions across domains and communities. This type of software is of vital importance to e-science and grid computing applications. The network has a membership of around 200. 15 workshops were held on a diverse range of topics [e.g. service-oriented computing in the humanities [see http://www.ekl.oulu.fi/dh2008/SOCH3_Oulu.pdf], semantic web, geospatial computing, testing, dependable systems, and formal methods] successfully bringing together communities involved in this work (software engineering, arts and humanities, grid computing, e-science, web services, business, services science). The interaction
between these communities has led to new collaborations, publications and project proposals.

Another example is the Digital Repositories in e-Science Network (DReSNet), run by Drs. Tobias Blanke and Mark Hedges. DReSNet is unique in its kind in the world and has (though relatively young) already developed a wide range of international contacts. It addresses the potential synergy between the fields of e-science and Digital Repositories, and the benefits of interaction and cooperation between these fields. DReSNet encourages participation from all fields. Ideas and experience can be shared in our blogs and forums. The Network also runs a programme of network activities including workshops and working groups, and has members from a range of UK and international higher education institutions, and is open to academic and non-academic institutions. The importance of this area was recognised by the keynote speech given by Tony Hey at the Open Repositories 2007 conference, where he called for an integration of repositories into the new scholarly life cycle envisioned in e-Research: via DReSNet, KCL is seeking to realize this aspiration.

As well as the SoSORNex project (see above) KCL's Computer Science department has significant e-science related interests. For example, Dr Simon Miles' research determining the provenance of scientific data was started in myGrid (EPSRC GR/R67743/01) and Provenance-Aware Service-Oriented Architectures (EPSRC EP/C528131/1) and led to activities such as:

- Working with an international community of e-science researchers to develop the Open Provenance Model, an effort towards standardisation of provenance representation.
- As part of the above, participating in the third Provenance Challenge, where teams of researchers demonstrated the use of OPM in e-science platforms, culminating in a workshop in Amsterdam in June 2009.
- Further development and dissemination of the results of the PASOA project was made through high quality journals including Computing in Science and Engineering, ACM Transactions on Software Engineering and Methodologies, ACM Transactions on Internet Technology, Communications of the ACM and the Journal of Grid Computing.

KCL's Department of Management (Drs Jon Hindmarsh and Paul Luff; Prof. Christian Heath) has developed significant interests in the area of e-Social Science. This includes the MixedMediaGrid (MiMeG), a collaboration with the University of Bristol which used e-science tools to support inter-institutional annotation of video media in social science research. This is important for the purposes of understanding analytic practices (also of great importance to the humanities), developing distributed infrastructure to support such collaboration, and building capacity across the social sciences. This was based on the VidGrid project undertaken by the same research group, which sought to leverage the potential of e-science and grid technologies in use of video media across distributed networks.

KCL has a major role in health e-science in support of Primary Care clinical research, following the move of Prof Brendan Delaney and his research team from Birmingham in the summer of 2009. The electronic Primary Care Research Network (ePCRN) was proposed, but not funded by the MRC e-Science programme 2nd call. However, during the preparation of this proposal we became aware of a similar commissioned project call in the USA, pilot projects for the National Institutes of Health 'Roadmap' for Clinical Research. A $3M project was jointly funded with the University of Minnesota and The University of California San Francisco. ePCRN has also received funding via the NIHR National School for Primary Care Research. ePCRN consists of two principal components; a distributed search system, based on a vocabulary service and OGSA-DAI/Globus Toolkit 4 that enables identification of potential trial subjects from general practice electronic health records; and a meta-data based clinical trial data management system. As of 2009 ePCRN has established an open source consortium, led jointly by Minnesota and KCL, with the role of maintaining, developing and promoting the use of ePCRN. ePCRN is being piloted in to Birmingham and London during early 2010. In addition, we are working with the MHRA General Practice
Information for the Panel

Research Database to develop ‘real time’ identification of subjects as they consult their GP, and with the Avon Longitudinal Study of Parents and Children to track a consented cohort throughout life (Wellcome Trust funded). Finally, we are leading a recently funded €7M FP7 integrated project, “Translational Medicine and Patient Safety in Europe: TRANSFoRm”. TRANSFoRm will extend ePCRN across Europe, build generic interfaces for proprietary health record systems and enable data integration between primary care clinical data and genomic data.

Another key example is the South London and Maudsley NHS Foundation Trust/KCL Biomedical Research Centre Case Register, run by Prof Robert Stewart. This is funded through NIHR, with the aim of extracting anonymised datasets for analysis from the SLAM NHS Foundation Trust electronic medical records system. This provides a ‘new generation’ approach, which enables medical researchers to use case records, while safeguarding the data’s security and patient confidentiality. This project has only been running for about a year so there are currently no outputs, a position paper is available at http://www.biomedcentral.com/1471-244X/9/51.

The Centre for Bioinformatics at KCL (Prof Christos Ouzounis et. al.) is an example of synergy between two different schools (Physical Sciences & Engineering and Biomedical & Health Sciences) and disciplines (computational science and biomedical research). The Centre, established in 2007, has been actively involved in the coordination of research in the area of computational biology and biomedicine, the provision of a focal point for research and training in bioinformatics, the deployment of resources in terms of hardware, software and databases to support biomedical research as well as the establishment of PhD and MSc programmes. The Centre for Bioinformatics links the physical sciences (including physics, mathematics, computer science and engineering) with biomedical research, and has been involved in College-wide activities such as the Biomedical Research Centres at KCL (funded by the NIHR), the Faculty of Translational Medicine and the Systems Biomedicine Graduate Programme, among others. It has also hosted the London Bioinformatics Forum meeting and has played a key role in hosting a series of seminars. The Centre has been funded by the EPSRC, the BBSRC, the Leverhulme Trust, the British Kidney Foundation, the British Heart Foundation, the (United States) National Institutes of Health and is a member of two Synthetic Biology Networks, funded by the BBSRC.

End of response by King’s College London (return to ‘A’ response list)

Response by Natural History Museum, London

- Compared with many areas of e-Science research, in biodiversity informatics adoption of e-Science technology and approaches has been slow, both in the UK and internationally. However, a marked acceleration in developments has occurred over the past few years and the rate of adoption of software, systems and workflows has been remarkable. There are strong signs that the biodiversity informatics community has come of age as it emerges from an experimental and individual project-based phase to the construction of common platforms built through collaboration (e.g. the Cyberplatform in the European Distributed Institute of Taxonomy (which includes tools for doing taxonomy), the Encyclopaedia of Life (a platform for producing species Web-pages), Wikispecies (species pages) and the Global Biodiversity Information Facility (a portal to digital information on species names and biological specimens from around the world)). But the shortage of intelligent digitisation of the taxonomic resource is a major constraint.

Although the UK e-Science Programme did not build a Platform specifically for biodiversity systematics, it allowed (e.g. through the CATE project) material contributions to the development of international platforms. There is, however, a need for the UK to play a greater role in these advances and show leadership if we are to continue to help shape developments in what are largely US- and EU-led initiatives.

The UK has enormous potential to realise this leadership. It has traditional strengths in taxonomy (which translates to information about species and the capacity to provide means of species identification) through its skill base and its important international
biological collections housed in major museums and herbariums. There is a decided risk that if the moment is not grasped, the critical mass of capability in the UK will not mature and neither will capacity be sustained – at least in a coordinated way.

Unquestionably much information on species has been posted online and this trend will continue at an ever increasing rate. Yet the value, both to research and wider societal issues relating to biodiversity will be compromised if data quality is not maintained and should stable e-platforms not be created and sustained. The UK’s strengths, together with the importance of e-Science and the need for a roadmap for the delivery of Internet-based taxonomy, were recognised in the House of Lords report on Systematics and Taxonomy (2008).

Biodiversity informatics was born of the combination of computational techniques and taxonomy, and the e-Science Programme has played a valuable part in developing the synergy that has been emerging internationally. There is potential, by no means fully realised, for introducing specimen-level data (including observational data from biological recording) into certain modelling initiatives (particularly on climate change) that were supported by the e-Science Programme. Although collections of biological specimens are not an unbiased sample of biodiversity through time and space, they offer nearly all the information we possess on a wide variety of species over decades and across the globe. As important is the opportunity that Web-based taxonomy offers for new specimen and species data to be collected, especially in groups of organisms that are amenable to input from citizen scientists.

The requirement for high quality information on species (including biological specimens) has never been greater given the threat to biodiversity globally. But so is the need for access to that information, regular updating, and the rendering of data in a form that is tractable to a diversity of readers (i.e. knowledge exchange). Establishing user-friendly platforms for e-biodiversity/taxonomy remains a considerable challenge in the UK and internationally if information flows are to grow.

End of response by Natural History Museum, London (return to ‘A’ response list)

Response by Rutherford Appleton Laboratory (RAL), STFC

- The e-Science programme facilitated significant developments in a number of areas directly relevant to the CCLRC/STFC facilities and programmes. These include:

  - creation of integrated electronic proposal submission and user management systems for ISIS and DLS

  - pathfinder developments in large volume data analysis tools on ISIS (TobyFit, the de facto standard for single crystal spectroscopy), leading to development of an integrated analysis software suite (MANTID) for the ISIS second target station.

  - Development and operation of an institutional repository (ePubs) for papers published by STFC staff or using STFC facilities

  - creation of the ISIS data archive containing all data collected at ISIS and development of a generic catalog system (ICAT) adopted by ISIS and DLS. Integration of data cataloging and archival into routing beamline operations in both ISIS and DLS.

  - First phase data management infrastructure for the Central Laser Facility

  - Operational UK grid supporting the UK particle physics community, integrating all UK particle physics groups and fully integrated into the LHC activities

  - Initial investments in the LHC grid by the UK, in particular staff funded at CERN, were vital to getting the LHC grid programme started.

  - Investments directly in the computing developments of the individual LHC experiments has given the UK community key positions and influence in these developments, thereby readying UK physicists to fully exploit the data from each of the experiments.
- Data storage services for BBSRC, NERC and AHRC.

- The Grid Support Centre and Grid Operations Support Centre were led by CCLRC/STFC which underpinned developments into the National Grid Service, which now provides a platform for collaborative research of benefit to potentially all HEIs and facilities such as those operated by STFC. The NGS is a platform that is supporting collaborative research across all domains.

_End of response by Rutherford Appleton Laboratory (RAL), STFC (return to ‘A’ response list)_

**Response by Anatomical Society of Great Britain & Northern Ireland**

- In bioinformatics, the e-science programme has generally funded projects based within the standard, traditional molecular paradigms. The programme has enabled some useful tool-making and the curation and annotation of databases: many of these projects have resulted from broad collaborations. The new facilities coming on line will certainly facilitate the informatics work of experimentalists.

The programme has two major weaknesses, one general and the second of particular relevance for anatomists:

1: No coherent body of work has been produced because the funded projects have little to do with one another.

2: The needs of systems biology, the major intellectual initiative at the moment, have been ignored.

The e-Science programme has therefore been of little importance or use to anatomists and systems biologists. Interestingly, the mouse community is in the process of agreeing to share data on mouse models via the Rome initiative, and this is something that the ASGBI strongly supports (see [http://network.nature.com/groups/naturenewsandopinion/forum/topics/5434](http://network.nature.com/groups/naturenewsandopinion/forum/topics/5434)).

_End of response by Jonathan Bard, Anatomical Society of Great Britain & Northern Ireland (return to ‘A’ response list)_

**Response by Diamond Light Source**

- The e-HTPX project had the aim of developing e-science resources which could be transferred to the Diamond Light Source. The transfer has taken place. Further development and maintenance was required. Fortunately Diamond has been able to devote resources to do this.

Other developments were transferred to the BBSRC PIMS project ensuring additional sustainability.

In some cases the transfer of developments to other projects included transfer of the developers themselves.

_End of response by Dr Colin Nave, Diamond Light Source (return to ‘A’ response list)_

**Response by Isaac Newton Institute for Mathematical Sciences**

- I think that the Programme was very influential:

  - in stimulating awareness of the issues;
  - in the nature of the tools needed and their development;
  - in creating a community across a wide range of disciplines active in the development of the new paradigm;
  - in building a strong international reputation for the UK in this area.
I presume that the review will have access to the wealth of reports that were prepared at various points of the programme, both for the core programme and for the various Research Councils.

One personal reflection: One of the best indicators that I felt was the success of the annual ‘All hands’ meeting; very good participation, and excellent feel. I was very concerned about whether it was yet into self-sustaining mode when the Programme and Steering Committee formally ended, but reassured to see it continue in a very impressive way, at least for the first years that I was able to keep in touch with it.

**End of response by Sir David Wallace, Director, Isaac Newton Institute for Mathematical Sciences, Cambridge**

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**Response by Linnean Society of London**

- We are not aware that the UK e-Science Programme built a Platform specifically for biodiversity informatics, but rather contributed to platform development in international projects. While this is not a limitation as such, the UK could and should take a greater leadership role given its traditional strengths in taxonomy and species recording.

International platforms for online biodiversity are being developed, but the adoption of e-science technology and systems have been rather slow; within the past few years the rate of progress has increased considerably. Notable among developments is the ‘Encyclopedia of Life’ ([www.eol.org](http://www.eol.org)), which provides a platform for delivering online pages on species. The ‘Global Biodiversity Information Facility’ provides Web-access to an increasing quantity of species names and specimen-level data. An e-platform has been evolving through several EU-funded initiatives, e.g. ENHSIN, BioCASE and now EDIT, the ‘European Distributed Institute of Taxonomy’, [http://www.etaxonomy.eu](http://www.etaxonomy.eu). The EDIT cyberplatform is providing tools for undertaking taxonomy, one of which has been derived from the CATE project (‘Creating a Taxonomic Esicience’ [www.cate-project.org](http://www.cate-project.org)), which was supported by NERC and the RCUK e-Science Programme. The ‘Scratchpad’ project, which is complementary to the cyberplatform, provides a means for communities of researchers to manage, share and publish taxonomic data online.

Of special note is the comparatively small amount of biodiversity data already digitised. The magnitude of the task is such that complete digitisation of specimens in the UK alone is a massive task, let alone those elsewhere. Mobilisation of the community is required to achieve the digital content needed to form an effective research infrastructure, but a metadata approach will be needed to create broad coverage given the large number of specimens and labour intensive process of digitisation. Yet biological collections hold the most comprehensive sample of distributional data of species nationally and globally, and also the best record in time. There is potential, therefore, for using such data in modelling projects, for example in assessing the effect of climate change on the distribution of biodiversity, but a greater level of digitisation is essential.

The UK has traditionally had great strength in taxonomy, both in terms of skills and resources – particularly biological collections, which are research and reference holdings of international importance. The Linnean Society has played an important role in encouraging the study of biodiversity, e.g. through publications, symposia and workshops, and by awarding small grants. With the enthusiasm for moving taxonomy/natural history information online, the UK has a significant role to play in developing suitable platforms, even if this input is to international initiatives. The critical mass of UK capability in biodiversity informatics needs further and more coordinated support for capitalising on existing skills. The House of Lords report on Systematics and Taxonomy (2008) recommended the need for a plan for Internet taxonomy.

The move to a truly Internet-based taxonomy will democratise biodiversity information, rendering it accessible to a large range of users. It is difficult to see how this important source of knowledge can flow more widely without it being released on an e-platform.
The main impediments to knowledge exchange are digitisation and a stable and universally accepted e-platform.

End of response by Dr Ruth Temple, Executive Secretary, Linnean Society of London (return to ‘A’ response list)

Response by The UK Computing Research Committee (UKCRC)

- We believe that the application of Computer Science (CS) to the normal and now improved research practices of the other scientific disciplines (including medicine, engineering and sociology) has been as dramatically significant as the impact of CS on all other aspects of life of our society and of its members. Without the e-science programme, this development would surely have been delayed in UK.

The programme has certainly contributed widely to inter-disciplinary research between CS and other scientific disciplines. It has provided a model of collaborative tool construction and application which could well be adopted by researchers in the many other branches of CS. The UKCRC has been promoting such intra-disciplinary collaboration, as necessary to meet some of the basic scientific Grand Challenges of our subject, in particular the connection between computing theory and practice. Some of these challenges could well benefit from adopting and adapting the tools, infrastructure and practices pioneered by other scientific disciplines in the eScience Programme.

End of response by Professor Muffy Calder, Chair, UKCRC (return to ‘A’ response list)

Response by Professor Dame Ann Dowling, Chair, Engineering Panel in RAE 2008

- In our view this has been disappointing to date.

Although the research submitted by institutions to the Research Assessment Exercise showed a relatively high proportion of computational research (as much as for 30% in some Engineering Units of Assessment), there was little evidence that those undertaking this research depended on or worked in collaboration with e-Science groups. The e-Science groups appear to have had little impact in engineering outside their own immediate circle.

End of response by Professor Dame Ann Dowling, Chair, Engineering Panel in RAE 2008 (return to ‘A’ response list)
B. How does UK e-Science activity compare globally?

The following key points were highlighted:

- All responses agreed that the UK e-Science programme was a world leader in the development of e-Science and still plays a leading role in the international e-Science community and is a major driver in international projects. The worldwide development of e-Science has grown momentum, which was felt to be as a result of the RCUK programme (University of Edinburgh).

- The UK e-Science programme was perceived internationally as the model to which set the standards that all nations aspired to follow, many countries have copied the UK initiative and it is thought that some are now pulling ahead due to large and sustained investments (US, Scandinavia and Japan).

- The UK has taken a broad view and has focused on data-driven science and the services to support it rather than on large computations and distributed super-computing. This was deemed as important as it meant that the UK expertise and infrastructure addressed a wider range of scientific activities. The UK has developed production computational platforms and set the standards for the development of Grid computing. The UK can justifiably be said to have pioneered the application of semantic technologies and ontologies to e-Science and e-Infrastructures. Mechanisms and standards for data access over Grids were led by the UK. The UK’s scientific workflow research has been technically influential and the emerging software adopted by scientists world-wide.

- Furthermore, the UK has directed much of its research efforts to data management, knowledge management, and service management, addressing key challenges in data integration, service interoperation, workflow, semantic metadata, provenance and secure, scalable data access. These challenges are now recognised as fundamental by the EU’s European Strategy Forum on Research Infrastructures programmes and the NSF’s CyberInfrastructure programme.

- The e-Science programme made way for good partner collaboration with high credibility to various US, EU projects. The UK has played a leading role in the collaboration between these partners in such projects, which has helped to exchange their e-Science expertise and add to the global e-Science achievements. Examples are described in University of Edinburgh, University of Manchester and the White Rose Universities responses, also highlighting the WRG (White Rose Grid) e-Science Centre collaboration with Beihang University in China.

- The UK programme held many International standing conferences such as the OGF (Open Grid Forum) Events and the e-Science annual All Hands Meeting, both attracting many international delegates. The NCeSS (National Centre e-Social Science) Hub-led International Conferences on e-Social Science have been widely recognised as setting the agenda for international efforts. The Arts and Humanities e-Science initiative have been keynotes in conferences around the world including the International Symposium on Grid computing in Taiwan (biggest Asian Grid conference). The KCL researchers were invited to organise a workshop in Australia to kick off an Australian humanities e-Science programme.

- The UK e-Science programme was successful in drawing prominent research leaders, both in and out of Computer Sciences into the programme. It is felt that attracting and engaging good researchers into e-Science and other multi-disciplinary research is not seen as a problem in the UK. There are some concerns expressed (Newcastle and Southampton) that multidisciplinary research, that produces outputs such as data software is sometimes regarded as a less scholarly pursuit than basic research and does not fit well within the single-discipline orientated structure of Universities and RAE.

- Many of the projects and centres have international members on their advisory boards and many members of the UK projects are representatives on international boards and review panels allowing contributions to the global e-Science developments (as highlighted in the responses from Southampton and White Rose Universities).
Follow the links below to view the responses

Visiting Panel:
- Aberystwyth University (no response against individual framework questions)
- Liverpool John Moores University
- Newcastle University
- Rothamsted Research
- University of Aberdeen
- University of Bristol (no response against individual framework questions)
- University of Cambridge
- University of Edinburgh
- University of Glasgow
- University of Manchester (The) (2 submissions)
- University of Nottingham (no response against individual framework questions)
- University of Oxford (2 submissions)
- University of Southampton
- University of Stirling
- Wellcome Trust Sanger Institute (no response against individual framework questions)
- White Rose Universities (Leeds, Sheffield and York)

Panel Visits:
- University of Reading
- Proudman Oceanographic Laboratory (no response against individual framework questions)

- Imperial College London (2 submissions)
- King’s College London
- Natural History Museum, London
- University College London (no response against individual framework questions)

- Rutherford Appleton Laboratory (RAL), STFC (a combined submission from all the projects being reviewed during the visit to RAL)

Others:
- Anatomical Society of Great Britain & Northern Ireland
- Diamond Light Source
- Institute of Physics (IoP) (no response against individual framework questions – please see Section F - Other Comments below)
- Isaac Newton Institute for Mathematical Sciences, Cambridge
- Linnean Society of London
- The UK Computing Research Committee (UKCRC)
- Professor Dame Ann Dowling, Chair, Engineering Panel in RAE 2008
- Professor Nigel Hitchin, Panel Chair of last RAE exercise (no response against individual framework questions – please see Section F - Other Comments below)
Response by Liverpool John Moores University

- Within my field we have been good partners with high credibility to the various US and European projects we collaborate with, evidenced by the adoption of proposed standards by international bodies.

End of response by Liverpool John Moores University (return to ‘B’ response list)

Response by Newcastle University

- The UK developed its own distinctive direction early into the programme. Unlike many other countries, the UK focus has been more on data-driven science and the services to support it, rather than on large computations and distributed super-computing. This was important as it meant that UK expertise and infrastructure addressed a wider range of scientific activities. Consequently, whilst in the early days the UK largely adopted US middleware (Globus, Condor, SRB), over time it began to develop its own complementary infrastructure such as OGSA-DAI, OGSA-DQP and Taverna, which now have wide international usage.

As well as finding its own niche, the UK programme was successful in drawing prominent research leaders, within and without of Computer Science, into the programme. Their energy, commitment and research outputs, harnessed by those running the programme, meant that the UK was able to influence e-Science internationally through bodies such as the GGF (later the OGF).

Attracting and engaging good researchers into e-Science and other multi-disciplinary research does not seem to be a problem in the UK, but there are some problems with recruitment and assessment as multi-disciplinary research does not fit well within the single-discipline oriented structures of Universities and the RAE. The leadership of Newcastle’s Computing Science School has however seen the benefits of multi-disciplinary research, and most recent academic appointments have been of bio- and neuro-informaticians; we now have thriving groups in those areas that are well integrated into the rest of the School: each of the School’s research groups has been engaged in funded e-Science research projects.

End of response by Newcastle University (return to ‘B’ response list)

Response by Rothamsted Research

- I am not able to provide a response to this question.

End of response by Rothamsted Research (return to ‘B’ response list)

Response by University of Aberdeen

- The UK does have some acknowledged strengths in e-Science technologies; these would include: semantics/linked-data and virtual research environments.

We found that high quality non-UK applicants applied for all e-Science studentships and posts advertised at Aberdeen. However, it is difficult to say whether this was due to the international stature and visibility of the UK e-Science programme – or if it was a consequence of the specific research topics advertised.

End of response by University of Aberdeen (return to ‘B’ response list)

Response by University of Cambridge

- At one stage the UK eScience programme was perceived internationally as the model to which all other nations would aspire. While the US was focussed on linking together HPC centres, we were innovating in data management, middleware, user interfaces and producing genuine new science. It’s now not clear to me how we are perceived.
internationally. The co-location of the 2009 All Hands meeting and IEE eScience conference should be a good opportunity to find out.

