

# RCUK Action Plan in Response to the 2009 International Review of e-Science

## Introduction

In 2009 an international panel of experts, chaired by Professor Dan Atkins of the University of Michigan, was convened by the Research Councils (RCs) to review e-Science research in the UK. The findings of the panel (<http://www.epsrc.ac.uk/research/intrevs/escience/Pages/default.aspx>) were launched at a Town Meeting in February 2010. This Action Plan, drawn up by a working group comprised of members of the Research Councils together with JISC, provides a response to the panel's report as well as a set of proposed actions in response to the report's recommendations. Please note that the actions listed here are meant as **exemplars**; this Plan does not include all relevant activities of the individual Councils.

## Context

It is important to note the wider context for this Action Plan. Firstly, at the time of preparation of this Action Plan, the allocations of funding to the Research Councils following the 2010 Comprehensive Spending Review (CSR) were not yet known. All actions included in the Plan are subject to funding being available following the outcome of the CSR.

Secondly, in 2009 the Department of Business, Innovation and Skills (BIS) commissioned the Research Councils to undertake a broader review of the provision of e-Infrastructure for research and innovation in the UK, which includes e-Science. The recommendations of this e-Infrastructure review were published in August 2010 and can be found on the RCUK website (<http://www.rcuk.ac.uk/escience/einfrastructure.htm>).

The 2009 International Review of e-Science was a key input into the 2010 e-Infrastructure review; its recommendations take into account, and build on from, the recommendations of the International Review, particularly R1, R2, R4, R6, R9 and R10. The Research Councils are currently considering the recommendations of the e-Infrastructure review and the next steps taken by the Councils in response will be influenced by the outcome of the 2010 CSR. Please note that the recommendations of the e-Infrastructure Review are not duplicated in this Action Plan.

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## Explanation

In the following table, the key recommendations of the report are numbered **R1** to **R12**. In addition, the report contains a number of embedded recommendations and suggestions (numbered here **S1** to **S59**), which have been extracted from the text. Many relate to the summary recommendations (R1 to R12) and are listed as an Appendix to this document. Others are grouped and included at the end of this table.

Report Recommendation	Relevant Stakeholders	Response and/or proposed actions
R1. Establish organisation and management structures that continue to treat e-Science as a designated strategic initiative spanning all Research Councils and having ongoing designated funding.	RCs, JISC	Although there is no longer a dedicated cross-Council e-Science programme, and support for e-Science is embedded within wider support for infrastructure, method development and research, JISC and the Research Councils continue to coordinate their activities in e-Science through regular meetings of its representatives at strategic and operational levels. JISC programmes in this area are overseen by the JISC Support of Research Subcommittee, which has RC representation.
<b>R2.</b> Establish more systematic and better supported mechanisms, including targeted funding, to nurture collaboration and bi-directional knowledge transfer between academia and industry in the creation, provisioning, and application of e-Science.	RCs, TSB, KTNs, HEIs	<p>The RCs continue to encourage knowledge transfer and exchange through a number of activities and schemes. The recent introduction of "Pathways to Impact" (<a href="http://impacts.rcuk.ac.uk/default.htm">http://impacts.rcuk.ac.uk/default.htm</a>) by the Research Councils will encourage all grant applicants to explore links to industry and opportunities for knowledge transfer. The Research Councils continue to provide funding for research collaborations with industry, subject to peer review, through its normal mechanisms.</p> <p>JISC continues to fund programmes and advice to improve processes for engagement between HEIs with industry.</p> <p><b>Actions:</b></p> <p>RCs and JISC to continue to work closely with the Technology Strategy</p>

		<p>Board in relevant areas. For example, “large data sets” has been identified as a potential priority area for collaboration between TSB and the Research Councils. RCs to participate in a workshop to launch the TSB “Harnessing Data” call (Autumn 2010).</p> <p>RCs to work with relevant KTNs to ensure the academic e-Science community is appropriately connected to potential industrial users of e-Science.</p>
<b>R3.</b> Sustain and strengthen the RCUK network of e-Science Centres.	RCs, HEIs	<p>EPSRC currently supports 4 centres for e-Science: the National e-Science Centre at Edinburgh/Glasgow, the White Rose Grid e-Science Centre, Belfast e-Science Centre, and South East Regional e-Research Consortium. Three of these centres have funding until 2013.</p> <p>JISC is currently reviewing the models that HEIs have adopted to support their researchers’ use of ICT and advanced technologies, including those supporting their researchers through e-Science centres.</p> <p><b>Action:</b></p> <p>RCs to agree a strategy for the future of e-Science centres in 2011/12 for implementation in 2012/13.</p>
<b>R4.</b> Sustain the operational e-infrastructure for e-Science created to the present.	RCs, JISC, HEIs	<p>The RCs continue to recognise the importance of discipline specific e-Infrastructures. BBSRC and MRC continue to support the European Bioinformatics Institute (EBI). In 2010, EPSRC funded the Software Sustainability Institute (SSI) to drive the continued improvement and impact of research software; the SSI has funding until 2015. STFC have continued support for GridPP, which will deliver a full-scale Grid for the exploitation of Large Hadron Collider data; the current project builds on earlier development phases, previously funded by PPARC, CCLRC and STFC.</p> <p>JISC continues to support core e-Infrastructure services such as the</p>