End of response by University of Cambridge (return to ‘B’ response list)

Response by University of Edinburgh

- The worldwide development of e-Science has growing momentum. This was triggered by the RCUK programme. Many countries’ programmes have started by copying the UK initiative and some are now pulling ahead (US, Scandinavia, Japan).

Our research engaged with internationally leading science in astronomy, particle physics, data integration, psychiatry, and materials (see A above).

The UK plays a leading role in collaboration between astronomical virtual observatories, in distributed heterogeneous data access and integration, (OGSA-DAI); computational steering, and psychiatry (see A above); in applying optical networking to science (ESLEA); in workflows (Taverna, Triana and Infosense); in digital curation and formal understanding of data provenance (DCC); in formal specification of resources required by user-defined functions (ReQueST). The UK is relatively weak at integrating the HPC and distributed high-throughput computing communities. It is not yet engaged sufficiently in exploring data-intensive science. The UK has very strong computer science and computational science communities and would benefit from building on the closer collaboration between them which started under the e-Science Programme.

The UK led the world in e-Science, but in critical areas has been overtaken by large and sustained investment in the US, Japan and elsewhere in Europe. The UK’s shift in focus away from cyberinfrastructure and its exploitation, and, in particular, the absence of a coordinating framework, risks snatching defeat from the jaws of victory!

End of response by University of Edinburgh (return to ‘B’ response list)

Response by University of Glasgow

- How developed is the global e-Science Platform, and what has been UK e-Science Programme contribution?

  - There are a variety of international HPC-oriented e-Science platforms including efforts such as TeraGrid; NAREGI; EGEE; NGS; ScotGrid etc. These are at different levels of maturity. I would argue that none of these are yet fully mature. The use of such resources is targeted still to HPC savvy communities. Challenges of security; managing data and meta-data from large scale simulations continue to be done in a variety of ad hoc ways.

  - The UK has and continues to play a leading role in the international community on all aspects of e-Science. This has including driving major international projects like LHC; major research projects like nanoCMOS, and development of international standards for Grid computing.

To what extent did the research undertaken through the Programme engage in “best with best” science-driven international interactions?

  - It attempted to achieve this, but as mentioned a major issue has been the overall fluidity of both the technologies/middleware, and the science and nature of research itself.

In which areas of e-Science is the UK the international leader? What has contributed to UK strengths and what are the recommendations for continued strength? In which areas is the UK less strong and what are the recommendations for improvement?
• At Glasgow there are particular strengths in the life sciences (both clinical and biological); nano-technology/electronics domain. The e-Science focus at NeSC Glasgow has also targeted these communities.

• We believe that the work at NeSC in Glasgow in the area of security is internationally leading. The NeSC at Glasgow has been involved in a portfolio of projects worth over £29m, worth over £8.5m to Glasgow and over £3.5m to NeSC. These figures are (we hope!) based upon recognition of the expertise in e-Science and the repeated successful delivery of e-Infrastructures that meet researcher needs.

Are there sufficient numbers of research leaders of international stature evident in the UK, in comparison to other countries? If not, which areas have potential for growth?

• There is no simple answer here. Each domain could argue that they are under resourced or adequately resourced in terms of international research leaders.

• There are always areas of potential growth whether it is in HPC expertise; software/middleware development; security; large scale data management challenges; biomedical research areas; clinical sciences; geospatial systems; etc.

• The area of e-Health is one where major opportunities continue to exist, e.g. targeted drug development based on genome wide association studies.

How does the UK compare internationally with its ability to attract, nurture and support e-Science researchers at every stage of their career?

• From experience at NeSC Glasgow the following can be stated. Every researcher that has worked at NeSC has been offered a continued position at NeSC, i.e. it has never been the case that researchers have had to leave NeSC due to insufficient funding existing for their position. Obviously staff occasionally leave due better paid positions elsewhere or for other reasons. I understand that other centres in the UK have not been as fortunate however.

• The staff themselves come from a variety of places including overseas (China, Pakistan) and the UK.

In the past eight years how has the UK’s global reputation for e Science research changed?

• The UK is internationally recognised for its e-Science Programme and remains at the forefront of e-Science research. However, the bigger question is how many of the scientific/research communities that e-Science supports have improved on the international stage during the time period of the e-Science Programme. I am not sure how the global reputation of research in the UK has changed in the last 8-years (or indeed comparing e-Science enabled researchers against non-e-Science enabled research). I am hoping that this review will advise on this.

• I can state that the university has improved considerably according to world rankings during the time period of the Core Programme – it is now ranked at 73 in the world according to (http://www.timesonline.co.uk).

End of response by University of Glasgow

Response by The University of Manchester (1)

• The most significant contribution has been the global adoption of the UK model of e-Science, essentially a user-focussed programme with a very wide portfolio of multidisciplinary projects supported by a much smaller core. This model, grounded on a national Grid infrastructure with support for a range of applications running on local, national and global resources, has avoided the trap of being entirely consumer driven. Programmes throughout Europe, SE Asia and Australia have been influenced by this model.
The UK pioneered the concept that e-Science research could build on software used routinely in academic and commercial applications rather than relying on special purpose “Grid middleware”, Taverna being a prime example. Another is the development of tools to hide the complexity of the Grid from the user. The Application Hosting Environment pioneered in RealityGrid, and further developed via funding from OMII-UK, is used to provide a uniform interface to Grids with different middleware. This pragmatic approach encouraged good software practice such as agile software engineering and the development of sophisticated methods of identifying user needs (supported through the e-Science Usability research programme and the ENGAGE project funded by JISC). This focus also encouraged the ingestion of software used in social collaboration (Web 2.0) as evidenced in the myExperiment project for social sharing of workflows. The UK Programme also embraced major initiatives such as the development of the Semantic Web and an understanding of the key role of metadata in e-Science. Usability and re-use became prime drivers in e-Science software development, in contrast to the almost exclusive early focus on raw computational power, this being only applicable to a relatively narrow range of users. This emphasis on users within the core e-Science Programme has been reinforced by the JISC-funded Virtual Research Environment and e-Infrastructure research programmes which have addressed a range of often complex non-technical issues shaping (and sometimes inhibiting) the wider use and adoption of e-Science methods and tools.

Thus, the UK Programme demonstrated both intellectual and technical leadership on a global scale. The NGS is a widely adopted model for a national infrastructure and OMII-UK is a model for the provision, curation and support of communally used software. These national infrastructures are currently being integrated in a European Research Infrastructure and the formation of a European Grid Initiative (EGI). At the same time the e-Science Programme has made major contributions to the development of a global e-Science community, with notable contributions to standards and community building at the Open Grid Forum (OGF). The two best-attended OGF events were both in the UK, OGFS at Edinburgh (2001) and OGF20 at Manchester (2007). The e-Science annual All Hands Meeting usually attracts over 600 delegates, many international. The NCeSS Hub-led International Conferences on e-Social Science have been widely recognised as setting the agenda for international efforts, as acknowledged in all three of the NCeSS external reviews. This demonstrates that the UK-based e-Science is active, healthy and aware of its responsibilities for developing research infrastructure on a global scale.

The UK e-Science Programme has made major contributions to international efforts to develop standards for distributed computing and access to distributed data. Staff at Manchester made major contributions to Grid standards (OGF) in the areas of Job Submission, Data Access and Integration, Levels of Authentication Assurance, Network Measurements, Usage Records, and Semantic Grid. Researchers at the Physics e-Science Centre made major contributions to the development of the EGEE Grid in the areas of Security and Virtual Organisation management. We also lead the W3C standards in ontology modelling in SKOS and OWL 2.0, strongly influenced by the experiences gained by computer science experts in AI when applied to real e-Science problems.

Through the e-Social Science programme, UK e-Science has been leading in research into how e-Science has developed, its patterns of adoption, barriers, enablers, impact and implications.

End of response by The University of Manchester (1) (return to ‘B’ response list)

Response by The University of Manchester (2)

• My viewpoint is very much from a domain-specialist bioinformatician who works primarily in the area of proteomics. However, within this domain I would say the UK is at the forefront with other leading players, particularly in the US and Germany. This area has held regular meetings and conferences centred around the science itself (e.g. The Human Proteome organisation meetings, HUPO), as well as more specific meetings to discuss data standards and tools (PSI initiative). Further, collaborating groups around
the world have been involved in the EU funded ProDAC project to improve data capture, standards and data sharing in the field involving groups in the UK, Germany, Switzerland, USA, Ireland and many others. This community driven approach has ensured that mostly the technological developments have been complementary rather than competing and hence the UK funded components of proteomics informatics have contributed to the international effort. Indeed, in some areas (such as development of data standards, interoperability tools including middleware, and data repositories) the UK is leading.

End of response by Professor Simon Hubbard, The University of Manchester (return to 'B' response list)

Response by University of Oxford (1)

- The UK e-Science Programme was a world leader. This is supported by the evidence that there are now several international programmes that have taken the UK programme as a model. It is probably not an exaggeration to say this is/was globally true.

This success brings with it a challenge. As other countries have begun to catch up with the UK lead how can we ensure that we remain internationally competitive particularly at a time of reduced funding? To successfully follow through on the opportunities we have created will require a continued effort and we believe a coordinated approach.

We are particularly concerned that the research infrastructure in the UK is not better coordinated. The picture with high-performance computing (which we see as a required component of e-science) is rather confused with EPSRC, NERC and STFC apparently moving forward with distinct strategies. How the developing NGS fits into that picture is also unclear and perhaps isn’t helped by the distinction at a European level between PRACE and the EGI infrastructure. There is little or no coordination regarding data repositories and this is likely to be an increasingly important element of science research – there is a need to have a coordinated strategy for both compute and data resources. Unless these issues are tackled we fear they will likely result in the UK trailing on an international scale.

End of response by University of Oxford (return to ‘B’ response list)

Response by University of Oxford (2)

- UK e-Science (e-Research) activity has not received the level of funding that US efforts in this area have enjoyed, but it has placed the UK among the major centres, internationally, for e-Science research*. It leads in two respects. I realize that too much has been said about the various naming problems in this area (i.e., e-Science versus Cyber-infrastructure), but a major contribution of the UK, in relation to the US, has been to more clearly define advances in ICTs as central to the advance of the sciences and humanities. For example, the concept of ‘cyber-infrastructure’ is too easily linked with a purely technical agenda, even though it is not portrayed in this way by leaders of cyber-infrastructure initiatives in the US, such as Dan Atkins. Secondly, UK e-Science has been able to foster somewhat more multi-disciplinary research, such as by focusing more attention on the social shaping of science and technology in this area. Generally, multiple research councils in the UK have been able to foster somewhat more multi-disciplinary streams of research, but this is more impressionistic than documented.

* See, for instance, data from the OeSS project that shows in terms of both publications and web presence, that the UK is the second most prominent country in the world: Meyer, E.T., Park, H-W., Schroeder, R. (2009). ‘Mapping Global e-Research: Scientometrics and Webometrics’. Proceedings of the 5th International Conference on e-Social Science, June 24-26, Cologne, Germany.

End of response by Professor William Dutton, Oxford Internet Institute, University of Oxford (return to ‘B’ response list)
Response by University of Southampton

- As one of the UK's leading universities Southampton operates on a global stage, and many of our activities related to e-Science provide the context to address this question. We participate in the international arena through OMII-UK, the Microsoft Institute for High Performance Computing and collaborations ranging from OreChem (chemistry) and NEMA (music), and through leadership roles in the Open Grid Forum and W3C. Our European engagement includes the OMII-Europe project, leadership in Semantic Grid and Service-Oriented Knowledge Utilities, and an extensive set of projects involving IT Innovation, our applied research centre focused on enabling the innovative application of information technology in industry and commerce (which is a member of the NeSSI European initiative for software and services and of the Future Internet Assembly). Many of our projects and centres have international members on their advisory boards, and Southampton's leaders are regularly members of international boards and review panels elsewhere.

How developed is the global e-Science Platform, and what has been UK e-Science Programme contribution?

UK e-Science is a model that is praised and copied elsewhere. In particular it is distinctive for its coordinated approach across all research councils, which in turn means the e-Social Science and the Arts and Humanities activities have been a particularly distinctive UK contribution. It has been careful to align research drivers with innovation and with infrastructure.

We also note that JISC has had a very important role in discipline-neutral infrastructure provision which supports all kinds of researchers, and that other countries typically do not have this model. We believe that JISC has an increasingly important role in this phase of e-Science. In addition to our own funding from JISC, particularly in the repositories and Virtual Research Environment areas, we are pleased to be participating in two major JISC projects as part of its Information Environment Programme: the National e-Infrastructure for Social Simulation (led from Leeds) and NeuroHub (led from Oxford).

From a technology viewpoint, the e-Science programme has led to leadership in the use of Semantic Web technologies and in what might be described as “service-oriented science” through provisions of services and the software that consumes them. UK e-Science is user-centric and data-centric. The e-Social Science programme is distinctive internationally for focusing on qualitative techniques, though in Southampton we have a rich mixture of quantitative and qualitative activities.

To what extent did the research undertaken through the Programme engage in “best with best” science-driven international interactions?

This paradigm of engagement was established at the outset with a series of N+N meetings (Southampton represented the UK in meetings with USA, Australia and later with Sweden) and has been maintained through inviting international leaders to participate in the e-Science programme as advisors, visitors and speakers at events like the All Hands Meeting and e-Social Science Conference. We enjoy a series of international visitors to Southampton, and our academics have a high visibility globally, facilitated by mechanisms such as the Worldwide University Network.

In which areas of e-Science is the UK the international leader? What has contributed to UK strengths and what are the recommendations for continued strength? In which areas is the UK less strong and what are the recommendations for improvement?

The UK leads in experience with models for software sustainability, in qualitative e-Social Science, in the use of Semantic Web technologies, in scientific workflow systems and in aspects of Science 2.0. Southampton has contributed to all of these.

UK e-Science set out with the mandate that all projects would involve Computer Scientists. This has contributed to the strength by kick-starting this important
engagement. Our experience suggests that continued strength will be achieved by ensuring the appropriate alignment of researchers, domain ICT experts, resource providers, software engineers and computer scientists. Continued strength requires that funding and reward structures are consistent with this alignment.

UK e-Science has led the way in Arts and Humanities and Southampton holds one of the seven awards. This is an excellent demonstration of cooperation between funders, with AHRC, EPSRC and JISC at the table and the creation of the Arts and Humanities e-Science Support Centre. The community has now weathered the termination of the funding for the Arts and Humanities Data Service by AHRC. There is clear enthusiasm and capability within Arts and Humanities research communities and we are confident this activity will flourish as future funding becomes available. We are pleased to have received funding from the Mellon Foundation to support some of our work in this area.

Southampton has enjoyed a close relationship between the library and the work of ECS, particularly in the area of institutional repositories; we have also worked closely with UKOLN for many years. In general the engagement of the library community in e-Science is improving but is not yet as strong as in the US where, for example, libraries have a significant role in the two recently awarded NSF DataNet projects.

Are there sufficient numbers of research leaders of international stature evident in the UK, in comparison to other countries? If not, which areas have potential for growth?

Southampton has produced many research leaders of international stature in e-Science, significantly including leadership by scientists as well as computer scientists. We believe that UK e-Science uptake would further benefit from (a) more domain-specific champions across all disciplines who use data intensive techniques; (b) leadership emerging in the next generation of researchers. We are encouraging both of these.

How does the UK compare internationally with its ability to attract, nurture and support e-Science researchers at every stage of their career?

The key weakness that is frequently observed within the community, not unique to the UK, is that reward structures (including promotion panels) do not always favour multidisciplinary research, nor research which produces outputs such as data and software. It is also reported that, in Computer Science, applied research is sometimes regarded as a less scholarly pursuit than basic research. Southampton has demonstrated its commitment to multidisciplinary research through initiatives including our Life Sciences Interface Forum and our Environment Initiative with focuses on health and energy. The career progression issues are well understood in Southampton and we have implemented a programme of leadership training.

Response by University of Stirling

- Institutional evidence from the University of Stirling

We nominate two examples whereby the DAMES programme plays a prominent role in global social science research initiatives, and one example from the CARMEN project:

1. Impact of the GESDE resources on international research and data organisations with interests in data on occupations, educational qualifications and ethnicity. Formal collaborations include with the EU-funded CESSDA-PPP; with a Swedish council VR funded project on occupational data (Bihagen, Univ. Stockholm, 2008-2011); and through engagement with leading figures in international research in the domains of the GESDE provisions (e.g. Prof. Harry Ganzeboom, Free Univ. Amsterdam; Prof. Peter Elias, Univ. Warwick and EU FP7; Prof. Kea Tijdens, Eurooccupations project).
2. Role of the DAMES Node in promoting Data Management as a distinct and important methodological topic (provoking engagement with international organisations in supplying data (e.g. CESSDA); Metadata standards (e.g. DDI), and approaches to harmonisation and standardisation of complex data resources.

3. The CARMEN project, part hosted as Stirling, is probably the biggest of its kind in the neuroinformatics field. It has attracted the attention of the International Neuroinformatics co-ordinating forum.

**Global shaping: Responses relevant to questions posed by the e-Science Review framework**

Stirling's e-Science projects have involved applied researchers participating in e-Science programme activities. By providing research resources and supporting collaborative clusters of activities (cf. response to 'A' above), established researchers based at Stirling have engaged with e-Science facilities. More significantly, their activities have filtered through to their collaborative networks, engaging wider research communities with new resources and the standards associated with them (see for example social science researchers' participation in six research and capacity-building workshops run by the DAMES Node, described at http://www.dames.org.uk/workshops/).

*End of response by University of Stirling (return to ‘B’ response list)*

**Response by White Rose Universities (Leeds, Sheffield and York)**

- Intensive global efforts have contributed towards the development of a variety of grid and e-Science technologies. As a result of these there are many products and solutions offered by different infrastructures and different countries grid/e-Science communities. Standardisation bodies (e.g. OGF, OASIS) are working towards common solutions, however, at present these solutions do not integrate well. For example, in the UK the NGS and the WRG adopted Globus Toolkit as their grid middleware whereas UK particle physicists built their grid (GridPP) using European middleware based on gLite. These are incompatible in many ways and cause confusion for users.

The UK e-Science Programme has strongly encouraged and facilitated UK researchers to collaborate with international partners engaged in e-Science and contribute meaningfully to global e-Science developments. At the time of its existence the UK e-Science Programme was internationally leading in e-Science research and developments. The UK researchers have participated and played key roles in many international activities e.g. in the European Commission funded Enabling Grids for e-Science (EGEE) project. The WRG researchers contributed towards the EC funded AssessGrid project that exploited risk management and assessment in addressing obstacles to a wide adoption of grid technologies and enabling their use in business and society.

The Programme has facilitated the White Rose Grid e-Science Centre collaboration with Beihang University in China. The EPSRC funded CoLaB (Collaboration between Leeds and Beihang universities) has been co-led by Director of the WRG e-Science Centre, Prof J Xu (Leeds), and Prof J Huai (Beihang). The outcome of this collaboration is the production grid middleware CROWN-C. Joint workshops, seminars, video-conferencing (via Access Grid) meetings and publications have enabled both teams to exchange their e-Science expertise and add to global e-Science achievements. This successful collaboration has now moved to a new phase of investigating virtualisation and resolving cloud computing research challenges.

The WRG e-Science researchers have contributed to global e-Science efforts by showcasing their results at a very large number of grid and e-Research national and international conferences and events (e.g. All Hands Meetings, OGF, IEEE DSN).
Over the last eight years the research community has become much more aware of the e-Science term in general and of its potential, novel and adventurous aspects.

*End of response by White Rose Universities (Leeds, Sheffield and York)* (return to ‘B’ response list)

**Response by University of Reading**

- We believe that UK e-Science activity is leading in Europe and is on par with US efforts. The NERC e-Science programme performed very highly-regarded scientific research using e-Science methods. It has also been responsible for driving developments in environmental informatics, which are acknowledged as world-leading and have resulted in the leveraging of other funding sources (e.g. European Union).

*End of response by University of Reading* (return to ‘B’ response list)

**Response by Imperial College London (1)**

- From many conversations it is clear that UK e-Science activity is greatly admired globally and viewed as leading the world in an important area. The programme has been much imitated, for example by the US Cyber infrastructure programme and similar activities in Australia and China.

We consider that the e-Science programme’s ultimate of adoption of Web Services and middleware technologies that were compatible with the public Internet has given the programme a decisive advantage and long-term applicability over the more low-level Globus-based Grid work in the US that was, initially, the starting point for the e-Science programme.

*End of response by Imperial College London* (return to ‘B’ response list)

**Response by Imperial College London (2)**

- From many conversations it is clear that UK e-Science activity is greatly admired globally and viewed as leading the world in an important area. The programme has been much imitated, for example by the US Cyber infrastructure programme and similar activities in Australia and China.

I also think that the e-Science programme’s ultimate of adoption of Web Services and middleware technologies that were compatible with the public Internet has given the programme a decisive advantage and long-term applicability over the more low-level Globus-based Grid work in the US that was, initially, the starting point for the e-Science programme.

*End of response by Professor John Darlington, Imperial College London* (return to ‘B’ response list)

**Response by King’s College London**

- Until 2007, the UK had arguably the strongest and most vibrant centrally-funded support for digital humanities research in the world, centred on the Arts and Humanities Data Service (AHDS) and the AHRC ICT Methods Network (funded between 2005 and 2007, and run by Lorna Hughes, now deputy director of CeRch). The UK's Arts and Humanities e-Science Initiative emerged from a creative merging of this tradition with the e-Science Programme itself: to this day it remains unique internationally. In the US for example, use of e-science and grid technology by humanists and performance researchers is typically technology-oriented, and is concentrated in big, established research centres. The only nation-wide initiative truly comparable to the UK is in Germany, where the TextGrid project ([http://www.textgrid.de/](http://www.textgrid.de/)) is charged with representing the e-science interests of humanities researchers. But TextGrid is a single 'monolithic' project: in the UK the principal strength of arts and humanities e-science has been its ability to engender multiple grass-roots activities. There has been a long-
standing tradition ‘Humanities Computing’ in the UK, with KCL’s Centre for Computing in the Humanities as an important and unique institution. Humanities Computing can be compared to what is known as computational sciences in disciplines like chemistry, physics, etc. It is centrally concerned with the common methods and techniques for analysing source materials, tackling problems and communicating results in the humanities disciplines. In this sense, e-science in the humanities is the most recent manifestation of this tradition of Humanities Computing. Based on this, it seems little wonder that there have been some strong project in arts and humanities e-science in the UK, where the e-Science Programme has sparked enthusiasm and desire in the arts and humanities community to collaborate with scientists and computing researchers; to address challenges posed by the new digital resources available in those domains. The activities within the UK’s arts and humanities e-science community demonstrate the specific needs that have to be addressed to make e-science work.

Over the four years of the Arts and Humanities e-Science Initiative’s existence, we have seen how e-science in those disciplines has matured towards the development of concrete systems and embedded infrastructures that systematically investigate the use of e-science for research.

Based on the tradition and experience of the Arts and Humanities e-Science Initiative, UK researchers have been keynotes in corresponding conferences around the world. For instance, Michael Fulford, director the UK Silchester VRE for Archaeology (http://vera.rdg.ac.uk), presented at the e-Research Australasia conference 2008, while at the time KCL researchers were invited to organise a workshop to kick-start a humanities e-science programme there. AHeSSC staff have been invited twice to represent the humanities at the biggest Asian Grid conference, the International Symposium on Grid computing in Taiwan. AHeSSC staff also played a leading role in the international coordination of Humanities, Arts and Social Science interests at the Open Grid Forum. This has recently led to the establishment of a Humanities Specialised Support Centre for the European Grid Initiative, again led by AHeSSC. AHeSSC staff were also invited to contribute to the formulation of the Supercomputing 08 Summer Institute for arts, humanities and social sciences and the University of Illinois at Urbana Champaign.

The two humanities ESFRI projects, Digital Research Infrastructures for the Arts and Humanities (DARIAH - http://dariah.eu) and Common Language and Resources Technology Infrastructure (CLARIN - http://clarin.eu) are the most important enablers of European arts and humanities e-Infrastructures. AHeSSC members are leading on the two central work packages of DARIAH, the strategic and technical elements. We work closely with CLARIN on joint workshops and technical initiatives DARIAH aims to develop and provide an infrastructure to support the exploration and use of ICT-based research methods, practices, and digital resources across the arts and humanities. DARIAH is working to support arts and humanities communities of practice to:

* Create, share, and curate digital research collections and publications
* Link and use distributed digital source materials, digital research collections, publications, and analogue sources
* Explore and apply ICT-based methods and tools to enable new research questions to be asked and old questions to be investigated in new ways
* Exchange expertise, methodological approaches, practices and knowledge across disciplines and domains

DARIAH’s first joint project application with researchers will aim to bring together European and international Holocaust archives. This is a key field for arts and humanities e-science, as here most of the research material is already available in digital formats. It seems that archival material on the Holocaust which is relevant for researchers, can be found in numerous institutes in European countries, the United States and Israel. These institutes can be categorised into two types, general and specialised. In some countries, the archival material on Holocaust forms part of the general archives on the Second World War, although specialised archives and museums on Holocaust exist in many countries. In comparison to other historical archives, specialised Holocaust archives are unique, in that they relate to the histories
of persons. These are key challenges, which arts and humanities e-science is well placed to address.

End of response by King’s College London (return to ‘B’ response list)

Response by Natural History Museum, London

- The UK has an exceptional tradition of recording species distributions since Victorian times. Today, biological recording schemes are better co-ordinated and include numerous initiatives (e.g. see Biological Records Centre www.brc.ac.uk; Birdtrack www.bto.org/birdtrack). The National Biodiversity Network is making the wealth of biodiversity information more accessible (www.nbn.org.uk). The UK also has long-term strengths in producing species keys, guides and inventories, and in the monography of species (and higher taxa). The Species 2000/Catalogue of Life project links distributed databases of names and makes the information Internet-accessible through a portal. Structuring specimen information in databases and moving it to effective e-platforms to facilitate Web-accessibility has been slower. However, as more data become available on the Web, there is a role for greater use of them in biodiversity and climate/earth systems modelling projects in the UK’s e-Science Programme. In these latter initiatives, the UK has a global impact, as it does in the management of information through data GRIDs.

Regarding the e-Science Programme specifically, the CATE project has developed close collaborations with EDIT (the European Distributed Institute of Taxonomy) and the Encyclopedia of Life project (see Principal Research Projects Submission). There is also much e-taxonomy/biodiversity informatics work in the UK (often with international collaboration) that lies outside the RCUK e-Science Programme. The need exists for better coordination within and outside the UK, but there is a will to address this weakness internationally, expressly from the resolution that emerged from the e-Biosphere conference (see Workshop Resolution at www.ebiosphere09.org). This conference, which was held in London in June 2009, brought together over 500 delegates from 63 countries to explore developments in the field and encourage the integration of diverse systems.

The quality of UK input to the international effort on biodiversity informatics has been high. However, given the size and importance of the facilities at its leading institutions the quantity of accessible content needs to be increased to make it commensurate. Mobilisation of data is partly a matter for the institutions, but the cost of digitisation remains a major challenge.

End of response by Natural History Museum, London (return to ‘B’ response list)

Response by Rutherford Appleton Laboratory (RAL), STFC

- Generally recognised as internationally competitive, with leading roles in a number of areas, for example:
  - Grid security policy development in EGEE and IGTF
  - Long term curation of digital data
  - Cataloging and management of data from photon and neutron facilities
  - Operational aspects of grid computing.
  - Standards development (Inspire, SKOS, work with OGC and OGF)

UK leadership has been recognised in a number of way, e.g.

- Computing coordinators of LHC experiments
- First chair of the wLCG Collaboration Board
- Chair of the WLCG Grid Deployment Board
- A number of OGF Area Directors and Working Group Leaders.
- International adoption of UK developments (see below)

End of response by
Rutherford Appleton Laboratory (RAL), STFC (return to ‘B’ response list)

Response by Anatomical Society of Great Britain & Northern Ireland

- The other major countries with something like an e-Science initiative in bioinformatics are the USA, Germany and Japan. The USA is the dominant player here, hosting most of the major genomic and organism databases, and providing considerable funding for making the associated tools. In the context of systems biology, Germany has a substantial interest in the use of graph theory in understanding networks. Japan hosts the KEGG database of pathways and genomic data, but its profile is not high in systems biology. The work coming out of the UK is good and high-profile: the output of the Hinxton Centre (EBI and Sanger Centre) is particularly important. Other major centres are Edinburgh and Manchester.

It is hard to claim that the e-Science initiative engaged the “best with best” in bioinformatics. Presumably this somewhat disappointing conclusion reflects a combination of the breadth of the original call for projects, the nature of the applications and the limited amount of money available.

Leadership: Bioinformatics is a mature subject with some major figures (particularly at the Hinxton Centre). By contrast, systems biology is too new for major leaders to have emerged: it needs a mixture of cleverness of ideas, integration of effort and experienced academics able to manage a project with light but firm reins and give youth its head – leaders will then emerge.

Areas of potential growth: standard bioinformatics needs to grow if we are to maximise the utility of all the experimental work currently being done in the UK; theoretical systems biology is an area where important intellectual work needs to be done.

Career support: Only a few centres are big enough to allow career development (Hinxton, Edinburgh, Manchester): more career development grants for advanced postdocs interested in systems biology are needed.

End of response by Jonathan Bard,
Anatomical Society of Great Britain & Northern Ireland (return to ‘B’ response list)

Response by Diamond Light Source

- For the area of interest, some of the practices developed and funded in the UK were transferred and developed further within EU via various Framework projects. Certainly leading within Europe.

End of response by
Dr Colin Nave, Diamond Light Source (return to ‘B’ response list)

Response by Isaac Newton Institute for Mathematical Sciences

- All of the interactions in the course of the Programme reinforced for me that the UK was seen as being at the very forefront of international activity by the grid computing activity. The integrated nature of the programme across core and applications for all the Research Councils was groundbreaking, both in reality and as seen by others. [This isn’t to say that everyone in the Computer Science community and the various application areas agreed with the remit given to the Programme and the strategy – see further comments below.]

Tony Hey had great insight in recognising that the key issue had moved on from the high end computing agenda to data management and information; my perception is that the US lagged in understanding this. The validity of this approach was reinforced for
me on a recent visit to the extraordinary facilities on the Genome Campus at Hinxton, where they are creating and managing a data deluge in which the exponent of growth is significantly greater than in Moore's law which underpins the growth in ICT technology to deal with it.

The nature of the programme in the UK was influential in stimulating similar activities in several other countries – my memory is the USA, China, Singapore, Australia amongst them; I am sure that Tony would be able to give chapter and verse.

_end of response by Sir David Wallace, Director, Isaac Newton Institute for Mathematical Sciences, Cambridge (return to ‘B’ response list)_

**Response by Linnean Society of London**

- The global e-Science Platform is still evolving, but EOL, the EDIT Cyberplatform and 'scratchpad' technology (see under A, above) are significant international developments. The RCUK e-Science input to the Platform is through the CATE project and we understand that the CATE team has collaborated closely with the EDIT Cyberplatform of which it now forms a part and, to a lesser extent, with the 'Encyclopedia of Life' project. It should be noted that there is biodiversity e-science in the UK that lies outside the RCUK Programme.

We consider that UK biodiversity informatics has a respectable standing internationally but, whether in the UK or beyond, it is in an early but fast maturing stage of development. Given the UK's long-term strengths in taxonomic skills and biological collections, even if numbers of taxonomists that describe and catalogue life are declining, the role for providing better access to biodiversity information is compelling and worthy of support. A further special strength of the UK lies in the biological recording of species, i.e. including observational data outside collections. There is great potential for such information to be used by those outside the taxonomic community in assessing changing patterns of species distribution. We emphasise that digitising records, whether in collections or elsewhere, remains a huge challenge. The Linnean Society has made considerable effort to digitise its unique holdings.

_end of response by Dr Ruth Temple, Executive Secretary, Linnean Society of London (return to ‘B’ response list)_

**Response by The UK Computing Research Committee (UKCRC)**

- The UK is a world-leader in the application of Computer Science to the development of e-Science.

The UK has taken a broader view of e-Science than some other countries. The UK has developed production computational platforms such as the National Grid Service. We have taken a lead in the application of cloud computing to e-Science and application hosting (in particular the work of the Belfast and Newcastle e-Science Centres) and computational steering (for example in the EPSRC’s RealityGrid pilot).

Furthermore, the UK has directed much of its research efforts to data management, knowledge management, and service management, addressing key challenges in data integration, service interoperation, workflow, semantic metadata, provenance, and secure, scalable data access. These challenges are now recognised as fundamental by the EU's European Strategy Forum on Research Infrastructures programmes and the NSF's CyberInfrastructure programme.

The UK can justifiably be said to have pioneered the application of semantic technologies and ontologies to e-Science and e-Infrastructure (the so called Semantic Grid). Mechanisms and standards for data access over Grids were led by the UK (the OGSA-DAI work). The UK’s scientific workflow research has been technically influential, and the emerging software adopted by scientists world-wide (e.g. the Taverna from the EPSRC myGrid Pilot, and the Triana and P-GRADE systems) and
transferred into commercial platforms (for example into the InforSense Knowledge Discovery Platform from the Discovery Net and MESSAGE pilots).

End of response by
Professor Muffy Calder, Chair, UKCRC

Response by Professor Dame Ann Dowling, Chair, Engineering Panel in RAE 2008

- The e-Science Programme has led to the development of centres with evidence of some world-leading or internationally excellent research.

End of response by Professor Dame Ann Dowling,
Chair, Engineering Panel in RAE 2008
C. What has been the impact (accomplished and potential) of the UK e-Science Programme?

The following key points were highlighted:

- It is clear from the responses that the e-Science programme has had a considerable impact, across the sciences, on the way researchers carry out their day to day work, exploiting the potential of new technologies for research itself. e-Science has provided researchers with more sophisticated tools and techniques to enable increasingly complex research questions to be addressed. Although some communities are still fully benefit from the e-Science programme, for some the exploitation of e-Science tools is already embedded in the way they approach their research.

- The e-Science programme has fostered interdisciplinarity, enabling new ways of working by promoting the exchange of expertise, methodological approaches, practices and knowledge across disciplines and domains. As scientific research is directed towards major societal challenges (such as the impact of climate change, sustainable growth and rapid response to crises in health and finance), interdisciplinary working is increasingly important. These problems cut across RCUK boundaries and therefore require input from the physical, environmental, biological, human and the social sciences.

- e-Science has not only provided platforms that enable increased levels of collaboration across different research disciplines, but also between academia and industry. DAME, BROADEN, IXI, DiscoveryNet, MyGrid, and GENIE are just a few examples of projects that have had a significant impact through take up by industry.

- The UK e-Science Programme, which is regarded as world-leading, has helped to establish many international links and has facilitated the development of lasting research collaboration with international communities. Keeping UK e-Science at the international forefront should remain a priority, with continued opportunities for collaborative activities allowing our researchers to engage internationally. International visibility has also presented the opportunity to work with industry.

- The e-Science programme has played an important part in the training of the next generation of researchers. Training and increased interdisciplinarity, fostered by the e-science programme, has created a new cadre of researchers, for example computational biology researchers prepared for the push towards integrative and systems biology.

- e-Science Projects have made an important contribution to public engagement, generating substantial publicity and contributing to a greater public engagement with science.

- e-Science has helped to support evidence based policy, with the potential to act as a platform for researchers engaging with policy research, but also the wider community including the public.
Follow the links below to view the responses

Visiting Panel:

Aberystwyth University (no response against individual framework questions)
Liverpool John Moores University
Newcastle University
Rothamsted Research
University of Aberdeen
University of Bristol (no response against individual framework questions)
University of Cambridge
University of Edinburgh
University of Glasgow
University of Manchester (The) (2 submissions)
University of Nottingham (no response against individual framework questions)
University of Oxford (2 submissions)
University of Southampton
University of Stirling
Wellcome Trust Sanger Institute (no response against individual framework questions)
White Rose Universities (Leeds, Sheffield and York)

Panel Visits:

University of Reading
Proudman Oceanographic Laboratory (no response against individual framework questions)

Imperial College London (2 submissions)
King’s College London
Natural History Museum, London
University College London (no response against individual framework questions)

Rutherford Appleton Laboratory (RAL), STFC (a combined submission from all the projects being reviewed during the visit to RAL)

Others:

Anatomical Society of Great Britain & Northern Ireland
Diamond Light Source
Institute of Physics (IoP) (no response against individual framework questions – please see Section F - Other Comments below)
Isaac Newton Institute for Mathematical Sciences, Cambridge
Linnean Society of London
The UK Computing Research Committee (UKCRC)
Professor Dame Ann Dowling, Chair, Engineering Panel in RAE 2008
Professor Nigel Hitchin, Panel Chair of last RAE exercise (no response against individual framework questions – please see Section F - Other Comments below)
Response by Liverpool John Moores University

- Speaking as an observational astronomer and telescope operator, the impact of our e-Science project on certain facilities which have an interest in time domain astrophysics has been high, and resulted in the development of solutions that are sustainable, scalable and reusable for distributing observation requests optimally. Without this framework, various ad-hoc solutions would have been engineered by different groups at ultimate greater cost and lacking Interoperability. The resulting scientific publications have been high impact (Nature, Science etc.).

End of response by Liverpool John Moores University (return to ‘C’ response list)

Response by Newcastle University

- The e-Science Programme placed an emphasis on industrial collaboration from the very start. Because of the commitment from the (then) Department of Trade and Industry, the original funds given to the regional e-Science Centres for projects could only be spent if matching funding could be found from industry. At Newcastle, we have worked closely with local, national and international companies. The region has a large number of small companies that could potentially benefit from e-Science technologies, but in general they have limited IT knowledge, and extremely low R&D budgets. Therefore, we have played a key role in allowing these companies to adopt appropriate technologies and techniques. We are well known to local industry and so are regularly approached to give advice and guidance on grids, clouds and e-Science. For example, the NEReSC director has accompanied the CEO of a local SME (Arjuna) to two industry conferences and to a meeting with an analyst in order to provide advice on how that company can enter the cloud computing market. We have also seen our first successful spin-off – an exploitation of the results of the e-Science eXSys project through a spin-off company, e-Therapeutics.

We have been working closely with the local RDA, OneNE, to increase the number of users benefitting from e-Science technologies in universities and industry, trying to make the advantages available to those without deep knowledge of e-Science infrastructure. OneNE provided additional funding to allow us to further develop an e-Science system – "e-Science Central" – that can be used by less expert users entirely through a website. We are currently trialling this with a number of research groups and local companies. A spin-off company (Inkspot Science Ltd) has been created to explore whether there is a business model to support this type of hosted service.

At a local level, the NEReSC has run many events for industry. These include two CloudCamps, each attended by around 100 people, of which about 80% were from industry, and one CloudSeminar, attended by 100 senior people from local industry.

Internationally, the visibility of the UK e-Science programme has given us opportunities to work closely with key computer companies such as Oracle, Microsoft and Red Hat. This has brought industry funding and expertise to the University, and then on to local industry – for example both Microsoft and Amazon accepted our invitations to speak to local companies at the Cloud Seminar. Because e-Science has developed new technologies, and pushed existing ones to the limit (e.g. Web Services) the relationship with major companies has been one of joint exploration for mutual benefit; commenting on NEReSC’s work on infrastructure, Dr. Mark Little, the CTO of JBoss wrote “your work has influenced vendor strategies as much as it has been influenced by those strategies, which is refreshing”.

End of response by Newcastle University (return to ‘C’ response list)

Response by Rothamsted Research

- In the biological sciences, specifically that part funded by the BBSRC, the e-Science programme provided a welcome re-invigoration of for the UK Bioinformatics community. After a period when Bioinformatics was funded as a special initiative, BBSRC decided to return the funding of computational biology to the open response-mode competition.
With funding committees that were stacked against them, many bioinformatics groups were struggling to keep afloat. The e-science programme provided many with the opportunities to develop a new generation of distributed resources, helped create new collaborations and increased cohesion in the research community. New databases and software tools were therefore developed in areas of bioinformatics that would not have been possible beforehand.

A very significant impact of the e-science programme was the training of young scientists. The nature of the programme promoted more interactions between biologists and computer science departments and more software engineers and CS practitioners moved into the biosciences. The training and increased interdisciplinarity fostered by the e-science programme created a cadre of computational biology researchers that were ideally prepared for the push towards integrative and systems biology that has become a BBSRC strategic priority.

End of response by Rothamsted Research (return to ‘C’ response list)

Response by University of Aberdeen

- Work at Aberdeen has targeted a number of important technological and societal challenges. The major societal issue has been to support evidence-based policy. While much has been said about use of evidence to support policy making, delivering on the vision of greater transparency in policy deliberations is some way off. e-Science tools have the potential to act as a platform not only for researchers engaging with policy research, but also with the wider community (including the public). There is thus real scope to use technology to create an interface between the research community, the public and policy makers.

Our experience has been that young researchers in particular have found the e-Science programme rewarding and stimulating.

End of response by University of Aberdeen (return to ‘C’ response list)

Response by University of Cambridge

- One need only look at the portfolio of projects funded by the eScience programme to see that it was unusually creative and adventurous.

A particular societal challenge I’d like to focus on is that of public engagement with science. eScience projects (or eScience-inspired projects) such as climateprediction.net, LHC@home and GalaxyZoo have generated substantial publicity and offered the general public a means of getting directly involved by contributing their time or spare computing resource. The kind of high throughput distributed computing enabled by eScience has undoubtedly contributed to a greater public engagement with science and I expect that similar projects will continue to do so.

End of response by University of Cambridge (return to ‘C’ response list)

Response by University of Edinburgh

- The UK pioneered tools and middleware for e-Science: DAME, BROADEN, IXI, DiscoveryNet, MyGrid, and GENIE are examples of projects that have had a significant impact through take-up by industry.

NeSC has been involved in many collaborative projects with industry: with large multinational companies (IBM, Oracle, Microsoft, Hewlett-Packard and Sun Microsystems) and end-user companies such as First Group (large transportation company) and Pepper’s Ghost Productions (small TV programme production company). These projects stimulated interest in e-Science and Grid Computing across the IT industry value chain from vendor to consumer and led to a series of ongoing projects – ensuring direct economic impact for the UK.
The eight initial Grid Core Programme projects (£2.4M) stimulated a broad portfolio of collaboration with industry and commerce, much of which was funded through the European Commission’s Framework Programme. These included the €16M NextGRID project with 20 partners (12 from industry); the €28.5M BEinGRID project with 95 partners (>80% from industry); and the €4.3M ADMIRE project with 6 partners (3 from industry).

The TSB-funded IECnet project has created the Grid Computing Now! KTN, which has recently been renewed and broadened to continue its outreach to industry. It now has 1,100 members, two-thirds from industry, and is championing the take-up of distributed computing in industry.

End of response by University of Edinburgh

Response by University of Glasgow

To what extent has the research undertaken through the e-Science Programme benefited the UK economy and our global competitiveness?

- The UK economy has benefited from numerous major international grants, e.g. from the EU frameworks. Obviously projects such as EGEE and GridPP have had major involvement from groups in the UK, but also numerous other grants would simply not have happened without the e-Science effort. For example, the major EU funded NeSC projects EuroDSD and AvertIT (funded at 5m) were based on software and expertise garnered through the e-Science Programme. EuroDSD is currently being expanded to included international collaborators from the US, Australia and the rest of the world. It is planned that this will become a pre-eminent international resource for research into a wider variety of rare diseases. AvertIT is currently exploring commercialisation of the software systems developed for prediction of hypotensive events in brain trauma patients.

To what extent did the research undertaken through the UK e-Science Programme address key technological/societal challenges?

- With the move to service-oriented architecture Grid-based e-Infrastructures; recent focus and exploration of Web 2.0 technologies, and more recently the role of cloud based systems and role of virtualisation, it is likely that technologies will continue to evolve. It is clear that usability for end users has grown significantly in importance and is a key factor in uptake and usage of any e-Infrastructure.
- At NeSC we continue to explore a wide range of societal challenges in various projects. Thus through projects such as DAMES and NeISS we are developing e-Infrastructures targeted specifically at supporting research into depression, self-harm and suicide. Through projects such as SHIP we continue to work closely with organisations such as the NHS to support a wider range of research impacting upon society, e.g. cardiovascular morbidity, breast cancer. A key aspect of this work is in technology transfer from academia to organisations such as the NHS, e.g. in how secure inter-organisational data sharing and collaborations can be supported.

What evidence is there to show that the UK e-Science programme supported the development of a creative and adventurous research base and portfolio?

- One measure of this is the breadth of research projects that have been funded through the e-Science Programme. The NeSC at Glasgow have been involved in projects as far ranging as paediatric endocrinology of rare diseases; brain trauma; clinical trials and epidemiological studies; genetics of hypertension; breast cancer tissue banks; drug discovery; cell signalling; language and literature research environments; nanoCMOS electronics; occupational data management; social simulation and challenges of social science data
management amongst others (www.nesc.ac.uk/hub/projects/). The common denominator across these is support for finer-grained security.

- The NeSC web site (www.nesc.ac.uk/projects) contains information on a wide range of projects funded through the Core Programme.

End of response by University of Glasgow (return to ‘C’ response list)

Response by The University of Manchester (1)

- A major impact has been in the automation of computationally based research. The increasing adoption of workflows and tools for data analysis allows the methods of scientific research to be copied, modified and shared. While this has been true of computer programs for a long time, the encoding in electronic form of processing and analysis of data from experimental science and from specialist scientific instruments is new and unprecedented. Moreover, as all forms of scientific research are increasingly centred round data, a major opportunity exists for the diffusion of computationally based methods into mainstream research. This is particularly so in the social sciences, where the rapidly expanding body of digital data is opening up new opportunities to address the most complicated social research topics such as migration, ageing population, global security, poverty, and the environment. The wealth of digital social data and the opportunities afforded by data integration have revived interest in computational techniques to support complex modelling, data mining, text mining and visualisation.

This automation has already produced major new results, which we illustrate with two examples. Biologists are being overwhelmed with data, far too much data to be easily comprehensible. They also have a huge space of possible hypotheses to explore. To cope with this, the space of hypotheses is often triaged based on prejudice/bias by looking for stories based on what is already known. The automated tools from e-Science allow them to do this analysis in an unbiased way – to explore a much bigger set of hypotheses and report back to scientists those that are supported by data (not prejudice). A concrete result has been the identification of a candidate gene for Trypanosomiasis (Sleeping sickness) resistance. A previous two year manual survey had failed to reveal this, but the result was subsequently confirmed by wet-lab experiments. Moreover the Taverna workflow used has been taken over unchanged to study colitis/inflammatory bowel syndrome in mice. A second example was the simulation of defects in liquid crystals undertaken in the collaboration between RealityGrid in the UK and TeraGrid in the US. Defects in a particular liquid crystal phase, the gyroid phase, were produced for the first time in a computer simulation, though they were known from observation. Distributed resources were required to make the solution Grid sufficiently large to remove the effect of artificial boundary conditions that suppressed their production in simulation. Once simulated, the development of defects in the crystal and their propagation could be studied purely in silico. Liquid crystals are of great practical importance in engineering and biology, but understanding of their imperfections cannot be fully studied via experiment. This work received two major awards at Supercomputing 2003 (“Most innovative data-intensive application”) and the International Supercomputing Conference in 2004 (“Integrated Data and Information Management”).

Another major impact has been the development of multi-site and multi-disciplinary research. The development of tools for internet based collaboration has ranged from sites for scientific social networking (myExperiment) to the deployment of an infrastructure for distributed collaboration (Access Grid). UK e-Science application projects were encouraged to adopt these approaches from the outset and funding was also provided for travel to sister projects on a global scale. Evidence of impact of this approach can be seen in the use of UK produced software in major projects. For example, Taverna has been adopted for the US cyberinfrastructure for cancer bioinformatics in the caBIG project; OGSA-DQP has been adopted by the US Public Health Grid for data integration and a great deal of software produced by the Programme has been deployed on the NGS and into Europe.

The potential impact of these achievements will be even greater as the rate of production of digital data – both born digital and post hoc digitised – increases in
scientific research. The impact of multidisciplinary working between geographically distributed teams will increase as scientific research is directed towards major societal challenges such as the impact of climate change, sustainable growth, and rapid response to crises in health, finance and communications. These problems require input from the physical, environmental, biological, human and social sciences.

The UK e-Science Programme has established successful prototypes for such research, which cuts across RCUK boundaries, and is integrated on an international scale. Examples of this include the RealityGrid projects and spin-offs such as Grid-Enabled Neurosurgery Imaging Using Simulation. These projects have been highly influential in developing the European Virtual Physiological Human Project, with the RealityGrid PI as the Principal Investigator of the VPH Network of Excellence.

Specific initiatives in the Programme, such as the Sisters projects which linked UK e-Science projects with their international partners, have led to ongoing collaborations in the areas of workflows and provenance. An example of this has been the interchange of ideas and methods between Taverna developed in the e-Science Programme and Kepler, extensively used in the US. Further evidence of this can be seen in the submissions of the various projects grouped under the myGrid stable.

An example of impact on application-driven fundamental computer science is the ISPIDER project in proteomic data analysis that spun out basic research in semantic service annotation verification leading to the quASAR software suite and a journal paper in ACM TWEB. Similarly, the Qurator project investigated fundamental data models for data quality in curated biological data using Taverna as a research platform. At a more fundamental level, advances in description logics were stimulated by the challenges of representing biomedical knowledge, leading to new mechanisms to represent and reason over structures that are currently being incorporated into the chEBI chemical compounds ontology by the European Bioinformatics Institute and into the HERMIT reasoning engine.

The Programme outcomes have already had an economic impact. By remaining open source Taverna has been able to penetrate research institutes and universities – over 320 of them – but also small biotechs and private research institutes too. 23 SMEs are known to use Taverna and 12 or more larger pharmacogenomic companies including Aventis Cropscience, BASF Corp, Bayer Cropscience, Novartis, Pfizer Inc, Philip Morris International SA, Roche, Bristol-Myers Squibb Pharmaceutical Research Institute, Wyeth-Ayerst Research, and J. Craig Venter Institute, Inc.

The adoption of the open source model of software development has allowed others outside the funded Programme to contribute to the software base of e-Science. The development of Open Source software has been supported by repositories, such as NeSCForge, the software repository of OMII-UK, and the use of SourceForge and GoogleCode by key projects (e.g. myGrid, RealityGrid).

End of response by The University of Manchester (return to ‘C’ response list)

Response by The University of Manchester (2)

- I would say it has been considerable, but the real benefits might not be recognised or fully appreciated for some time yet. Scientific disciplines, especially bioscience, move at frighteningly fast speeds – today’s cutting edge technology and capability can become obsolete in a matter of months and this can have a direct effect on e-Science tools and technology. That said, much of current developments I am aware of have been generic such workflow and pipeline development toolkits (myGrid and satellite projects).

End of response by
Professor Simon Hubbard, The University of Manchester (return to ‘C’ response list)
Response by University of Oxford (1)

- The e-Science programme has had a significant impact at Oxford University. It is clear that there has been significant impact in a number of disciplines particularly those that are tackling large-scale global collaborations, to name a few at Oxford - particle physics, astrophysics, heart modelling, cancer informatics, neuro informatics, climateprediction and some more surprising ones such as classical collections. Perhaps a surprising aspect has been the uptake of collaborative technologies such as Access Grid that have been taken up not only for meetings and seminars but for shared classes and courses with other Universities.

A more subtle impact perhaps is the approach to shared resources and data – an example of this is the project in which Oxford is a partner to develop the MRC data sharing service – this builds directly on the work done within the e-Science Programme.

We are beginning to see uptake too in the humanities and social sciences. At Oxford we are in the midst of developing a strategy for the digital humanities. There is a great deal of potential here as increasing numbers of research artefacts become digitized or indeed are created in a digital form.

End of response by University of Oxford (return to ‘C’ response list)

Response by University of Oxford (2)

- The e-Science programme has been changing the profile of the computer sciences in the UK. This is most evident in the case of Oxford, where the e-Science research programme led to the launch of the OeRC. Computer sciences are being increasingly repositioned as a strategic discipline across the sciences and humanities. This positioning is in part because success in e-Science most often entails success in collaboration between the social sciences and domain researchers in other disciplines and areas.

There is a growing community of researchers in the UK formed by the e-Science Programme, which has engaged a critical mass of researchers and institutions committed to this area. Moreover, this community is well networked with colleagues around the world, primarily in North America, Australia, New Zealand, and the rest of Europe. This is enabling the area to build on its quality, and to organize rapidly to compete successfully for new grant and other funding opportunities.

End of response by Professor William Dutton, Oxford Internet Institute, University of Oxford (return to ‘C’ response list)

Response by University of Southampton

- To what extent has the research undertaken through the e-Science Programme benefited the UK economy and our global competitiveness?

Southampton e-Science has led to spin-out companies. The Geodise pilot project led to the dezineforce spin-out (www.dezineforce.com) which builds on top of research and publications from Geodise. It was founded in 2007 with Venture Capital and Angel funded from Feb 2008. Prof Simon Cox is Chief Scientist at dezineforce and the company employs 12 people.

We continue our industrial engagement which benefits aerospace, marine and automotive design: Geodise also led to collaboration in the Centre for Fluid Mechanics Simulation project (CFMS - a TSB funded 3 year programme ~20M Euro), where Cox leads a Workpackage with Microsoft in collaboration with BAE Systems, Airbus, Rolls-Royce, MBDA and 10 further aerospace corporations (with Keane).

In terms of potential, the new tools and techniques being delivered by the e-Social Science Quantitative Node will have direction application in social statistics and are set
to inform policymaking. These and other e-Social Science methods stand to bring socio-economic benefits through improved decision-making.

To what extent did the research undertaken through the UK e-Science Programme address key technological/societal challenges?

The LifeGuide project, funded under the e-Social Science programme, is creating an internet-based set of resources that will allow researchers to flexibly create and modify two fundamental dimensions of behavioural interventions: providing tailored information and advice, and supporting sustained behaviour (it is currently being used by the new NHS Centre for Smoking Cessation and Training). Our Small Grant (Grid-enabled data collection and analysis) used an e-Science approach to enhance the training of nurses through practice-based learning.

In Southampton the e-Science experience, particularly in e-Social Science, has fed directly into our participation in the Digital Economy Programme (project and DTC), which is aimed at realising the transformational impact of ICT for all aspects of business, society and government.

What evidence is there to show that the UK e-Science programme supported the development of a creative and adventurous research base and portfolio?

The e-Science funding awarded to the established EPSRC Interdisciplinary Research Collaborations (IRCs) was important in this regard, and Southampton benefited from participation in two: Equator (ubiquitous computing) and Advanced Knowledge Technologies.

For example, the Advanced Knowledge Technologies Interdisciplinary Research Collaboration conducted the CoAKTiNG project (Collaborative Advanced Knowledge Technologies in the Grid). The tools it generated were trialled with NASA and aspects of the research were continued through the ESRC e-Social Science Small Grant “Grid-enabled data collection and analysis”, an important project in Southampton in that it brought together a successful team across three faculties.

End or response by University of Southampton (return to ‘C’ response list)

Response by University of Stirling

Institutional evidence from the University of Stirling

Research from the DAMES Node has contributed to key social science research challenges involving social care, mental health patterns, and social inequalities (see e.g. http://www.dames.org.uk/publications.html).

Research on data management within the DAMES Node has encouraged formal engagements with other major research capacity programmes in the UK, including contributions to the ESRC’s ADMIN Node and Administrative Data Liaison Service (both concerned with accessing and analysing administrative data); the UK Economic and Social Data Service; and the ongoing e-Stat and Lancaster-Warwick-Stirling ESRC Node’s associated with quantitative data analysis.

The primary benefit of research on the CARMEN project is/will be on the sharing of neurophysiological datasets. These are very expensive to acquire, so sharing them, and sharing the techniques for processing them is important. No equivalent systems exist elsewhere in the world.

Impact: Responses relevant to questions posed by the e-Science Review framework

In the domain of social science research using large scale social survey datasets, the UK stands out as an international leader with exceptionally high volumes of, and quality in, data resources (e.g. in UKHLS the largest longitudinal household panel survey in the
world; world leading initiatives in linking census microdata and administrative data; outstanding resources in social science repeated cross-sectional microdata). The UK also boasts world-leading expertise in the analysis of these data resources (e.g. the Centre for Multilevel Modelling). The ESRC and JISC e-Science investments can be seen as strengthening, supplementing and further developing those world-leading initiatives and resources, such as through investment in pioneering data analytical resources (projects such as CQeSS, NeISS and e-Stat); and through data management resources for enhancing standards of analysis and the accessibility and documentation of analysis of complex data resources (such as in the DAMES Node).

End of response by University of Stirling (return to ‘C’ response list)

Response by White Rose Universities (Leeds, Sheffield and York)

- The UK e-Science Programme has led to significant economic and social enhancements. It provided platforms enabling increased levels of collaboration across different research disciplines, and between academia and industry. It enabled UK researchers to pursue more adventurous research, including distributed computing. It stimulated innovation and increased the UK standing in international consortia and research which addresses key technological/societal challenges.

The WRG team has been involved in a number of research projects that contributed to these activities. For example the EPSRC e-Science pilot project DAME (Distributed Aircraft Maintenance Environment) built a system for distributed diagnostics based on the grid. The project was pursued by a collaborative team from the three White Rose Universities, Oxford and business users from Rolls-Royce, Data Systems and Solutions Ltd and Cybula Ltd. The project demonstrator was the maintenance of aero engines for Rolls-Royce. These engines are beginning to be instrumented so that automated systems can detect when any maintenance events are needed. The DAME system allows engineers to use the data from different engines held in data repositories around the world to help diagnose problems in these engines. The project developed knowledge based tools for the search and analysis of this data, within a collaborative portal environments based on grid middleware.

Another example is the EPSRC and BAE NECTISE project pursued by a large consortium, including the Leeds WRG team, which researched successfully the use of Service Oriented Architecture (SOA) for integration of systems in a dynamic military environment. The NECTISE project has researched the question of how BAE Systems delivers Network Enabled Capability (NEC) to the UK MoD, taking account of the aims summarised in the 2005 Defence Industrial Strategy.

The ESRC and DTI Hydra project and its ESRC second phase HYDRA II project led to the ESRC MoSeS project which used e-Science techniques to develop a national demographic model and simulation of the UK population, specified at the level of individuals and households. Through MoSeS, users such as town planners can forecast trends in UK healthcare, business and transport, as well as demographic changes going forward dozens of years. The results of these forecasts can be produced as readable reports, or visualized onto maps such as those in Google Earth.

Building on the experience of early collaborative visualization projects gViz and eViz (An Advanced Environment to Enable Visual Supercomputing) our WRG researchers contributed towards the EPSRC Integrative Biology project and the European Astrophysical Virtual Observatory project.

Collaboration with industry is an integral part of the White Rose Grid strategy. The WRG secured funding from the Yorkshire and Humber Development Agency; Yorkshire Forward, to raise awareness of grid technologies and foster links with industry in the region. Furthermore, nearly all WRG projects were undertaken in partnership with industry. Our partners included Rolls-Royce, BAE Systems, DS&S, eXludus, Numerical
Algorithms Group (NAG), Shell Global Solutions, Cybula, Sun Microsystems, Esteem Systems and others.

End of response by
White Rose Universities (Leeds, Sheffield and York) (return to ‘C’ response list)

Response by University of Reading

- The programme has exposed the research communities from the different research councils to new ways of working, especially with data, and the establishment of pilot projects worked well, for NERC in particular. The UK science and government research agencies, e.g. the Met Office, have certainly benefited from the programme and it has enabled UK researchers to win substantial European Union Framework funding.

There is still great societal benefit to be gained from an e-science and e-research agenda that exposes more and more data to a wide community of users, lowering barriers to access using the internet and creating tools that enable the bringing together of data from different fields/ institutes or government departments. In some cases, UK Government has been slow in realising this because government agencies do not always share e.g. environmental data as they have been encouraged to have an internal market, and don’t tend to share with industry partners who are traditionally regarded as competitors.

The best evidence for creative and adventurous research could be made from a list of projects that focus on live data access from widely distributed sources. Many current projects are based on such methods. The tools and standards for doing this have grown greatly through e-science support.

End of response by University of Reading (return to ‘C’ response list)

Response by Imperial College London (1)

- We believe that the impact of the UK e-Science programme has been very considerable. It showed conclusively that, given appropriate funding structures, computer scientists and applied computational researchers could work effectively together and design and construct infrastructures that would have an impact on the day to day practice of working scientists and that, furthermore, this way of working could be maintained to observe the operation of these infrastructures in practice and continue to enhance them and develop new support for collaborative working.

The programme’s early identification of the importance of modern data-driven science and the development of high-performance and high-throughput tools to support this, building on practices already in place in the Life Sciences, had a major impact widening the application of HPC parallel clusters to areas of science beyond numerical modelling.

The programme also demonstrated that much of the computing technology and infrastructure being developed was generic across many application areas and, that a properly structured programme, should have mechanisms to both identify and capitalise on this generality.

This generality, coupled with the e-Science programme’s inclusion of all the scientific research councils, had a very strong impact in breaking down the artificial silos that, at least in computational terms, previously existed between the various application domains and funding councils. In turn, when applied to the public Internet this generality helps break down the silos between academia, business and government, both as users and providers of Internet services.

A major and continuing impact of the e-Science programme has been away from academic science and is now finding application on the public Internet in the development of commercial and public Internet and mobile services. As mentioned
above the e-Science programme’s ultimate adoption of Web Services and middleware technologies that were compatible with the public Internet meant that many of the technologies and applications developed in the e-Science programme were applicable to the general Internet. The general concepts of the encapsulation of complex computational technologies behind a simple user-oriented interface and the transparent use of HPC resources is exactly what is needed to build sophisticated but easy to use consumer facing Internet services. For example our work within the London e-Science Centre led directly to the formation of the Imperial College Internet Centre. Here we were able to develop a range of collaborations with commercial and public organisations such as Vodafone, O2, the BBC, BT, Transport for London, RBS, the Science Museum and the development of a wide range of consumer-oriented Internet and mobile applications for example, transport advice, digital media, Internet personal and public services, community healthcare, public access to archive material and digital libraries.

The other area where we feel the e-Science programme is having an impact is in the development and application of public Cloud Computing resources such as Amazon EC2. The idea of Grids was to make access to complex HPC resources easy and transparent. While the early Globus-based realisation of Grids was far from this ideal the latter adoption by the e-Science programme of Web Service technologies made this possible. Our work in the e-Science Core Programme project “A Market for Computational Services” built a complete infrastructure to support an open transparent market in computational services, both hardware and software. This project was collaborative with Sun Microsystems who went on to launch the Sun Network.com, the first publicly available utility computing platform. Latter developments by Amazon, IBM, Google and others have now made considerable computational and storage facilities transparently accessible with no cost of ownership. This public computational infrastructure now means that the agenda of the e-Science programme of freeing science workers from the complexities and cost of ownership and use of computational facilities can now be repeated at the public and global level. This opens up opportunities for the development of a whole range of public and consumer oriented services that can be accessed and used without either the service vendors or the users having to own and maintain complex physical resources.

These tendencies and opportunities have we think, led to the Research Councils’ Digital Economy and the TSB’s Digital Britain programme. We think the UK is well placed to benefit from these developments and some of the credit for this should go to the e-Science programme.

The MESSAGE project has demonstrated how eScience can enable the creation of an entirely novel form of data collection and processing infrastructure, based on the combination data from a large number of static and mobile sensor platforms. Moreover, it has illustrated how these data open up new opportunities both for the science base underlying the analysis of traffic and urban air quality and for the practical delivery of improved traffic management policies to mitigate Urban air quality.

End of response by Imperial College London (return to ‘C’ response list)

Response by Imperial College London (2)

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End of response by
Professor John Darlington, Imperial College London (return to ‘C’ response list)
Response by King's College London

- At KCL, the principal impact of the e-Science Programme (both accomplished and potential) has been the opportunities afforded to link up research groups, projects and expertise in the College and beyond, that would not otherwise have been linked up. AHeSSC's role as coordinator and support organization for the Arts and Humanities e-Science Initiative has placed KCL in direct contact with seven of the UK's most leading-edge projects on the application of technology to the humanities and arts, and with those projects' own research networks. We have sought to take maximum advantage of those collaborations, for example feeding the experience gained into formulating the research programme for the Anatomy Museum.

For arts and humanities more generally, KCL is leading the process of understanding and developing the potential impact of the e-Science Programme. The basic concepts and directions of e-Science and its potential impact on arts and humanities have been established. Now, new methodologies are emerging from the interesting contradiction of arts and humanities e-science, which is a paradox in itself. This is rooted in a linguistic distinction, which hints (as with most linguistic distinctions) at more than merely a difference in the way of describing things; a point made by the classicist Greg Crane in his keynote address to the e-Science All Hands Meeting in 2008, in which he proposed the concept of e-wissenschaft. On the other hand, the English language distinguishes between the 'humanities' and 'science' in a way that reflects a specific treatment of the division of labour in research. The paradox played a productive role: Many of the successful grass-roots activities in arts and humanities e-science originated from newly formed productive partnerships with the sciences. This meant not only to work together on a common problem, but also the adoption of a new different viewpoint in humanities research regarding old questions. For example, examining the way computer science tries to simulate the understanding of meaning in music and texts helped the research practice of textual studies and musicology. Discovering the statistics behind data and text mining technologies means understanding what a more mathematically-oriented methodology can deliver and what it will fail at. This enhanced perspective on research practices and methodologies can be seen as one of major impacts of e-science on arts and humanities, next to enabling better research in a shorter period of time by giving quick access to resources (as has been the experience of the e-Social Sciences, both in KCL and beyond). In the absence of larger e-infrastructures, the impact of e-science on the arts and humanities has been mainly methodological. This is a positive trend, as the reflection on methods and approaches is an important part of humanities research.

Arts and humanities e-science has never limited itself to more traditional ideas of e-science, which link e-science mostly to the application of certain advanced network technologies in supporting sciences. These technologies like the grid have their place but they might generate the impression that the solution is already there and only needs to find the right application and those willing to give the money. From our experience in the wider world of e-science, e-science will fail if it deems itself as just as an application of technologies. Rightfully, it will then be perceived as an invasion of technologies, whose developers presume to know the solution without knowing the problem. This perception is likely to be even more marked in the arts and humanities. In the past, their development and success were rarely due to advances in computing. Humans are still vastly superior to machines when it comes to discussing history, analysing concepts or revolutionizing arts. But, they are interesting in finding out about new ways of performing these tasks.

Deep methodological differences between computing sciences and humanities are often best expressed in seemingly minor differences in language, which we experience again and again when arts and humanities research meets computing. For example, authenticity cannot be solved with checksums from a humanities perspective, authenticity is ensured by recording context information about the creation of a document and its purpose. After all, a JPEG2000 derivate of a TIFF image may be the same thing from an intellectual point of view, but the checksum will deny this. Another example for two different languages in computing and humanities is the usage of the word transparent: Computer scientists would generally say transparent to any technical
procedure that is invisible to the user. Humanities scholars on the other hand mostly consider any technology transparent, which transparently displays its full complexity to the user without obscuring it. Innovation emerges exactly at those intersections of different languages and perspectives. For example, the Purcell Plus project at Goldsmith College works on the better understanding of the new availability of huge amounts of digital music resources on the Internet. Musicology has transformed itself from a data-poor discipline into a data-rich one (see http://wiki.esi.ac.uk/Musicology). With these new resources, new empirical approaches to musicology seem to be feasible for the first time. Purcell Plus focuses on the comparison of computational methods to describe similarities of music pieces with the more traditional theoretical musicology based ones. This shift in methodologies has only become possible with e-science means and methods to integrate music resources, and to provide useful access to them.

End of response by King’s College London (return to ‘C’ response list)

Response by Natural History Museum, London

- For the rapidly expanding field of biodiversity informatics, the impact has been chiefly through recognising the importance of moving taxonomy to the Web. As with other e-Sciences, biodiversity informatics has benefited from dedicated funding that might not have been forthcoming through responsive-mode applications. The strength of e-Science projects is in the blend of computer science with individual disciplines, and this can often mean taking a greater level of risk with projects. Moreover, innovation lies largely in the synergy between the two fields, rather than in computing or taxonomy on their own. As such, it can be more difficult for interdisciplinary projects to gain funding – particularly if referees come from specific disciplines and look for innovation mainly within their fields of interest.

RCUK funding for biodiversity informatics has been limited, although that which has been provided has been most welcome. Certainly the field is closely aligned with, and even driven by, the societal challenge of biodiversity loss. As noted already, biodiversity informatics has only recently become established as a coherent field. Project work inside and outside the e-Science Programme shows inventiveness and a genuine will to create an adventurous research base. Evidence for this statement comes from the gaining of competitive research grants from the e-Science Programme (CATE project), the European Commission (numerous integration projects in taxonomy) and the US National Science Foundation (Planetary Biodiversity Inventory scheme) plus the recognition by leading taxonomic institutions of the importance of this area of endeavour.

End of response by Natural History Museum, London (return to ‘C’ response list)

Response by Rutherford Appleton Laboratory (RAL), STFC

- The ICAT system originally developed at CLRC has been adopted by the SNS at ORNL and by the Australian National Synchrotron. There is also strong interest in this system and its ability to integrate data from different facilities, from other neutron and photon sources around Europe. STFC have initiated a pan-European consortium (PaNdata) to develop integrated data access across these facilities. Activities such as PaNdata provide the opportunity to standardise data handling across multiple facilities, with implied benefits to the users of these facilities.

ICAT built on experience with the NCSA Storage Resource Broker and early work on SRB, e.g. integration of GSI security, was contributed to NCSA and integrated into standard SRB.

The infrastructure deployed at RAL allows full integration of data acquisition and analysis and, through ePubs, provides the basic building blocks required to link data and publications.
GridPP will enable UK physicists access to LHC physics in a way that is both collaborative and competitive. It has already demonstrated its ability in the run-up to LHC data taking to participate in the Worldwide LHC Computing Grid at the levels required for both storage of data and the processing of it.

The UK National Grid Service has demonstrated the ability to deliver resources across the UK to a variety of scientific disciplines and has the potential to grow into a pervasive infrastructure for an even wider range of research areas.

The development of GridPP and the NGS has provided the basis of a UK "National Grid Initiative" (NGI) which is a full partner in the newly created European Grid Infrastructure (EGI). Within the UK this NGI now has over 30 partner HEIs and provides a strong basis for further integration of UK activities and their international interactions, e.g. in support of the projects listed in the ESFRI road map.

Response by Anatomical Society of Great Britain & Northern Ireland

- Although it is probably too early to give a considered appraisal, the impact of the science programme in academic bioinformatics thus far has been minor.

Commercially, some projects may be useful to the pharmacological industry.

Response by Diamond Light Source

- Various projects seem to have produced developments which are in common use.

See below for potential impact

Response by Isaac Newton Institute for Mathematical Sciences

- See comments also in section A, and in particular that the review needs to have access to existing detailed reports.

One overarching comment: The impact has to be looked at differently in the different Research Councils. In STFC (PPARC as was), there was already understanding and momentum. EPSRC subjects were to a greater or lesser degree ‘ready’. The largest impact may in reality have been in BBSRC and NERC, where the potential is huge, the need is acute, and the challenges greater because of the much greater heterogeneity of data. It is really encouraging to see the philosophy of the Programme embedded in strategic thinking now in BBSRC and NERC.

Response by Linnean Society of London

- The fact that the NERC/RCUK Programme has recognised the importance of Webbased taxonomy has, in itself, been important. Support for developing software and workflows and for testing systems using specific taxonomic content is less likely to be funded outside a dedicated programme. The Linnean Society is dedicated to encouraging natural history research, communication and species conservation across all groups of organisms. It therefore welcomes any support for biodiversity informatics,
a subject which is already growing in impact as the Web becomes the dominant source of such data.

Loss of biodiversity and the response of species to environmental change are the main areas of societal importance in the field of biodiversity informatics. Much of the research is novel, given the relatively early stage of the subject’s development. The element of novelty seems particularly appropriate for Research Council support.

*End of response by Dr Ruth Temple, Executive Secretary, Linnean Society of London* (return to ‘C’ response list)

**Response by The UK Computing Research Committee (UKCRC)**

- We have evaluated the impact under ten headings, selecting just a few examples to illustrate each point.

**UK Centres of excellence**

Prestigious centres of e-Science research have been set up at most of the leading CS Departments in UK. They include Oxford, UCL, Newcastle, Manchester, Edinburgh, Nottingham, Imperial, Belfast and Southampton, most of which are major nodes in the UK’s National Grid Service. The programme also established novel institutions that have developed close links with CS, such as the National Centre for e-Social Science and the first national Digital Curation Centre.

The UK has had the foresight to recognise that research software must be hardened, supported and sustained if it is to have a life time beyond prototypes and impact beyond its origins. The National Grid Service and the Open Middleware Infrastructure Institute-UK are important steps to the achievement of software sustainability.

**Digital Economy**

The eScience programme has been excellent grounding for the cross council Digital Economies programme, building on experience of common research challenges, inter disciplinary methods and intra-disciplinary mix of theory and applied computing. All three funded hubs of the Digital Economy Programme have their roots in the e-Science programme and are located at leading e-Science and e-Social Science centres driven by CS researchers (Watson at Newcastle, Rodden at Nottingham, Edwards at Aberdeen).

**Industrial connections**

Over 70 companies were involved in the first phase of the initiative; and some are funding follow-on work. Notably Microsoft Corp at Redmond, are still heavily engaged on novel publishing methods emerging from the EPSRC CombeChem pilot at Southampton; and they provide financially to support work at Newcastle on cloud computing and Manchester on data mining.

The Belfast e-Science Centre, in conjunction with the BBC and BT, have developed infrastructure to handle petabytes of personal media data and are pioneering mechanisms to extend the BBC iPlayer. Belfast developed the UK’s first financial services grid with First Derivatives plc integrating the technology and the approach within First Derivatives product line.

The North East Regional e-Science Centre’s approach to “cloud-based” e-Science garnered the following statement from the CEO of JBoss "your work has influenced vendor strategies as much as it has been influenced by those strategies, which is refreshing".

**Spin-out companies**

The MESSAGE and DiscoveryNet Pilots had direct exploitation routes into Inforsense, a pre-existing company at Imperial recently bought by IDBS. E-Science spin-outs include Cybula at York arising from the DAME project; Inkspot from the North East Regional e-Science Centre and EverI from the Belfast e-Science Centre. The myGrid
project based at Manchester is partnering with an established biotech support company Eagle Genomics.

**International leadership**

The Digital Curation Centre has combined theoretical computing research with practice. It is the model for EU’s PARSE programme. The Protégé-OWL ontology development tool is currently being used to develop the next generation of the International Classification of Diseases by the World Health Organisation.

The National e-Science Centre and the e-Science Institute have taken an international lead in education and dissemination, bringing together computer scientists with natural scientists. They are now models for countries throughout Europe and Australia.

The UK showed significant leadership on moving Grid standards to Web Services, which was strongly endorsed by industry, including Microsoft and IBM, who committed resources (people and project funding) to facilitate this.

**International standardisation**

Leading UK CS researchers have been instrumental in leading international standards, for example in: Open/Global Grid Forum including architecture (OSGI), Data access (OGSA-DAIS), Job submission (JSDL), Grid programming (SAGA), and Semantic Grid; and W3C Semantic Web languages RDF, SKOS and OWL.

The W3C OWL 2.0 specification, driven by realistic life science case studies, is being incorporated into the chEBI chemical compounds ontology by the European Bioinformatics Institute.

Research into provenance of data and workflows has lead to new mechanisms for data representation in large scale astronomy and biological archive data. The international Open Provenance Model movement is now forming part of a W3C incubator in provenance representation. OPM has been adopted by Microsoft Corp in their Trident scientific workflow system.

**Marks of international distinction**

UK CS researchers have spoken at every major international conference in the field and chaired most of them. Our annual All Hands Meeting attracts over 600 delegates including significant numbers from overseas and from industry. UK CS researchers have also advised on NSF, EU and OECD e-Science and e-Infrastructure policy. The technical manager of the EU’s EGEE III pan-European e-Infrastructure emerged from the UK (Newhouse).


**Interdisciplinary connections**

The programme has activated a genuine appreciation from many scientists for the methods of software engineering which deliver benefit not only in the original implementation of new tools, but also in subsequent tool evolution, driven by the needs of scientific researchers.

The Taverna workflow system, is used by over 350 organisations world-wide including universities, public and private scientific research institutes national and international, and private industry (including 25 SMEs and 12 major R&D Biotechs/Pharmaceutical companies). Moreover, although it was originally developed for the Life Sciences, it has subsequently been adopted by astronomy, chemistry, social sciences, climate modelling and notably by the US NCI caBIG cancer cyberinfrastructure and the EU NordicGrids.
The DAME distributed decision support system for real-time monitoring of airplane engines has been adopted by Rolls-Royce; moreover the techniques developed have been transferred to a virtual laboratory (CARMEN) for neurophysiology where the signals are neural activity recordings rather than engine instrument readings.

**Educational benefits in UK**
Within CS itself, e-Science topics such as distributed and grid computing have established themselves with real case studies in undergraduate and postgraduate curricula.

CS PhD students working in the e-Science programme include the EuroSys Roger Needham PhD Award winner (Cook, 2007) and the runner up of the CPHC/BCS Distinguished Dissertation competition (Missier, 2008).

**Computer Science Research**
The e-Science programme stimulated fundamental and applied computer science research into problems prevalent in e-Science applications and large scale infrastructure through investments in established CS Interdisciplinary Research Centres, an EPSRC Fundamental of CS in e-Science special programme and by bringing together CS researchers and scientists in pilots and centres.

Work on the use of description logics and ontologies for the representation of biomedical knowledge by Oxford and Manchester led to new ontology development tools (Protégé-OWL) adopted by the World Health Organisation amongst many others, and fundamental research into ontology modularisation, explanation and the representation and reasoning over structures.

*End of response by Professor Muffy Calder, Chair, UKCRC* (return to ‘C’ response list)

**Response by Professor Dame Ann Dowling, Chair, Engineering Panel in RAE 2008**

- We are surprised given the scale of investment in e-Science that relatively few institutions referred to e-Science in the information they provided in their RAE2008 Submissions to the Engineering Units of Assessment. The submissions are now available on-line at [http://www.rae.ac.uk/submissions/](http://www.rae.ac.uk/submissions/) and analysis of the institutions’ RA5a statements about their research environment and esteem indicators (which can include information of collaborators) give the following number of references to e-Science:

<table>
<thead>
<tr>
<th>Unit of Assessment</th>
<th>Sub-panel area</th>
<th>Number of Institutions referring to e-Science in their RA5a</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>Electrical &amp; Electronic Engineering</td>
<td>6</td>
</tr>
<tr>
<td>25</td>
<td>General Engineering and Mineral &amp; Mining Engineering</td>
<td>2</td>
</tr>
<tr>
<td>26</td>
<td>Chemical Engineering</td>
<td>1</td>
</tr>
<tr>
<td>27</td>
<td>Civil Engineering</td>
<td>3</td>
</tr>
<tr>
<td>28</td>
<td>Mechanical, Aeronautical &amp; Manufacturing Engineering</td>
<td>2</td>
</tr>
<tr>
<td>29</td>
<td>Metallurgy and Materials</td>
<td>0</td>
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</tbody>
</table>

*End of response by Professor Dame Ann Dowling, Chair, Engineering Panel in RAE 2008* (return to ‘C’ response list)
D. What are the future opportunities for UK e-Science?

The following key points were highlighted:

- It is widely agreed that the strong initial momentum generated by the UK e-Science programme must be sustained. It is generally felt that e-Science is an important research area that unites the skills of both computer and application scientists. The multi-disciplinary e-Science community is viewed as being energetic and containing a wide depth of knowledge. The challenge now facing UK e-Science is to consolidate the good work that has been undertaken and to establish itself as a widespread practice, which will help deliver an increasing level of impact.

- In a changing world, the needs of scientists change, and the infrastructure of the e-Science programme has to evolve. The UK should not underestimate the challenges and costs of sustaining the collaborations that have already been initiated. Without this there will be a genuine danger of fragmentation and loss of momentum. The Engineering Taskforce and the e-Science Institute in Edinburgh, which provided opportunities for training, sharing experiences and learning about the new technologies relevant to e-Science were highly valued.

- The initial work of the UK Programme focussed firmly on applications in science and engineering. The arts and humanities now present a major opportunity to enhance the impact of e-Science on an additional discipline. Whilst the social science research community is not well suited to collaborative data management and there are major challenges in transforming the research habits in this area, there is great potential to share best practice within e-Science to enhance future research and data sharing within this area.

- It is seen as imperative that the integration of the Technology Strategy Board and Research Council strategies is continued. This will help provide a number of opportunities for engagement with industry and entrepreneurship at Universities. The potential for operating in areas of knowledge exchange with industrial partners is seen as an opportunity to lever funding, even in the current financial climate.

- It is genuinely believed that e-Science within the UK has the potential to be on the leading edge of research in to areas that have the potential for high impact. The UK has the potential to be at the forefront of research in disciplines such as: Energy, Living with Environmental Change, Global Threats to Security and Ageing: Life Long Health and Wellbeing. To support this research, in a manner that is internationally competitive, transcends individual councils and will require effective coordinated cross-council e-Science collaboration.

- It is seen as essential that the UK fully utilise the expertise and knowledge that were generated in the early phases of the e-Science Programme. Opportunities exist in exploiting the skill base that has already been acquired by the UK. It is also important to invest in postgraduate training to create a generation of scientists and engineers who routinely exploit computational and data-intensive methods in their daily work. It is seen as imperative that real researchers have the confidence and skills to drive developments within the e-Science programme.
Follow the links below to view the responses

Visiting Panel:
- Aberystwyth University (no response against individual framework questions)
- Liverpool John Moores University
- Newcastle University
- Rothamsted Research
- University of Aberdeen
- University of Bristol (no response against individual framework questions)
- University of Cambridge
- University of Edinburgh
- University of Glasgow
- University of Manchester (The) (2 submissions)
- University of Nottingham (no response against individual framework questions)
- University of Oxford (2 submissions)
- University of Southampton
- University of Stirling
- Wellcome Trust Sanger Institute (no response against individual framework questions)
- White Rose Universities (Leeds, Sheffield and York)

Panel Visits:
- University of Reading
- Proudman Oceanographic Laboratory (no response against individual framework questions)

- Imperial College London (2 submissions)
- King’s College London
- Natural History Museum, London
- University College London (no response against individual framework questions)

- Rutherford Appleton Laboratory (RAL), STFC (a combined submission from all the projects being reviewed during the visit to RAL)

Others:
- Anatomical Society of Great Britain & Northern Ireland
- Diamond Light Source
- Institute of Physics (IoP) (no response against individual framework questions – please see Section F - Other Comments below)
- Isaac Newton Institute for Mathematical Sciences, Cambridge
- Linnean Society of London
- The UK Computing Research Committee (UKCRC)
- Professor Dame Ann Dowling, Chair, Engineering Panel in RAE 2008
- Professor Nigel Hitchin, Panel Chair of last RAE exercise (no response against individual framework questions – please see Section F - Other Comments below)
Response by Liverpool John Moores University

- There is still much to do on optimized remote access to facilities (not computers!) to solve socio-political ("its mine not yours" / "my facility is X times better than yours so I should have more of your time in exchange") issues. A markets based approach to facility valuation has great promise here.

End of response by Liverpool John Moores University (return to 'D' response list)

Response by Newcastle University

- The initial work of the UK Programme was firmly focussed on applications in science and engineering. However, with the commitment of the full range of the UK research councils, opportunities arose to spread out into other areas. The arts and humanities now present a major source of opportunities. As in many sciences, vast amounts of data can be collected, and there is huge potential for sharing, automated analysis and annotation. Our experience is that those working in those areas are creative and very open to new ideas, but in general there is limited knowledge of how computer infrastructure could be exploited. Therefore, dedicated effort is need on both sides to identify and grasp these opportunities. At Newcastle, this potential has been recognised, and the University has invested heavily in it. This includes: Culture Lab – a £4M refurbishment creating open-plan multi-disciplinary research spaces, a performance space and dedicated electronics, workshop, multimedia and sound spaces; and the Informatics Research Institute – providing funding to continue the work of NEReSC, and expand it into new areas (e.g. the digital economy, creative arts and education). This allowed Newcastle to play a major part in the UK Digital Economy programme, culminating in the successful bid to create a £12M Hub in “Social Inclusion through the Digital Economy”. This will build on the ongoing work on e-Science infrastructure and apply to the societal challenge of how to use new technologies to benefit those who may otherwise be left behind – the old, disabled and disaffected youth.

Analysing the current state of e-Science in the UK, the main strengths are: the wide acceptance that it is an important research area across both computer and application scientists; the energetic, multi-disciplinary community; and the depth and breadth of knowledge. Weaknesses are: the removal of core funding for centres of excellence which reduces the effort available to pioneer the application of e-Science in new areas; the removal of the visionary and effective leadership that drove the early years of the programme; and, the research evaluation exercises that are based on single disciplines.

The main opportunities are to continue to take e-Science out into new areas, for example the arts and humanities. The main threat is that the lack integrated, service-based solutions will limit the uptake of e-Science techniques to those with high levels of IT skills. Our view is that the research councils should be running programmes that encourage the initial moves of e-Science techniques into new areas of research; these will gain the confidence and support of key researchers, showcase the potential benefits, and encourage others in those areas to engage. The core programme’s pilot projects were an excellent example of this; Newcastle gained enormously from the two it led, and the other two in which it played a major role.

End of response by Newcastle University (return to ‘D’ response list)

Response by Rothamsted Research

- In the biological sciences, it is well-known that we are about to experience a step-change (1-2 orders of magnitude) in the volumes of genome data that will be produced by “Next Generation” sequencing instruments. This is going to require significant investment in e-science infrastructures, software and data management schemes that if these data are to be made available to the UK and international research community.
The huge changes in data generation rate are not restricted to genome sequence data. Many other areas of biology are moving to real-time data capture as new sensors are developed and quantitative imaging of live biological structures (high content screening) becomes affordable for academic (and commercial) research scientists.

Many commentators are predicting that biology will soon overtake high energy physics as the most data-intensive science. This offers myriad opportunities for e-Science to have an impact on areas of (bio)science which will affect public policy objectives and economic growth and wellbeing in the UK e.g. adapting to climate change, food and energy security, public health etc etc. A re-orientation of e-science research towards the biosciences, their applications and their industries will give e-science new potential impact for the next few decades.

*End of response by Rothamsted Research (return to ‘D’ response list)*

**Response by University of Aberdeen**

- Within the e-Social Science programme there is an excellent mix of computer scientists and social scientists (across a range of sub-disciplines). This community is closely knit (thanks to the part played by the National Centre for eSocial Science). This community is able to view e-Science from multiple perspectives, creating a platform to address future challenges.

RCUK should consider future funding for e-Science, but focussed on technology developments needed to support research into key economic, social or environmental challenges, e.g. climate change.

*End of response by University of Aberdeen (return to ‘D’ response list)*

**Response by University of Cambridge**

- Two important features of the eScience programme were the Engineering Taskforce and the popularity of the eScience Institute in Edinburgh as a venue for face-to-face meetings and training. Both were invaluable means of sharing experiences and learning about the new technologies releveant to eScience. A new set of Special Interest Groups may help replace the former and a renewed impetus behind the All Hands meeting the latter.

I believe that the research councils should focus on supporting new science rather than divert funds to large scale software engineering or knowledge transfer activities that are at least one step removed from the practice of doing science. One of the strengths of the eScience programme was that it supported relatively small scale, innovative science and recognised that the necessary technology (whether that be Globus & Condor or web services) almost always feeds in from elsewhere.

*End of response by University of Cambridge (return to ‘D’ response list)*

**Response by University of Edinburgh**

- It is vital for the UK’s economy and research base that the strong initial momentum in e-Science is sustained through coordination across agencies shaped by a clear and broad multidisciplinary vision to grasp the increasing opportunities brought about by the digital revolution. A strategy for data-intensive computing is urgently required.

Further work is needed to draw together the UK’s excellent HPC, numerical analysis, and computer science research communities. It is particularly important to invest in postgraduate training to create a generation of scientists and engineers who routinely exploit computational and data-intensive methods in their daily work.

Internationally, great strength has been developed in collaborating by sharing data; for example, IPCC collaboration on earth-systems data, the European INSPIRE Directive for geospatial data, and the international pooling of genetic data as exemplified by the
EBI. The challenge is to step up from individual beacons of data sharing excellence to a pervasive environment, rich in data, methods and tools for all researchers.

End of response by University of Edinburgh

Response by University of Glasgow

- Is the research community appropriately structured to respond to current and emerging technological/societal challenges? If not, what improvements could be implemented?
  - Numerous future opportunities exist for UK e-Science. Particular application domains can all benefit from e-Science technologies and expertise. At NeSC Glasgow, a particular focus has been upon supporting collaborations requiring finer-grained security across organisational boundaries. In this area, a multitude of future opportunities exist and are being vigorously pursued. This includes funding through UK Research Councils, organisations like the Chief Scientist Office in Scotland, the Wellcome Trust, as well as EU funding streams.
  - A major challenge is in typical lack of inter-operability of developed e-Science solutions. Much more focus on development of a production level software stack for compute-oriented problems is required. Initiatives such as the EGI “seem” to be starting from an EGEE software stack basis. Given our experiences at NeSC Glasgow, I am concerned about these kinds of developments.

What are the current strengths, weaknesses and opportunities in UK e Science?

- A major strength is in the expertise that has now been acquired in working with a wide array of research communities using a wide range of technologies. At NeSC in Glasgow we have acquired a portfolio of projects and expertise in various software systems and the practicalities involved in their application. Many research communities have now been exposed to the benefits of e-Science and have engaged (although many more remain un-engaged).
- It could be argued that too much effort has been focused on HPC-oriented Grid solutions. Many researchers are not constrained by access to HPC facilities, but rather require support for data management and security issues.
- A major weakness has been the fluidity and immaturity of many of the middleware solutions that currently exist. There is much confusion with e-Science software and Grid software vs web services and the move to web 2.0 and cloud based systems.

Where should the Research Councils focus support for e-Science activity in the future?

- It is key that a strong and stable middleware-base exists for researchers to use/adapt in the future.
- I would suggest that expert centres are established to aid others in software deployment and usage areas. (Many e-Science centres and researchers have wasted far too many hours in trying to get the same piece of software to a usable status).
- Whatever future focus the research councils identify, I would suggest that continued assessment and a far more rigorous monitoring and evaluation process are made. If a project is funded to develop middleware then this has to be proven to function and address benchmarking requirements from external evaluators for example. The area of software testing; conformance; compliance to standards; performance evaluation and benchmarking are well understood in other domains, e.g. the telecoms community. Currently the e-Science community has been far more ad hoc (chaotic?).

End of response by University of Glasgow
Response by The University of Manchester (1)

- UK e-Science has established the capacity to provide support in key technologies described above that will become increasingly essential to research. However, the world is not static; the needs and expectations of scientists change, and the infrastructure has to evolve. We should not underestimate the challenges and costs of sustaining the collaborations and the software/resources that we have initiated. We should also expect to have to continue to work energetically at coordinating efforts between the research councils and with global e-Science initiatives. Without this, we will be in danger of fragmentation and loss of momentum.

Although terrific progress has been made, usability of e-Infrastructure by other scientific programmers and scientists with less technical expertise still remains as both an opportunity and a challenge. Scientific gateways that hide underlying complexity from end users are essential; otherwise, a majority of scientists will never embed e-Science into their everyday work. Other non-technical barriers to the wider adoption of e-Science need to be addressed, including lack of skills and uncertainty over funding models for sustaining what has been achieved. The technical infrastructure needs to be embedded within a “human infrastructure” consisting of social and organisational arrangements that enable the technologies to be effectively utilised, maintained and further developed.

Much of e-Science is predicated on increased sharing of resources, data, publications and expertise, and on enhancing collaboration between scientists in both formal and informal ways. However, there are significant governance, cultural, funding and political/legal constraints that may inhibit the willingness of scientists to share their work more openly. This is not so much a technical issue (though bureaucratic models for secure access to resources do not help) but a social-political one that must be addressed by funding councils, learned societies and political will. The stress placed by the UK programme in developing a specific “social” dimension to the application of technology provides an opportunity to address these challenges, for example in the Digital Economy initiative.

The automation of the handling and analysis of massive volumes of data provided by sensor networks, large scale instruments, robotic laboratory apparatus, and supercomputers. The development of tools that can scale to such quantities of data is still in its infancy, though, clearly, workflow systems will be essential, as indicated by the EU ESFRI projects. This problem raises (at least) two key challenges, that have been addressed in the Programme. The first is scale, with petabytes of data needing to be analysed and defined, in many domains. The development of a reliable infrastructure for processing such data on a European scale with EGEE and on a national scale with NGS, along with campus and regional Grids, makes this possible. The second is of complexity, with multiple sources of data in widely differing formats. It is a major achievement of the UK Programme that it identified this second challenge very early on. It therefore did not pour all its resources into developing distributed supercomputing but developed projects, which used tools from the semantic web and research on data integration, and scientific workflows.

These two challenges relate to the “fourth paradigm” of scientific research, where data becomes the focus and access to tools provided over the internet become the key research instruments.

New models of publishing and tools for scientific collaboration - which will be increasingly between disciplines that are unfamiliar with each others’ research methods and technical terms. Scientists will publish methods alongside their data and articles, and publish “nanopublications” or research objects that represent computationally processable facts and opinions. Data, methods and articles will be seamlessly connected, and openly accessible. Semantic technology for information searching and transformation will need to build on preliminary work on Semantic Web and Semantic Grid. The UK Core Programme has collaborated with JISC to develop such tools. This provides the possibility for the sustainable development of such tools, given JISC’s remit to support research generally across all HEIs. The work on e-Laboratories being
conducted by the e-Social Science programme, and building on the myGrid outcomes, is one example.

The provision of tools for mining and searching scientific literature. This is also undergoing very rapid growth. For example, Medline contains over 14 million records, extending its coverage with more than 40,000 abstracts each month. Without automation via such tools, it will be increasingly difficult to establish whether research is genuinely novel and will increasingly lead to a dilution of the impact of scientific research via duplication.

The UK e-Social Science programme has developed tools that can transform the discipline, for example by social simulation. It is also developing tools to exploit the social data increasingly ‘born digital’ as a by-product of people’s everyday activities. It has brought together stakeholders from government, research data services and the commercial sector to investigate the challenges in making this data more accessible for research, and is leading in the development of tools to enable medical and social researchers to share research data and collaborate.

End of response by The University of Manchester (return to ‘D’ response list)

Response by The University of Manchester (2)

- The opportunities for UK e-Science are now to translate the good work in to more widespread practice – and to deliver increased impact. This is partly a cultural problem in research science which can often be slow to appreciate the long-term benefits of e-Science and remains focused on short-term goals (understandably in many cases, owing to the pressures on modern scientists to publish papers and write grants).

End of response by Professor Simon Hubbard, The University of Manchester (return to ‘D’ response list)

Response by University of Oxford (1)

- If the UK is to remain internationally competitive there is a need to maintain the efforts in e-Science research and infrastructure –as is often the case we face the opportunity of snatching defeat from the jaws of success.

In all disciplines there are increasing amounts of data created with the use of public funds. These must be accessed and analysed in innovative ways to provide better answers to society’s pressing questions, for example, those identified as Cross-Council themes: Energy, Living with Environmental Change, Global Threats to Security and Ageing: Life Long Health and Wellbeing.

An area that was touched on in the programme but certainly needs further attention is that of skills. We need to ensure that the next generation of researchers are equipped with the appropriate skill set and that means education and training from the undergraduate through to graduate programmes.

As noted above we believe there needs to be a coordinated approach to research infrastructure and failure to act strategically will mean that each researcher or research community has to act independently to find the resources they need, creating delays in science advances and providing poor return on investment. It will also mean that we are not well positioned in terms of international influence and our capability to host shared international facilities in the UK (EU PRAE etc).

It would be good to see a continuing integration of the now TSB and research council strategies in this area as e-science appears to provide a number of opportunities for engagement with industry and entrepreneurship at the Universities.

End of response by University of Oxford (return to ‘D’ response list)
Response by University of Oxford (2)

- e-Science in the UK has the potential to weather the potential decline in overall research funding because it is well positioned in relation to many other disciplines. It can be on the leading edges of research in areas that are of extremely high priority, such as climate change and health.

UK e-Science is also positioned well across the disciplines and internationally. The social sciences and humanities are increasingly looking to computational sciences as a means to advancing their own research agendas. For example, it looks as if two researchers from the e-Science community will be directing the UK’s e-Social Science Programme, replacing a social scientist. This is a remarkable level of trust extended beyond the domain of the social sciences. The potential problem of this marriage of computer sciences and domain researchers is to keep computer science problems at the cutting edge of domain research, rather than being a service to domain researchers. There should be a requirement that e-Science projects are viewed as advancing both the computational and domain sides of any collaboration.

Secondly, more international scholars are looking to the UK for collaborative partnerships and insights into how more multi-disciplinary work can be accomplished.

End of response by Professor William Dutton, Oxford Internet Institute, University of Oxford

Response by University of Southampton

- Is the research community appropriately structured to respond to current and emerging technological/societal challenges? If not, what improvements could be implemented?

Two distinct efforts are needed: (1) the research community must be able to benefit from new technologies, techniques and methods in conducting research; and (2) innovation in these new developments must continue.

Achieving the first requires a balance of common infrastructure and domain-specific function. This requires some form of cooperation across research communities. Furthermore, challenges such as climate change require a degree of interdisciplinarity and scale of team that has not been supported before and hence also requires cooperation and perhaps collaborative working mechanisms. Both of these are an argument for the continuation of some form of cross-council “core programme”, and for effective symbiosis with JISC, which has already demonstrated its support for community-specific activities through cofounding arrangements.

Achieving (2) requires funding for continued interdisciplinary research which is applied and adventurous. We believe a crucially important engine for both (1) and (2) is the next generation of researchers, and we are committed through our DTC programmes to building capacity in new methods and encouraging adventure and innovation.

What are the current strengths, weaknesses and opportunities in UK e Science?

Based on our experience in Southampton: **Strengths:** volume and breadth of the activity in the academic community, pervasive engagement of computer scientists, emphasis on new research outcomes, data centric approach. **Weaknesses:** kick-started activities are fragile and required sustained multidisciplinary investment to establish themselves; an appropriate degree of coordination is required to maximise interdisciplinary potential and avoid re-invention. **Opportunities:** to accelerate science, invest in better understanding of data and dissemination of new methods.

Where should the Research Councils focus support for e-Science activity in the future?

Challenges in climate, health and energy require data-intensive techniques and large multidisciplinary collaborations. To support this transcends individual councils and requires an effective coordinated cross-council e-Science activity. The emphasis on
data should be maintained and supplemented with due attention to method, and it follows that the users of research data need sustained and usable tools and training in new methods.

End of response by University of Southampton

Response by University of Stirling

- Institutional evidence from the University of Stirling

The DAMES Node offers a critical contribution to an otherwise neglected aspect of social science research (data management). In the context of secure access requirements for micro-data, growing recognition of the need for documentation through replication in social science research, and recognition of the impact of data management operations such as standardisation upon analytical results, the Node has a unique opportunity to establish standards for collaboration and communication involving structured metadata and social science workflows. Success in these provisions will lead to a step change in the conduct of social science research.

Future opportunities: Responses to questions posed by the e-Science Review framework

The social science research community is not well suited to collaborative data management due to the use of proprietary software packages and lack of incentives for documentation and replication. There are major challenges in transforming the research culture to value documentation and replication, such as in asserting replication policies comparable to those found in other sciences as requirements for publication.

We suggest that DAMES’ initiatives in data management activities exemplify a global trend in issues of dealing with growing volumes of data and permutations for data analysis. E-Science initiatives such as DAMES, and those found across UK institutions, therefore offer resources for organising and navigating the global ‘data deluge’.

End of response by University of Stirling

Response by White Rose Universities (Leeds, Sheffield and York)

- To harvest the e-Science Programme’s achievements it is essential that selected e-Science activities are supported in the future, in particular the transfer of e-Science technologies/frameworks purposely developed for certain domains into new application areas. The e-Science Programme has facilitated multi-disciplinary collaboration. This capability needs to be nurtured. There is a clear need to promote scientific collaboration further and support sharing knowledge within established consortia as well as to create further research institutes across different domains. The existence of virtual flexible institutes will help researchers from different disciplines to improve their cross domain knowledge and use the advances of other disciplines in their domain.

The UK e-Science Programme has helped to establish many international links and has facilitated the development of lasting research collaboration with international communities. These activities need to be continued in the future.

The UK e-Science Programme enabled the WRG researchers to build considerable knowledge and skills base in e-Science technologies. We have learned how to understand, apply and develop more advanced technologies and new frameworks in certain fields. This is one of our current strengths. It would be a significant weakness of this initiative not to fully utilise the expertise and knowledge gained in the early phases of this Programme. Thus e-Science opportunities lie in exploiting our acquired skills base. For example the framework for managing large volumes of distributed data in one discipline may be adopted by other disciplines. e-Science technologies are transferable across different domains. A forward looking initiative for exploiting our e-Science expertise will enable the UK to consolidate on current e-Science achievements.
There are many successes in e-Science and these need to be supported in the future. More emphasis needs to be placed on increasing effort for supporting real researchers, thus enabling them to innovate and be adventurous. Too often intensive efforts go into technical developments that are not used by researchers, instead of supporting individual user’s requests and for operation staff working with real researchers.

End of response by White Rose Universities (Leeds, Sheffield and York) (return to ‘D’ response list)

Response by University of Reading

- We believe that wider and improved use of e-Science would provide better means for researchers to respond to current and emerging challenges. As such, more researchers should be using this new way of working, both in the areas where e-Science is stronger and in those where is yet to impact more widely. There is now great opportunity to achieve this. In order to do so, we believe that the focus of the work needs to change from researching the technologies to providing concrete research tools that are immediately useful to broad communities of researchers. It is necessary that real research users drive developments; that code and tools are not unnecessarily duplicated; and that tools are completed to a usable level. It is also necessary to integrate these tools to create e-Research environments. This opportunity must be grasped before the knowledge and expertise gained in the e-Science programme is dissipated.

All the UK Research Councils’ strategies allude to e-Science being a key enabling mechanism for modern research. We hope that this will lead to collaborations between scientists and technologists being the norm in scientific research, rather than the province of a few dedicated projects. However, this is new territory for the Research Councils, who need to develop mechanisms for assessing proposals of such interdisciplinary projects. Changes will need to be made to reviewing and assessment processes, and different kinds of research output other than papers (e.g. software, data provision) must be recognized as valuable.

End of response by University of Reading (return to ‘D’ response list)

Response by Imperial College London (1)

- We believe there are major opportunities. The collaborative, computing and applied groups, way of working has been shown to be very productive and to lead to real advances in working infrastructure. If this posture can be kept up the opportunities are major.

Also the widening of the e-Science agenda to encompass Internet and mobile applications has provided access to a global community for the application of these ideas. The basic way of working and software technologies developed in the e-Science programme have general applicability here and, if correctly used, the opportunities to make major public or commercial developments to the advantage of the UK are major.

More effective and efficient techniques for managing federations of databases. Creation of GRID computing resources for both data management and computation in a form that IT services become a utility that can be paid for in relation to use and without the capital investment in hardware. Secure management of data.

End of response by Imperial College London (return to ‘D’ response list)

Response by Imperial College London (2)

- I think there are major opportunities. The collaborative, computing and applied groups, way of working has been shown to be very productive and to lead to real advances in working infrastructure. If this posture can be kept up the opportunities are major.
Also the widening of the e-Science agenda to encompass Internet and mobile applications has provided access to a global community for the application of these ideas. The basic way of working and software technologies developed in the e-Science programme have general applicability here and, if correctly used, the opportunities to make major public or commercial developments to the advantage of the UK are major.

End of response by Professor John Darlington, Imperial College London

Response by King’s College London

- In the past, the sciences have typically been built around experimental and instrumental data: the e-Science Programme was a response to the growth of the volume and complexity of this data. The humanities on the other hand have historically been built around the library and the archive. Just as e-science bought to the physics and astronomy communities the new kinds of research enabled by massive processing power and grid capacity, the greatest future potential of e-science for the humanities is to define and realize new ways in which humanities research agendas can exploit digital (or digitized) resources. The present mass of such data is dispersed, fuzzy, semantically and/or linguistically incompatible, inconsistently available, created at different times for different purposes, multimedia and multifaceted. By its very nature, it defies the core concepts of order, *topos* and classification that humanists have for decades devised, and subsequently taken for granted, in their institutions, libraries and familiar research environments. Put simply, e-science can help provide those humanists with the equivalent tools and ordering systems that they need to deal with the global mass of digital information and resources. Some of these needs will involve grids, some ontologies, some processing power, some Semantic Web technologies: we need to research and understand those requirements, and address the technological and cultural challenges they present. In practice, this means continuing the integration of e-science within the research practices of the digital humanities. Particular areas can be identified. For example, the application of digital tools and methods is well advanced in the field of musicology (see above, also the link http://wiki.esi.ac.uk/Musicology): we consider that there are significant opportunities for further research networks and projects in this area. Likewise text mining (see above) will allow humanists, long used to dealing with non-digital text corpora at the scale of the library to adapt existing methods, and create new ones, that are scalable to digital collections of many terabytes in size. Another critical area is geospatial computing (see http://www.oerc.ox.ac.uk/ieee/geospatial). Some 80% of all information on the internet is in some way linked to, or descriptive of, place: mapping technologies for the humanities and arts, which have long been a small and highly specialized niche, are now coming to the fore as a key set of methods which humanists will need to exploit their data.

It is an oft-quoted truth that research in the humanities and arts has a strong intellectual and strategic focus on outcomes and research results. E-science however presents these communities with a superb opportunity for enrichment by focusing on research processes. KCL’s work in the area of data provenance (see above) illustrates the importance of this in a ‘classic’ e-science sense, but future research could draw on this intellectual basis in the fields of (e.g.) intangible cultural heritage, text analysis and interpretation support (an aspect being examined in detail by the Arts and Humanities e-Science Initiative project, e-Science for the Study of Ancient Documents - http://esad.classics.ox.ac.uk/). Given the pool of experience of such projects in Europe however, there are significant opportunities for collaborating with Europe-wide grid infrastructures. This includes working with (for example) the EGI to assess humanities user needs for grids, and applying this experience in the UK with regard to national services such as the NGS.

A key finding of the Arts and Humanities e-Science Initiative thus far is that data-driven research does not need to be about processing power and large scale computation. Rather, it can be about enabling new forms of scholarly communication. This is particularly appropriate for the new kinds of interdisciplinary collaboration that e-science involves. Given that the Arts and Humanities e-Science Initiative is founded on complex
collaborative projects, the humanities are very well placed to bring scholarly communities together in this way.

End of response by King’s College London (return to ‘D’ response list)

Response by Natural History Museum, London

- A greater spirit of collaboration exists internationally in biodiversity informatics (e.g. the Encyclopedia of Life project) than even three years ago. However, there is much further to go in structuring the efforts of the community if a common global infrastructure is to be achieved. Such an infrastructure will need to ensure maximum interoperability of data, agree acceptable standards, expand vastly the amount of digital data available online, and provide open access to data and relevant Web services.

Opportunities will be impeded if citation measures other than publications are not developed and accepted in the assessment of science outputs. Evidence being taken in this review seems to place less emphasis on database and software developments, which are often key results of e-Science projects.

Today most science is conducted with a strong ‘e’ dimension. However, further development and integration of computing with other disciplines is still needed, and the view that e-Science can stand alone without dedicated support is risky. With the biodiversity informatics community becoming established and increasingly conscious of the role it might play in stemming biodiversity loss (even if this is indirect through information provision), a strong argument can be made for future support of this area from the UK Research Councils – particularly as this community has become better co-ordinated in recent years and the subject more strongly developed. The role of the Research Councils might especially be to support novel aspects of biodiversity informatics.

End of response by Natural History Museum, London (return to ‘D’ response list)

Response by Rutherford Appleton Laboratory (RAL), STFC

- To leverage the expertise in data management and operational infrastructure to take a leading role in the development more broadly applied data management standards and services. Thereby, ensuring that UK researchers requirements are taken into full account and positioning UK researchers to exploit broader infrastructure (including access to data) as it becomes available.

The standard catalog interfaces deployed by DLS and ISIS allow, in principal, integrated data searches across these facilities. The integration of this data access with the computational infrastructure coordinated by the NGS provides the building blocks for large scale data analysis by users from across the UK (and beyond). These opportunities are now being exploited by ISIS and DLS through integration into their supported data analysis frameworks.

End of response by Rutherford Appleton Laboratory (RAL), STFC (return to ‘D’ response list)

Response by Anatomical Society of Great Britain & Northern Ireland

- The UK bioinformatics community is adequately structured for and quite capable of responding to challenges: too much of the current work is virtuous but dull. What the community requires is the stimulus to apply for an interesting and directed e-Science call. Academic anatomists would benefit were this in the general area of theoretical systems biology.

End of response by Jonathan Bard, Anatomical Society of Great Britain & Northern Ireland (return to ‘D’ response list)
Response by Diamond Light Source

- Linking all the developments so that experimental processes, data, calculations etc. in broader scientific areas can be combined is an opportunity. In the area of life sciences, this would fit in with the priority for systems biology.

End of response by Dr Colin Nave, Diamond Light Source (return to ‘D’ response list)

Response by Isaac Newton Institute for Mathematical Sciences

- I have touched on this above. Without wishing to diminish in any way the importance of the paradigm for a huge diversity of researchers, areas in BBSRC and NERC are particularly exciting to my mind.

End of response by Sir David Wallace, Director, Isaac Newton Institute for Mathematical Sciences, Cambridge (return to ‘D’ response list)

Response by Linnean Society of London

- The research community in biodiversity informatics is distributed internationally, but shares common aims of building a digital infrastructure and developing systems for carrying out Web-based taxonomy. There is a much greater willingness now to collaborate, particularly in making information interoperable and in contributing to common platforms (notably ‘Encyclopedia of Life’). As biodiversity informatics matures further, technologies are likely to become an integral part of training in taxonomy/systematics.

Much effort is still needed to develop technology and improve data standardisation, so easing data sharing. The greatest challenges remain in increasing vastly online content and accelerating involvement of the taxonomic community. Support from RCUK on user-friendly and robust systems would be highly desirable, particularly in more novel areas.

A further opportunity in this area is to engage further the voluntary sector, including ‘citizen scientists’, in the digitisation of data. There are many amateurs in the UK skilled in species identification and recording in many groups of organisms. The national moth recording scheme (http://www.mothscount.org) is an example of a well organised project. The use of volunteers is established in digitising herbarium collections (herbarium@home.org). There are opportunities for expanding these approaches to other groups. A relatively small amount of support for coordination might lead to gains by means of willing helpers.

End of response by Dr Ruth Temple, Executive Secretary, Linnean Society of London (return to ‘D’ response list)

Response by The UK Computing Research Committee (UKCRC)

- The programme successfully stimulated working collaborations between natural scientists and computer scientists. It also established strong international collaborations. It is important that these established collaborations continue and be allowed to flourish, and that we maintain the research environment that has made such collaborations possible. This will require continued coordination between the research councils to enable mutually beneficial inter-disciplinary research.

UK CS research could benefit from using some of the e-Science technologies to better facilitate collaboration, sharing test data sets and application repositories. (e.g. for machine learning research, software verification research and other large-scale scientific challenges) There is a great opportunity for the EPSRC ITC and Digital Economy programmes to explicitly support such exploitation.
The substantial legacy of applications and data arising from the programme should not be allowed to whither as the underlying technologies evolve. We strongly support initiatives that release academia from a perpetual process of rewriting and reinvention. Technical approaches for the preservation of data and environments, such as virtualisation should also be pursued alongside initiatives that support long term data conservation and software sustainability.

End of response by
Professor Muffy Calder, Chair, UKCRC

Response by Professor Dame Ann Dowling, Chair, Engineering Panel in RAE 2008

- Better connections with mainstream engineering research are necessary if e-Science is to have wider impact

End of response by Professor Dame Ann Dowling, Chair, Engineering Panel in RAE 2008
E. How did the Programme Strategy (having a Core and individual Research Council Programmes, developing tools and applications in parallel) affect the outputs from UK e-Science?

The following key points were highlighted:

- The Programme strategy worked very well, and was judged as being a model to follow by many other countries.

The aspects which worked particularly well were:

- An excellent core programme leadership team was put in place spanning all research councils and the DTI. This provided vision, and direction, but still managed to incorporate the views of the community.

- The balance between investment in pioneering research and in delivering core foundations was extremely well judged. The leadership through the Director General of the Research Councils, coordination through the e-Science Steering Committee and drive from the e-Science Core Programme Director provided a focus and enabling mechanisms that lifted the overall performance of the whole research community.

- The programme was well funded allowing a wide range of significant research projects and sub-programmes to be funded. Core technological developments would have been impossible to fund via the individual research councils funding models and a centralised programme was therefore essential.

- Great effort was put into multi-disciplinary community-building. The programme transformed UK research behaviour: Prior to the programme, meetings that encouraged interdisciplinary thinking were rare. The creation of centres of excellence (including regional e-Science centres) gave resources to set up multi-disciplinary collaborations and to transfer best practise. Both Computer Scientists and Application scientists were included. This led to more multi-disciplinary collaborations.

- Key research leaders were drawn into the programme – It was certainly the case that the Core Programme allowed expertise to be garnered that could be applied in different research council programmes.

- Future programmes need to treat software as a facility, that is, recognise that the collections of software libraries, platforms, tools and systems require a large investment in developing and maintaining software for research.

- Specific cross council efforts are arguably a better way to co-ordinate efforts. The Wellcome Trust, EPSRC, ESRC and MRC joint funding for research into access and use of electronic patient records is a good example of this. Further cross council research ventures that capitalise on previous investments and experiences should most certainly be undertaken.

- However, in some cases, more cohesion and coordination between the core e-science programme and individual Research Council programmes would have been beneficial.

- The approach of a fast ramp-up in funding (in 2001-2) with a sharp cut-off (in 2007-8) was not appropriate. A slower ramp-up and a longer tail might have given more time to experience, understand and address key issues (such as the “software engineering gap”) and foster new practices in Research Councils. Young researchers have been given opportunities to work in exciting projects that cross disciplines. A clear career path for these researchers will have benefits in terms of retained expertise and future of e-Science activities.

- Biodiversity informatics was a small part of the e-Science Programme. As such the Core Programme structure was not particularly relevant to what was a very experimental approach to developing software alongside a considerable cultural change towards larger scale collaboration in taxonomy. Nevertheless, there is much potential for higher level data management when this field expands from the more pioneering stage evident until very recently. Mergers of biodiversity informatics systems are already apparent, but there is much further to go.
Follow the links below to view the responses

Visiting Panel:
- Aberystwyth University (no response against individual framework questions)
- Liverpool John Moores University
- Newcastle University
- Rothamsted Research
- University of Aberdeen
- University of Bristol (no response against individual framework questions)
- University of Cambridge
- University of Edinburgh
- University of Glasgow
- University of Manchester (The) (2 submissions)
- University of Nottingham (no response against individual framework questions)
- University of Oxford (2 submissions)
- University of Southampton
- University of Stirling
- Wellcome Trust Sanger Institute (no response against individual framework questions)
- White Rose Universities (Leeds, Sheffield and York)

Panel Visits:
- University of Reading
- Proudman Oceanographic Laboratory (no response against individual framework questions)

- Imperial College London (2 submissions)
- King’s College London
- Natural History Museum, London
- University College London (no response against individual framework questions)

Rutherford Appleton Laboratory (RAL), STFC (a combined submission from all the projects being reviewed during the visit to RAL)

Others:
- Anatomical Society of Great Britain & Northern Ireland
- Diamond Light Source
- Institute of Physics (IoP) (no response against individual framework questions – please see Section F - Other Comments below)
- Isaac Newton Institute for Mathematical Sciences, Cambridge
- Linnean Society of London
- The UK Computing Research Committee (UKCRC)
- Professor Dame Ann Dowling, Chair, Engineering Panel in RAE 2008
- Professor Nigel Hitchin, Panel Chair of last RAE exercise (no response against individual framework questions – please see Section F - Other Comments below)
Response by Liverpool John Moores University

- Seemed to work well from my point of view, with initial seed funding from the core programme allowing the development of a basic prototype that could then be developed with Research Council into real world tools and applications with strong scientific utility overseen by the domain experts.

End of response by Liverpool John Moores University (return to ‘E’ response list)

Response by Newcastle University

- The UK Programme strategy worked very well, and was judged as being a model to follow by many other countries. The aspects which worked particularly well were:
  - An excellent core programme leadership team was put in place spanning all research councils and the DTI. This provided vision, and direction, but it did listen to the community.
  - It was a well funded programme allowing a wide range of significant research projects and sub-programmes to be funded.
  - Great effort was put into multi-disciplinary community-building.
  - The creation of centres of excellence (including regional e-Science centres) gave resources to set up multi-disciplinary collaborations and to transfer best practise.
  - Both Computer Scientists and Application scientists were included. This led to more multi-disciplinary collaborations than I have seen in the last 25 years.
  - Key research leaders were drawn into the programme – they gave it credibility and won “hearts and minds” to draw in others (by September 2006, a total of 90 e-Science grants worth £45M had been awarded by EPSRC; 74% (£26M) of these grants had PIs in CS departments, the overwhelming majority of these PIs were in RAE 5 or 5* departments).
  - The National e-Science Centre provided both vision and training.
  - Funding to fully participate in international community events led to international impact on academia and industry.

Overall, the programme created many application scientists who are aware of what e-Science can do for them. A smaller, but still significant number can develop and configure this technology to meet their research needs. The programme also created many Computer Scientists with systems design and building skills (esp. in service-based computing). Some of the infrastructure we built was widely used (OGSA-DQP, produced with Manchester, has had over 600 downloads and is used internationally) and this gave us valuable experience in producing systems for real users, rather than just the more typical research prototypes. At Newcastle we produced around a dozen PhD students and RAs who got good jobs in industry (some senior, some local, some national and some international) because of those skills.

End of response by Newcastle University (return to ‘E’ response list)

Response by Rothamsted Research

- From a Rothamsted (and a Biological Sciences) perspective, it is difficult to provide a balanced response to this question as we do not have a wide enough perspective over e-Science as a whole.

There is no doubt that the individual Research Council programmes had a positive impact on the outputs from the e-science programme as a whole. I was involved in the selection/review of both MRC and BBSRC e-science research and these have created...
strong outputs – many of which in Bioinformatics have mutually supported the research communities of both councils.

As an indirect user of the Core e-science research, it is hard to judge its impact because to a large extent it is hidden from those using application-level e-science tools. For me, the question would be whether the distribution of funding between Core and Research Council Programmes was justified by the outputs. My personal experience when I learned about the high level of investment in e-science Core (e.g. middleware) technologies was to question whether this was going to deliver to the individual RC programmes in a cost-effective way and how could this be evaluated? I expect others, better acquainted with the impact of the Core programme on the individual Council Programmes will provide their views on this issue.

End of response by Rothamsted Research

Response by University of Aberdeen

- The experience at Aberdeen is that the e-Science programme brought together computer scientists with researchers in other disciplines in a true partnership approach to address problems. Local feedback indicates that these partnerships would not have arisen without the programme as a catalyst.

Furthermore, the networks formed through the e-Science programme have acted as a platform for bids to other cross-council programmes – most notably the Digital Economy programme. The University of Aberdeen was successful in securing one of the three Digital Economy Research Hubs (£12.4M award over 5 years, 2009-2014); the two Directors of the Aberdeen Hub (Edwards – Computer Science, Farrington – Human Geography) began their collaboration through the e-Science programme.

While it is clear that the e-Science programme has led to the training of a cohort of research staff and students, it is less clear whether these individuals will act as e-Science evangelists in future, or if they will simply return to their conventional disciplinary ‘silos’. Our local experience would imply that it is individuals within the ‘user’ disciplines who are most likely to promote e-Science tools in future, rather than the technology researchers/developers.

End of response by University of Aberdeen

Response by University of Cambridge

- The programme strategy appeared from my point of view to work well as a cross-research council activity.

End of response by University of Cambridge

Response by University of Edinburgh

- The programme transformed UK research behaviour: prior to the programme one NERC project involved a computer scientist, during the programme ~50% of applicants and participants in NERC e-Science projects were computer scientists, with significant acceleration of eminently publishable research. Prior to the programme meetings that encouraged interdisciplinary thinking were rare. During the programme >600 people a year joined in e-Science All Hands Meetings, a great multidisciplinary fair and international conference that spawned interdisciplinary research. Prior to the programme there was no venue for consensus building and research thinking that spanned disciplines. The programme created the regional centres, NeSC and eSI to serve this purpose. The combined effect of AHM and these three measures was to build a thriving community with strong international connections.

Prior to the programme there was no mechanism for delivering research infrastructure that served a wide range of purposes and disciplines other than the HPC national provision and the JISC-supported JANeT digital network. As a consequence of the
programme, cross-cutting services accessible to a broad range of researchers, such as
OMII-UK, NGS and DCC were established by the RCs and further supported by JISC.
The JISC Support for Research (JSR) was established and has extended support to
researchers in the arts and humanities, as well as increasing the engagement in all
other communities.

The balance between investment in pioneering research and in delivering core
foundations was extremely well judged. The leadership through the Director General of
the Research Councils, coordination through the e-Science Steering Committee and
drive from the e-Science Core Programme Director provided a focus and enabling
mechanisms that lifted the overall performance of the whole research community. The
early contributions by the DTI were invaluable in stimulating knowledge exchange and
partnerships with industry. This strong platform of support enabled the UK to play a
major role in European projects, international standards and global research
collaboration. The balance, coordination and focus need re-establishing to gain the
maximum return on the UK’s investment and to ensure the UK continues to equip its
researchers and industry with the new skills and facilities required for competition and
well-being in a digital age.

The e-Science programme demonstrated the high value of aligning research-driven
innovation with foundational research and e-Infrastructure provision. The capabilities
and the model thus generated are vital for success in the majority of cross-council
programmes. Coordination is necessary to pool efforts rather than wastefully re-invent
the ‘e-Wheel’.

Future programmes need to treat software as a facility, that is, recognise that the
collections of software libraries, platforms, tools and systems require a large investment
in developing and maintaining software for research. It is a major step to take software
from a successful demonstration in one project and to make it ready for larger
community use. Those software items that prove of highest value to researchers must
then be selected and maintained as researchers’ requirements and computational
contexts evolve. This requires well-organised international collaboration with the UK
taking a leading and trusted role.

End of response by University of Edinburgh

Response by University of Glasgow

- What progress would have occurred if a specific Programme had not been in place?
  - It was certainly the case that the Core Programme allowed expertise to be
garnered that could be applied in different research council programmes.
  - It is difficult to say what would have happened to research as a whole in the
  biological sciences say if BBSRC had not supported an e-Science programme.
  The work undertaken on projects such as the BBSRC funded GEMEPS at NeSC
  Glasgow certainly provided expertise to support researchers requiring microarray
  experiment analysis tools. The same researcher is currently involved in an
  Scottish ITI project looking at Pharming of miRNA —as noted previously,
  continued involvement in a given domain by a given researcher is key to
  successful software development and support of e-Science researchers more
gen erally.

What was the impact of the programme on the provision of skills and trained people in
the UK?

- As noted previously, NeSC at Glasgow have taken a leading role in education
and training. At Glasgow, there have been numerous advanced MSc students
(36); PhDs (2) and a range of final year undergraduate dissertations undertaken
in all aspects of e-Science. I currently supervise 4 PhD students.
  - Many groups across Glasgow, Scotland and beyond have gained awareness of
 the opportunities made possible by e-Science. (I have given 61 public
 presentations in my role at NeSC on e-Science and its application to a variety of
different communities – this does not include conference paper presentations). Many of these presentations have resulted in new collaborations, e.g. with researchers in various faculties in Glasgow such as the Arts and Humanities (ENROLLER project); in electronics (nanoCMOS project); at Stirling (DAMES project); in Strathclyde (drug discovery portal project).

What was the ‘added value’ of the Programme strategy? Is this a good model for cross-council Programmes? Could the model be improved and if so in what way?

- The added value often comes from combining expertise from multiple research domains / funding streams.
- I would suggest that specific cross council efforts would certainly make sense and are arguably a better way to co-ordinate efforts. The Wellcome Trust, EPSRC, ESRC and MRC joint funding for research into access and use of electronic patient records is a good example of this. Further cross council research ventures that capitalise on previous investments and experiences should most certainly be undertaken.

End of response by University of Glasgow (return to ‘E’ response list)

Response by The University of Manchester (1)

- As detailed above this structure provided a very cost effective approach to the support of e-Science research. It enabled the Programme to steer a course between two major rocks. The first being the possibility that the application projects would each develop their own bespoke infrastructure which would need to be recreated for different usage and which would be impossible to support and maintain. The second was the possibility that a massive funding of infrastructure projects at the expense of application based projects would lead to the development of software designed for software engineers not application users. The Core Programme was sufficiently compact that it had to reuse software developed on a global scale thus aiding interoperability. Its compactness also meant that it was required to work with major application focussed projects to build its infrastructure.

The network of e-Science Centres which had a key interest in developing a user base, yet not enough support to do this without relying on institutions such as the NGS and OMII-UK, established healthy dependencies between components of the Core Programme and between the Core and the Application Projects. The Centres have also nurtured key specialisms, for example, the Reading e-Science Centre developed links between the Core Programme and the NERC e-Science programme and the Belfast e-Science Centre has developed industrial partnerships linking e-Science to Digital Media (BBC) and Financial Services (First Derivatives).

The highly successful and well attended series of All Hands Meetings (AHM) provided evidence of this approach. The early meetings were more heavily focussed on the providers of the initial infrastructure but more recent meetings have an increasingly application-driven agenda as can be seen in the Calls for Papers and the actual content of the AHMs. They act as a litmus paper for the “Application pH” of the Programme and its change over time.

Perhaps the most important and valuable result of the strategy was the uptake of e-Science tools by key user communities. At Manchester we observed this in the interplay between the myGrid pilot project along with subsequent myGrid Platform Grants and the OMII-UK work on Taverna. The former developed new research methods and research communities, especially in the biosciences domain, and the latter enabled reliable software to be produced in a manner responsive to the growing user base. A second example is the development of tools for the support of advanced methods of computational simulation developed in the RealityGrid project and subsequent RealityGrid Platform Grant. These tools were developed in response to the needs of computational scientists and further developed and hardened via funding from OMII-UK to produce the Application Hosting Environment (AHE). This is now a user-centred method of access to very cyber-Infrastructures such as DEISA in Europe and TeraGrid.
in the US. AHE will be used in international collaborative projects on simulation of complex systems such as the Virtual Physiological Human.

*End of response by The University of Manchester* (return to ‘E’ response list)

**Response by The University of Manchester (2)**

- This was a sensible strategy that has, by and large, worked well in my view. Core technological developments would have been impossible to fund via the individual research councils funding models and a centralised programme was therefore essential. Equally, smaller scale domain-specific e-Science programmes, such as our own (ISPIDER), would not have made sense to fund centrally. Our applications and needs have been tailored to proteomics and although some generic technology has arisen from ISPIDER, using bioinformatics examples to test and evaluate the tools, much of our output would be considered to be specific to biological applications areas such as post-genome science.

*End of response by Professor Simon Hubbard, The University of Manchester* (return to ‘E’ response list)

**Response by University of Oxford (1)**

- The structure of the programme was rather new in its approach. The results across the research councils varied as different councils took slightly different approaches. It was very good however to get an integration of computer science and discipline sciences working together and this seems to have, in some quarters, affected a cultural change and approach. The close collaboration between the DTI and the research councils, most notably EPSRC and the Core Programme, was very effective and resulted in new industrial collaborations. Indeed it was due to the e-science programme that Oxford University signed a strategic collaborative agreement with IBM.

*End of response by University of Oxford* (return to ‘E’ response list)

**Response by University of Oxford (2)**

- I have not been closely enough involved with the e-Science Programme management to judge the success of this strategy.

*End of response by Professor William Dutton, Oxford Internet Institute, University of Oxford* (return to ‘E’ response list)

**Response by University of Southampton**

- What progress would have occurred if a specific Programme had not been in place?

Before the e-Science programme Southampton had many successful engagements between Computer Science and other disciplines and established cross-campus HPC activities. The programme enabled us to build on this established culture and scale up the existing collaborations, as well as developing entirely new ones. For example, CombeChem and the ESRC Small Grant each involved collaborations across three faculties, which would have been unusual before. There is a substantial set of research papers that would not have come about without e-Science.

*What was the impact of the programme on the provision of skills and trained people in the UK?*

The programme is still producing a generation of researchers who are better able to conduct data-intensive science, as well as a diverse set of research assistants and developers uniquely skilled in interdisciplinary working, and computer scientists who are much better at appreciating the needs and practices of real users. Our experience in Southampton has been that these multidisciplinary workers are achieving successful careers both inside academia and in industry.
What was the ‘added value’ of the Programme strategy? Is this a good model for cross-council Programmes? Could the model be improved and if so in what way?

The model is effective and is essential to support future research practice which is increasingly cross disciplinary and data intensive. The programme has been most effective with funding as the instrument of coordination; as spend decreases new coordination methods may be required.

Response by University of Stirling

- **Institutional evidence from the University of Stirling**

  The DAMES Node developed out of the previous exploratory GEODE project. That project was evoked by ESRC outreach initiatives (the e-Social Science All Hands conference of 2004) which inspired an initial proposal to explore how e-Science approaches might contribute to the well established problems of working with complex occupational data. In this instance, the ESRC’s ‘seed funding’ of that proposal served to demonstrate the potential contribution from organising data resources, and in turn led to the larger DAMES Node and further funding of related activities by the ESRC (e-Stat) and JISC (NeISS).

  The ESRC’s focussed investments in e-Social Science have provided the University of Stirling with a unique opportunity to establish a suite of projects associated with data management and analysis of large scale quantitative data. This strategy has prompted new research initiatives in working with complex data at Stirling, and has encouraged the promotion of methodological standards which emphasise the review of multiple data permutations, and improved efforts in documentation and replication.

  **Programme strategy: Responses relevant to questions posed by the e-Science Review framework**

  The University of Stirling is an institution which has benefitted greatly from the e-Science Programme strategy. It has used its projects to impact upon applied research in the social sciences and beyond. Projects at Stirling have served to provide a coordinating hub around a major research programme in the domain of quantitative applications in the social sciences. They have also helped foster interdisciplinary collaborations (between computing science researchers and other departments). The e-Science Programme strategy has therefore proved highly successful in promoting effective collaboration and impact within the University.

  In the social sciences generally, the e-Social Science funding programme has promoted exciting initiatives across a range of social science disciplines. That range may appear uneven in some instances (such as apparent under-representation of educational research, psychology, or economics). However, the social sciences have a history of methodological initiatives ‘trickling down’ from pioneering application areas to new disciplines, which supports the ESRC model of funding selected specialist projects.

Response by White Rose Universities (Leeds, Sheffield and York)

- Without the e-Science Core Programme it would be impossible to build a collaborative community of researchers working across different fields. Individual programmes of Research Councils would not be able to setup a multidisciplinary research community on such a scale. The existence of the e-Science Core Programme ensured better knowledge dissemination and coherence across a spectrum of activities.

  This Programme had a huge impact on development of skills and knowledge of the research community and support staff in academic institutions.
The Programme stimulated e-Science technologies provision and educated local universities' operational staff (systems administrators) in e-Science techniques and tools.

End of response by
White Rose Universities (Leeds, Sheffield and York) (return to ‘E’ response list)

Response by University of Reading

- We are of the view that more cohesion and coordination between the core e-science programme and individual Research Council programmes would have been beneficial.

The Programme certainly forged connections that would otherwise not have happened, and inspired new ways of working. However, we feel that the approach of a fast ramp-up in funding (in 2001-2) with a sharp cut-off (in 2007-8) was not appropriate. A slower ramp-up and a longer tail might have given more time to experience, understand and address key issues (such as the “software engineering gap”) and foster new practices in Research Councils.

Young researchers have been given opportunities to work in exciting projects that cross disciplines. A clear career path for these researches will have benefits in terms of retained expertise and future of e-Science activities.

End of response by University of Reading (return to ‘E’ response list)

Response by Imperial College London (1)

- We believe that this factor was vital and contributed hugely to the success of the e-Science. It developed a way of working that encouraged the joint (applied and computing) design and development of advanced but practically useful facilities that tested for real the putative technical solutions. When shown to be realistic and practical these advances could be generalised and further developed for reuse and reapplication via the Core Technology programme. Similarly developments in the Core Programme can be informed by knowledge of the requirements of the applied groups and any necessary practical considerations.

This is in contrast to what we would term the idealised one-way view of computing research and development where capabilities are designed in isolation from any practical application and only after considerable research and development applied and tested.

This idealised view is not generally applicable in computing, particularly in the Internet age; many major developments can occur very quickly from the innovative exploitation of some infrastructure capability and ideas can stem as much from the explorations in the applied domain as from stand-alone blue skies computing research. This is not, of course, to deny the importance of basic Computer Science research but to observe that in many important areas computing and applied research should be much more closely coupled than in conventional model. Furthermore this coupling should be a permanent feature, reinforced by continued funding mechanisms, not just a one only venture.

End of response by Imperial College London (return to ‘E’ response list)

Response by Imperial College London (2)

- I think this factor was vital and contributed hugely to the success of the e-Science. It developed a way of working that encouraged the joint (applied and computing) design and development of advanced but practically useful facilities that tested for real the putative technical solutions. When shown to be realistic and practical these advances could be generalised and further developed for reuse and reapplication via the Core Technology programme. Similarly developments in the Core Programme can be
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End of response by
Professor John Darlington, Imperial College London (return to 'E' response list)

Response by King’s College London

- Given that the AHRC only came into existence in 2005, the arts and humanities did not have access to any e-science funding in the Programme’s early phase. However, this meant that when the AHRC was formed, it was possible to establish the Arts and Humanities e-Science Initiative, along with JISC and EPSRC. Most significantly, this meant that the arts and humanities could draw on the body of experience accumulated by the e-Science Programme. This was articulated by Sheila Anderson in the 2006 Arts and Humanities e-Science Scoping Survey (see http://ahessc.ac.uk/about-ah-escience). The principle outcome of having such a funding model was that the arts and humanities focused on domain research questions, not the development of technology. This is by far the best model for these communities, and accords closely with long experience with the established digital humanities.

End of response by King’s College London (return to ‘E’ response list)

Response by Natural History Museum, London

- Biodiversity informatics was a small part of the e-Science Programme. As such the Core Programme structure was not particularly relevant to what was a very experimental approach to developing software alongside a considerable cultural change towards larger scale collaboration in taxonomy. Nevertheless, there is much potential for higher level data management when this field expands from the more pioneering stage evident until very recently. Mergers of biodiversity informatics systems are already apparent, but there is much further to go.

End of response by Natural History Museum, London (return to ‘E’ response list)

Response by Rutherford Appleton Laboratory (RAL), STFC

- The strong application focus of the separate Research Council programmes was invaluable in getting broad engagement across the research community and ensuring that requirements from across the research communities could be addressed at some level. The parallel development of the core programme risked developing tools which were not well connected to the Research Council requirements or programmes. In practice the effectiveness of connections between core programme and RC programmes varied significantly. This reflects the very different requirements and levels of development of the different RC communities. The separate RC programmes have allowed UK researchers to develop leading activities across a very broad range of initiatives.

The separation of Core and separate RC programmes has made it more difficult to create sustainable common activities (collaborations or infrastructure) e.g. across
Research Councils, with the end of the formal e-Science programme. One reason for this is the lack of formal pressure to coordinate technical developments has tended to discourage common solutions. Recent European developments are in fact now having a focusing effect in the UK.

Without the combination of Core, PPARC and CCLRC Programmes it would not have been possible for the UK to participate as fully in the Worldwide LHC Computing Grid

End of response by
Rutherford Appleton Laboratory (RAL), STFC  (return to 'E' response list)

Response by Anatomical Society of Great Britain & Northern Ireland

- The programme has been useful to a number of fields, and the grants have been used to fund postdocs and RAs, and hence provide advanced training.

The added value of the programme has been in bringing together people in different fields and subjects under the umbrella of a transdisciplinary project.

The model would be improved (for bioinformatics) were the calls more focused.

End of response by Jonathan Bard,
Anatomical Society of Great Britain & Northern Ireland  (return to ‘E’ response list)

Response by Diamond Light Source

- There initially appeared to be a strong drive to ensure all e-science developments were "Grid enabled". The Grid toolkits (e.g. various manifestations of Globus) were not in a sufficiently stable state and, in the end proved to be a distraction.

Once focused on getting applications running using stable technology the advantages of having separate core and application developments was an advantage.

There may now be an advantage in transferring to the more modern (and stable) technology but it would require a significant commitment to investigate this.

End of response by
Dr Colin Nave, Diamond Light Source  (return to ‘E’ response list)

Response by Isaac Newton Institute for Mathematical Sciences

- Since I was intimately involved, it is for others to judge this. The following comments may be helpful:

1. My personal view is that John Taylor had great vision in establishing the Programme with that structure.
2. He was very clear that the whole Programme had to be able to operate in a way which enabled it to progress more quickly than the rate of change in the external world.
3. We received a very clear mandate at the start of the Programme that practical impact was the objective.
4. Both 2. and 3. significantly conditioned the mode of operation, particularly in the core Programme.
5. I think it is fair to say that as a result of representations by (some in) the CS research community that more fundamental CS work was required if the Programme was to be successful, we received further steer to support such work and thereby to extend the time-horizon for impact.
6. The nature of the Steering Committee, with a ‘core’ activity which was under our direct influence through Tony Hey, and the RC programmes on which we could have only an indirect influence, was a very interesting experiment. My personal view (and I would say that wouldn’t I) was that it worked.
7. I can say for sure that the dynamic round the table was excellent. We also had very good input from the international members.

End of response by Sir David Wallace, Director, Isaac Newton Institute for Mathematical Sciences, Cambridge (return to ‘E’ response list)

Response by Linnean Society of London

- The input of the Programme to biodiversity informatics was not extensive, and was not part of the core programme, although the contribution was certainly valued. Biodiversity informatics has been in an experimental development phase and the impact on skills and training has yet to mature fully. Certainly we expect to see developments being introduced in training courses in systematics (e.g. the MSc at Imperial College in Advanced Methods in Taxonomy and Biodiversity).

End of response by Dr Ruth Temple, Executive Secretary, Linnean Society of London (return to ‘E’ response list)

Response by The UK Computing Research Committee (UKCRC)

- The programme needed to rapidly establish and coordinate a cross-council core of activity to establish key infrastructure, international and national strategy, cross-council links (for example with JISC and the DTI), and cross-council centres such as the National Data Curation Centre, the National Grid Service and the Open Middleware Infrastructure Institute-UK. The Core programme was crucial in this.

The research councils’ individual programmes were required to build programmes relevant to their disciplines and in some cases specialist centres such as the National e-Social Science Centre and the NERC e-Science Centre.

End of response by Professor Muffy Calder, Chair, UKCRC (return to ‘E’ response list)

Response by Professor Dame Ann Dowling, Chair, Engineering Panel in RAE 2008

- We have no comment on this.

End of response by Professor Dame Ann Dowling, Chair, Engineering Panel in RAE 2008 (return to ‘E’ response list)
F. Other comments

Follow the links below to view the responses

Visiting Panel:
- University of Edinburgh
- University of Manchester (The) (1)
- University of Oxford (2)
- University of Stirling
- White Rose Universities (Leeds, Sheffield and York)

Panel Visits:
- Imperial College London (1 & 2)
- Natural History Museum, London

Rutherford Appleton Laboratory (RAL), STFC (a combined submission from all the projects being reviewed during the visit to RAL)

Others:
- Anatomical Society of Great Britain & Northern Ireland
- Institute of Physics (IoP)
- Isaac Newton Institute for Mathematical Sciences, Cambridge
- Linnean Society of London
- The UK Computing Research Committee (UKCRC)
- Professor Nigel Hitchin, Panel Chair of last RAE exercise
Response by University of Edinburgh

- The future of computational sciences and e-Science should be fully integrated. They will become increasingly important modes of thinking in all disciplines across the full spectrum of RCUK interests. They will need a substantial research contribution from the computing science community and will also draw increasingly on software engineering, mathematics, numerical analysis and statistics. The RCUK, in collaboration with the Higher-Education Funding Councils, should encourage the tertiary education sector to modify its degree programmes to deliver the required skills and change of culture.

End of response by University of Edinburgh  
(return to ‘F’ response list)

Response by The University of Manchester (1)

- The UK Programme also funded research into fundamental computer science inspired by or related to e-Science. Such projects were linked to the application focus of the Programme and data-intensive sciences such as biosciences and astronomy. At Manchester we provided an environment (via the e-Science Centre using the University and EPSRC Core Programme investment in the Centre) where such cross-fertilisation could occur. Examples of this are work in the fundamental theory of Description Logic via projects such as REOL. An example of a key problem here is the need to find a way of expressing the equivalence of workflows. It was discovered in an e-Science Pilot Project (myGrid) that this was not possible with the state-of-the-art in the languages used for semantic reasoning. This was then fed back into the work of the Description Logic group in Computer Science at Manchester. It is highly unlikely that this cross fertilisation would have occurred without the major intellectual and financial stimulus of the e-Science Programme. It also illustrates the creative role of the e-Science Centres and large-scale multidisciplinary projects in providing incubators for this.

Another exciting possibility arising from the Programme is that the tools developed in it to study large complex systems can be applied to the very foundations of the internet which is the tool to develop this new method of scientific working. In developing such a study of how information and knowledge can be mined from the distributed computing systems of the internet and the World Wide Web, it is very possible that new forms of research will develop to allow science to keep pace with the explosion of data enabled by modern instruments and information systems. Such a science of the internet will need to develop algorithms and methods for dealing with scale and complexity. At the same time, these advances will help fertilise greater interaction between the human sciences and digital sciences.

End of response by The University of Manchester  
(return to ‘F’ response list)

Response by University of Oxford (2)

- By any measure of the sciences, the e-Sciences are young and need to be viewed as an emerging area of the computational sciences.

There needs to be continuing work to ensure that the e-Science programme develops more fully as a multi-disciplinary enterprise. This is not a time for retrenchment, but for building even stronger links with the social sciences, law and the humanities, where advances in ICTs can be applied in ways that could enhance the quality of the sciences and humanities.

End of response by Professor William Dutton,  
Oxford Internet Institute, University of Oxford  
(return to ‘F’ response list)
**Response by University of Stirling**

- This institutional response has been purposefully kept shorter than the maximum permitted in recognition of the smaller range of e-Science activities at the University of Stirling.

*End of response by University of Stirling* (return to ‘F’ response list)

**Response by White Rose Universities (Leeds, Sheffield and York)**

- This review is carried out very early after the end of the e-Science Programme and thus the impact of some results may not be clearly evident.

*End of response by White Rose Universities (Leeds, Sheffield and York)* (return to ‘F’ response list)

**Response by Imperial College London (1)**

- The eScience programme, especially the demonstrator projects, enabled and indeed encouraged the establishment of large multi-disciplinary teams. Maintaining and developing such teams is highly desirable but the abrupt end of the eScience programme and the well-know weakness of discipline-oriented peer review of multi-disciplinary work, make this a challenge.

It was an exciting programme, far-sighted, very well run and extremely challenging, and we enjoyed working in it.

*End of response by Imperial College London* (return to ‘F’ response list)

**Response by Imperial College London (2)**

- It was an exciting programme, far sighted, very well run and extremely challenging, and I enjoyed working in it.

*End of response by Professor John Darlington, Imperial College London* (return to ‘F’ response list)

**Response by Natural History Museum, London**

- Although taxonomists/systematists were slow to start adopting and developing e-technology and systems on a large scale, efforts to develop biodiversity informatics are now occurring globally. The UK’s effort in this field do not match its strengths in taxonomy nor its physical infrastructure (notably biological collections). There is a strong case for further support given the societal value of information on species in relation to biodiversity loss.

*End of response by Natural History Museum, London* (return to ‘F’ response list)

**Response by Rutherford Appleton Laboratory (RAL), STFC**

- Much of the early work in the e-Science programme has been embedded into the day to day operations of STFC facilities. Many of the early developers have moved on and much of their work, and developments carried out in collaboration with other research councils, is not reported here (e.g. data visualisation and analysis of large datasets in climate modelling GODIVA, infrastructure for High Throughput Protein Crystallography, e-HTPX, processing and visualisation of heart and cancer modelling in Integrative Biology).

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The merger of PPARC and CCLRC to form STFC, and subsequent restructuring, has also impacted the information reported here.

End of response by
Rutherford Appleton Laboratory (RAL), STFC

Response by Anatomical Society of Great Britain & Northern Ireland

- One outcome of understanding how genetic networks cooperate to build tissues in embryos will be a better understanding of how mutations that affect these networks produce congenital abnormalities: the opportunities for translational research and mutually beneficial co-operation between basic scientists and paediatric clinicians should be exploited.

Modern imaging modalities also have computational requirements: the development and (clinical) application of these modalities continues to benefit from the interaction of academic anatomists and theoretical physicists.

End of response by Jonathan Bard,
Anatomical Society of Great Britain & Northern Ireland

Response by Institute of Physics

- Handling up to 20PB of data a year from the Large Hadron Collider (LHC) makes harnessing together the huge CPU and storage capacity of the Grid vital to the research field of particle physics. The UK consortium, GridPP, contributes 14% in terms of computing power to the 200,000 CPU Worldwide LHC Computing Grid (WLCG) and brings 7PB of disk storage and 2TB of tape. It also contributes in parallel to the Enabling Grids for E-sciencE (EGEE) programme with 270 sites spread across 50 countries offering 150,000 CPU for projects in all science areas. Through GridPP, UK scientists in a wide range of disciplines are readily able to access this vast facility.

GridPP is a collaboration of 19 UK Universities, STFC and CERN and was established in 2001. It has one national Tier-1 centre, multiple regional Tier-2 centres and then clusters of Tier-3 facilities in every institution. In the year to July 2009, GridPP contributed 17% of the total EGEE computer time (85 million CPU hours) to more than 40 virtual organisations spread across a broad spectrum of scientific areas.

Commercial uses of the GridPP technology, enabled by fruitful collaborations with particle physicists, include image search algorithms, analysis of seismic responses and models for commodity trading. The GridPP collaboration has trained a large number of PhD students in a technology that is now rapidly growing in its applications for both academic and commercial environments, and a number of these PhD students have gone on to form their own companies.

End of response by
Tajinder Panesor, Institute of Physics

Response by Isaac Newton Institute for Mathematical Sciences

- It was fun and exciting to be a part of the Programme. You have a huge amount to digest. Good luck!

End of response by Sir David Wallace, Director,
Isaac Newton Institute for Mathematical Sciences, Cambridge

Response by Linnean Society of London

- The Linnean Society is grateful for the opportunity to submit this evidence. The Society believes that natural history information and taxonomy are highly appropriate for
becoming largely or entirely Web-based to the benefit of a much wider range of users than currently is the case.

*End of response by Dr Ruth Temple, Executive Secretary, Linnean Society of London* (return to ‘F’ response list)

**Response by The UK Computing Research Committee (UKCRC)**

- At the outset of the UK e-Science programme there was a concern in many quarters of the CS community that their role would be simply to provide programming services to science projects. As this response indicates these fears were unfounded and significant computer science was embedded in the programme. In part this came from leadership within the CS community and in part from vigilance by the funding agencies (predominantly EPSRC): including a core CS research component in the programme was critical. It is important that e-Science continues the outward transfer of computing expertise to other disciplines, and at the same time core computer science has the resources to pursue its own scientific agenda.

*End of response by Professor Muffy Calder, Chair, UKCRC* (return to ‘F’ response list)

**Response by Professor Nigel Hitchin, Panel Chair of last RAE exercise**

- I'm afraid the Computer Science subpanel of Panel F in the RAE, has declined to offer any evidence. They are the ones who had most experience.

I had the following response from the Chairman of the Statistics subpanel:

"e-Science is the invention of computer-enabled methods and their application to research."

In this sense, a large proportion of the work seen by the Statistics sub-panel comes under the e-science umbrella. I also imagine the same could be said of Applied Maths and, nowadays, some of Pure as well. This is largely a matter of our own self-perception. For example, even in a very rigorous area of pure mathematics, computer methods could be used to generate or "verify" conjectures even if proofs themselves were carried out by non-e-means.

Turning specifically to Statistics, large areas of statistics, and also of probability, would fall under the e-science umbrella. This includes both basic methodology (almost all of which has "computer-enabled" components) and the areas and techniques of application. Within methodology, one could immediately point to the "computational Bayesian revolution" where methods such as Markov Chain Monte Carlo have changed the face of statistical approaches to many important problems. There are many other examples.

It is perhaps disingenuous to suppose that e-science is intended to be interpreted in such an inclusive way, but it is up to others to exclude work which we would include.

...... and this from the Pure Mathematics subpanel:

E-science didn't form a major part of the pure submission to RAE08. The only submissions where I recall e-science (broadly interpreted) playing a significant role were St Andrews and (notoriously) Royal Holloway - the former via their involvement in the GAP project, the latter through the extensive work done there on electronic security, cryptography, etc. In addition, of course, there is/was a reasonable sprinkling of individual researchers and small research teams in pure, who might be said to have an e-science involvement - off the top of my head I think of Derek Holt (Warwick) with Sarah Rees (Newcastle) in "computational group theory", and Miles Reid's former student Gavin Brown at Kent with his data-base of graded rings compiled using Magma; see
Of course, there are a substantial and growing number of people scattered across much current research in pure who use computers as an "experimental" tool in their research - but I don't suppose this sort of cottage industry stuff is what is being asked for.

One might also speculate whether there is a significant interaction (or should be) of e-science with the Heilbronn Institute in Bristol (run by GCHQ) but it may be hard to get reliable info on that.

I appreciate that this is quite vague. I leave it to you to distil what you can from it.

*End of response by Professor Nigel Hitchin, Panel Chair of last RAE exercise* (return to 'F' response list)
A. Did the UK e-Science Programme build a Platform which enables e-Science tools, infrastructure and practises to become incorporated into mainstream research in the UK?

The following key points were highlighted:

- There is broad agreement that the programme allowed the development of software tools and technologies, but penetration and adoption of those tools is considered to vary according to discipline area. Some multi-disciplinary collaborations have been enabled and standards have been disseminated, but significant barriers still exist and the general perception is that there is still potential in e-Science to be tapped.

- The e-Science programme enabled three broad types of platform; centres (discussed by the universities of Glasgow, Manchester and Newcastle), the Grid, and major facilitation projects, particularly the Open Middleware Infrastructure Institute (OMII). The Grid is a distributed HPC project, supported by the programme at different organisational levels from the National Grid Service to regional services (the White Rose Grid) and local campus Grids. Barriers to widespread usage of the Grid still exist, for example the digital certificates used to access the service are perceived as being too difficult to use and manage. Distributed HPC is not seen as a major output of the e-Science Programme to the biosciences, mentioned by Rothamsted Research. OMII is based at the Universities of Manchester and Southampton and is a widely used workflow system operating across the sciences (cited in the evidence from the Universities of Newcastle and Oxford). The diverse nature of the platforms can be a hindrance; Newcastle University’s submission described the lack of integrated e-Science platforms as a barrier to wider impact, and the Anatomical Society said that no coherent body of work has been produced. Additionally, there are concerns over long-term sustainability of some platforms (for example the National e-Science Centre at Glasgow). This is also reflected in submissions from the Universities of Glasgow (related to training) and Stirling.

- While it is noted (by the University of Glasgow) that there are few disciplines that have not been touched by the Programme in some way, the penetration of the projects into the research community vary according to the disciplines. There remains a perception that the major end-users of the tools are researchers who were primarily funded to work on or with e-science tools, cited by the University of Glasgow.

- While cross disciplinary projects do appear to have been enabled (University of Southampton), other submissions reported disappointing engagement. Barriers to engagement in cross-disciplinary programmes were discussed broadly by Newcastle University and in relation to work between biological and computing sciences by the University of Reading. Despite this, significant biological and life science projects were widely cited (Universities of Manchester, Edinburgh, Imperial College London), noting the observation from Rothamsted Research that e-Science projects are mainly in the data access and manipulation fields. The biodiversity community (University of Reading, Natural History Museum, Linnean Society) used the e-Science Programme to develop tools that underpin some of the major biodiversity databases, and biomedical researchers have additional work on visualisation tools. The biomedical sciences are considered to yet to fully benefit from the e-Science Programme (discussed by the University of Glasgow).

- In physics, remote access to large infrastructure projects (e-HTPx enabling access to Diamond, Grid-PP/LHC Grid for access to the LHC) were enabled and widely used. In astrophysics, Liverpool John Moores indicated that e-Science is considered as the province of software engineers, despite multiple astrophysics projects existing at Edinburgh, and the submission from Oxford indicating that astronomers and other physics-related projects were both easily integrated into the e-Science Programme and willing to use new technologies. Evidence presented from engineering (Dame Anne Dowling, Engineering Chair for the RAE) indicates that uptake and provision of tools by researchers is low.

- Social Sciences have benefited from collaborative tools and visualisation (University of Stirling, Southampton) as well as data integration and visual media annotation (King’s College). King’s College London cites numerous projects, in the Arts and Humanities for example, The Arts and Humanities e-Science Initiative.
B. How does UK e-Science activity compare globally?

The following key points were highlighted:

- All responses agreed that the UK e-Science programme was a world leader in the development of e-Science and still plays a leading role in the international e-Science community and is a major driver in international projects. The worldwide development of e-Science has grown momentum, which was felt to be as a result of the RCUK programme (University of Edinburgh).

- The UK e-Science programme was perceived internationally as the model to which the standards that all nations aspired to follow, many countries have copied the UK initiative and it is thought that some are now pulling ahead due to large and sustained investments (US, Scandinavia and Japan).

- The UK has taken a broad view and has focused on data-driven science and the services to support it rather than on large computations and distributed super-computing. This was deemed as important as it meant that the UK expertise and infrastructure addressed a wider range of scientific activities. The UK has developed production computational platforms and set the standards for the development of Grid computing. The UK can justifiably be said to have pioneered the application of semantic technologies and ontologies to e-Science and e-Infrastructure. Mechanisms and standards for data access over Grids were led by the UK. The UK’s scientific workflow research has been technically influential and the emerging software adopted by scientists world-wide.

- Furthermore, the UK has directed much of its research efforts to data management, knowledge management, and service management, addressing key challenges in data integration, service interoperation, workflow, semantic metadata, provenance and secure, scalable data access. These challenges are now recognised as fundamental by the EU’s European Strategy Forum on Research Infrastructures programmes and the NSF’s CyberInfrastructure programme.

- The e-Science programme made way for good partner collaboration with high credibility to various US, EU projects. The UK has played a leading role in the collaboration between these partners in such projects, which has helped to exchange their e-Science expertise and add to the global e-Science achievements. Examples are described in University of Edinburgh, University of Manchester and the White Rose Universities responses, also highlighting the WRG (White Rose Grid) e-Science Centre collaboration with Beihang University in China.

- The UK programme held many International standing conferences such as the OGF (Open Grid Forum) Events and the e-Science annual All Hands Meeting, both attracting many international delegates. The NCeSS (National Centre e-Social Science) Hub-led International Conferences on e-Social Science have been widely recognised as setting the agenda for international efforts. The Arts and Humanities e-Science initiative have been keynotes in conferences around the world including the International Symposium on Grid computing in Taiwan (biggest Asian Grid conference). The KCL researchers were invited to organise a workshop in Australia to kick off an Australian humanities e-Science programme.

- The UK e-Science programme was successful in drawing prominent research leaders, both in and out of Computer Sciences into the programme. It is felt that attracting and engaging good researchers into e-Science and other multi-disciplinary research is not seen as a problem in the UK. There are some concerns expressed (Newcastle and Southampton) that multidisciplinary research, that produces outputs such as data software is sometimes regarded as a less scholarly pursuit than basic research and does not fit well within the single-discipline orientated structure of Universities and RAE.

- Many of the projects and centres have international members on their advisory boards and many members of the UK projects are representatives on international boards and review panels allowing contributions to the global e-Science developments (as highlighted in the responses from Southampton and White Rose Universities).
C. What has been the impact (accomplished and potential) of the UK e-Science Programme?

The following key points were highlighted:

- It is clear from the responses that the e-Science programme has had a considerable impact, across the sciences, on the way researchers carry out their day to day work, exploiting the potential of new technologies for research itself. e-Science has provided researchers with more sophisticated tools and techniques to enable increasingly complex research questions to be addressed. Although some communities are still fully benefit from the e-Science programme, for some the exploitation of e-Science tools is already embedded in the way they approach their research.

- The e-Science programme has fostered interdisciplinarity, enabling new ways of working by promoting the exchange of expertise, methodological approaches, practices and knowledge across disciplines and domains. As scientific research is directed towards major societal challenges (such as the impact of climate change, sustainable growth and rapid response to crises in health and finance), interdisciplinary working is increasingly important. These problems cut across RCUK boundaries and therefore require input from the physical, environmental, biological, human and the social sciences.

- e-Science has not only provided platforms that enable increased levels of collaboration across different research disciplines, but also between academia and industry. DAME, BROADEN, IXI, DiscoveryNet, MyGrid, and GENIE are just a few examples of projects that have had a significant impact through take up by industry.

- The UK e-Science Programme, which is regarded as world-leading, has helped to establish many international links and has facilitated the development of lasting research collaboration with international communities. Keeping UK e-Science at the international forefront should remain a priority, with continued opportunities for collaborative activities allowing our researchers to engage internationally. International visibility has also presented the opportunity to work with industry.

- The e-Science programme has played an important part in the training of the next generation of researchers. Training and increased interdisciplinarity, fostered by the e-science programme, has created a new cadre of researchers, for example computational biology researchers prepared for the push towards integrative and systems biology.

- e-Science Projects have made an important contribution to public engagement, generating substantial publicity and contributing to a greater public engagement with science.

- e-Science has helped to support evidence based policy, with the potential to act as a platform for researchers engaging with policy research, but also the wider community including the public.
**D. What are the future opportunities for UK e-Science?**

The following key points were highlighted:

- It is widely agreed that the strong initial momentum generated by the UK e-Science programme must be sustained. It is generally felt that e-Science is an important research area that unites the skills of both computer and application scientists. The multi-disciplinary e-Science community is viewed as being energetic and containing a wide depth of knowledge. The challenge now facing UK e-Science is to consolidate the good work that has been undertaken and to establish itself as a widespread practice, which will help deliver an increasing level of impact.

- In a changing world, the needs of scientists change, and the infrastructure of the e-Science programme has to evolve. The UK should not underestimate the challenges and costs of sustaining the collaborations that have already been initiated. Without this there will be a genuine danger of fragmentation and loss of momentum. The Engineering Taskforce and the e-Science Institute in Edinburgh, which provided opportunities for training, sharing experiences and learning about the new technologies relevant to e-Science were highly valued.

- The initial work of the UK Programme focussed firmly on applications in science and engineering. The arts and humanities now present a major opportunity to enhance the impact of e-Science on an additional discipline. Whilst the social science research community is not well suited to collaborative data management and there are major challenges in transforming the research habits in this area, there is great potential to share best practice within e-Science to enhance future research and data sharing within this area.

- It is seen as imperative that the integration of the Technology Strategy Board and Research Council strategies is continued. This will help provide a number of opportunities for engagement with industry and entrepreneurship at Universities. The potential for operating in areas of knowledge exchange with industrial partners is seen as an opportunity to lever funding, even in the current financial climate.

- It is genuinely believed that e-Science within the UK has the potential to be on the leading edge of research in to areas that have the potential for high impact. The UK has the potential to be at the forefront of research in disciplines such as: Energy, Living with Environmental Change, Global Threats to Security and Ageing: Life Long Health and Wellbeing. To support this research, in a manner that is internationally competitive, transcends individual councils and will require effective coordinated cross-council e-Science collaboration.

- It is seen as essential that the UK fully utilise the expertise and knowledge that were generated in the early phases of the e-Science Programme. Opportunities exist in exploiting the skill base that has already been acquired by the UK. It is also important to invest in postgraduate training to create a generation of scientists and engineers who routinely exploit computational and data-intensive methods in their daily work. It is seen as imperative that real researchers have the confidence and skills to drive developments within the e-Science programme.
E. How did the Programme Strategy (having a Core and individual Research Council Programmes, developing tools and applications in parallel) affect the outputs from UK e-Science?

The following key points were highlighted:

- The Programme strategy worked very well, and was judged as being a model to follow by many other countries.

The aspects which worked particularly well were:

- An excellent core programme leadership team was put in place spanning all research councils and the DTI. This provided vision, and direction, but still managed to incorporate the views of the community.

- The balance between investment in pioneering research and in delivering core foundations was extremely well judged. The leadership through the Director General of the Research Councils, coordination through the e-Science Steering Committee and drive from the e-Science Core Programme Director provided a focus and enabling mechanisms that lifted the overall performance of the whole research community.

- The programme was well funded allowing a wide range of significant research projects and sub-programmes to be funded. Core technological developments would have been impossible to fund via the individual research councils funding models and a centralised programme was therefore essential.

- Great effort was put into multi-disciplinary community-building. The programme transformed UK research behaviour: Prior to the programme, meetings that encouraged interdisciplinary thinking were rare. The creation of centres of excellence (including regional e-Science centres) gave resources to set up multi-disciplinary collaborations and to transfer best practise. Both Computer Scientists and Application scientists were included. This led to more multi-disciplinary collaborations.

- Key research leaders were drawn into the programme – It was certainly the case that the Core Programme allowed expertise to be garnered that could be applied in different research council programmes.

- Future programmes need to treat software as a facility, that is, recognise that the collections of software libraries, platforms, tools and systems require a large investment in developing and maintaining software for research.

- Specific cross council efforts are arguably a better way to co-ordinate efforts. The Wellcome Trust, EPSRC, ESRC and MRC joint funding for research into access and use of electronic patient records is a good example of this. Further cross council research ventures that capitalise on previous investments and experiences should most certainly be undertaken.

- However, in some cases, more cohesion and coordination between the core e-science programme and individual Research Council programmes would have been beneficial.

- The approach of a fast ramp-up in funding (in 2001-2) with a sharp cut-off (in 2007-8) was not appropriate. A slower ramp-up and a longer tail might have given more time to experience, understand and address key issues (such as the “software engineering gap”) and foster new practices in Research Councils. Young researchers have been given opportunities to work in exciting projects that cross disciplines. A clear career path for these researches will have benefits in terms of retained expertise and future of e-Science activities.

- Biodiversity informatics was a small part of the e-Science Programme. As such the Core Programme structure was not particularly relevant to what was a very experimental approach to developing software alongside a considerable cultural change towards larger scale collaboration in taxonomy. Nevertheless, there is much potential for higher level data management when this field expands from the more pioneering stage evident until very recently. Mergers of biodiversity informatics systems are already apparent, but there is much further to go.