		<p>SuperJANET network and videoconferencing support, and is developing strategies for moving priority embryonic services which have established need into the JISC service portfolio, for example, the Digital Curation Centre and the NGS. The NGS aims to enable coherent electronic access for UK researchers to all computational and data based resources and facilities required to carry out their research, independent of resource or researcher location.</p> <p>The RCs and JISC continue to explore the potential of alternative e-infrastructures. In July 2010, RCs held a workshop for invited academics and commercial providers to discuss the opportunities and challenges for cloud computing to research in the UK. JISC has undertaken a number of reviews of cloud computing technologies (<a href="http://www.jisc.ac.uk/whatwedo/programmes/researchinfrastructure/cloudcompute/review.aspx">http://www.jisc.ac.uk/whatwedo/programmes/researchinfrastructure/cloudcompute/review.aspx</a>).</p> <p>See also R6.</p> <p><b>Actions:</b></p> <p>JISC and the Research Councils to explore the recommendations of the RCUK workshop on cloud computing in terms of the future provision of cloud computing for research. For example, JISC and EPSRC to launch a joint call for “pilot projects in cloud computing for research” in October 2010.</p>
<p><b>R5.</b> Recognise in Programme calls and funding policies that there are people in several complementary roles that need to be funded in a balanced way.</p>	<p>RCs, JISC</p>	<p>The RCs identify skilled people as a key component of e-infrastructure. For example, the recently commissioned Software Sustainability Institute (SSI) supports the active collaboration of research scientists and software developers.</p> <p>Under Full Economic Costing, there is no barrier to the appropriate resourcing of research projects, including the inclusion of software developers on research grants. Both individually and collectively, the</p>

		<p>RCs stimulate multidisciplinary approaches to research, employing a broad portfolio of flexible funding mechanisms and approaches.</p> <p>JISC has recently reviewed the various models and support staff roles that HEIs have adopted to support the advanced use of ICT by researchers. This review identifies and highlights the importance of these roles, and the requirement that they be reflected in funding budgets.</p> <p><b>Actions:</b></p> <p>The RCs will continue to provide strategic support to skilled people as a key component of relevant research projects and e-infrastructure. For example, as part of the e-Social Science strategy, ESRC will invest resources in a 'Partnership fund', strictly for joint activities, and a 'visitors fund' which will support exchanges, prioritising linking across investments and mobility of 'Research Technologists' for whom other programmes are unsuitable.</p> <p>The Research Councils will continue to monitor their processes to ensure there are no barriers to appropriate and balanced support for research.</p>
<p><b>R6.</b> Continue funding policies that strongly encourage or require the creation and adoption of shared e-infrastructure.</p>	<p>RCs, JISC, HEIs</p>	<p>The Research Councils and JISC employ, and will continue to employ, funding policies that strongly encourage or require the creation and adoption of shared infrastructure (for example, the HECToR HPC facility at Edinburgh, GridPP, NGS and the White Rose Grid).</p> <p><b>Actions:</b></p> <p>RCs, under the RCUK banner, will continue to work together to provide shared e-infrastructure where there is added value to the wider UK research portfolio.</p> <p>The JISC Research Communities Engagement programme will continue</p>

		to raise awareness of shared e-infrastructure and tools available to researchers. The JISC Virtual Research Environment programme will continue to encourage, facilitate and demonstrate use of shared and local e-infrastructures and tools.
<b>R7.</b> Encourage and support even more participation of the arts and humanities research communities in the e-Science Programme.	AHRC	AHRC continue to explore opportunities for coordinated support of e-Science with the other councils and JISC. For example, AHRC are engaged with JISC and NEH in supporting the “Digging into Data” programme. AHRC are co-sponsoring a workshop with BBSRC on the challenges on visualisation of large biological data sets.  <b>Action:</b>  Subject to the CSR, AHRC will develop a theme in the area of “Digital Transformations” and will take into consideration the needs of e-Science.
<b>R8.</b> Encourage and support even greater leadership by the social science research community in the adoption of e-Science methods.	ESRC	In October 2009 ESRC appointed Professor David De Roure National Strategic Director for e-Social Science, and Dr Marina Jirotko as Deputy Director, to maximise the benefits from the existing e-Social Science investments by setting out and overseeing the future strategic direction of e-Social Science.
<b>R9.</b> Develop a dual strategy that both (1) accelerates the adoption of e-Science methods in the “mainstream market” of researchers; and (2) refreshes the investments in the “early market” to produce the next wave of innovation in e-Science services and application.	RCs, KTNS, TSB, HEIs	The Research Councils encourage knowledge exchange through a number of activities and schemes, including the requirement for “Pathways to Impact” statements in grant applications (see R2). STFC e-Science supports the exploitation of e-Science technologies throughout the STFC's programmes and the research communities they support, together with researchers funded by all Research Councils across the national science and engineering base.  JISC have undertaken a three part review of the uptake of e-infrastructure ( <a href="http://www.engage.ac.uk">www.engage.ac.uk</a> ): <i>E-IUS</i> produced use scenarios and videos exemplifying uptake of e-Science technologies; <i>Engage</i>

		<p>addressed short term barriers to adoption of the NGS; and, <i>e-Uptake</i> investigated longer term issues to improve the uptake of e-science technologies.</p> <p><b>Actions:</b></p> <p>RCs will continue to support the wider dissemination and exploitation of the research it supports, including the uptake of e-Science tools and methods.</p> <p>BBSRC will continue to encourage the uptake and development of e-Science tools and approaches for the biosciences through its responsive mode (highlighted in the Technology Development for the Biosciences priority) and through the Strategic Tools &amp; Resources Development Fund.</p> <p>EPSRC will explore activities to embed e-science in the wider engineering and physical science portfolio through the promotion of e-science tools, including the launch of a call in autumn 2010 for networks of users and providers of e-infrastructures.</p> <p>Subject to the CSR, in Autumn 2010, ESRC will release a 'Demonstrator' call which will make available competitive funds for translating existing Digital Social Research innovation to practice, available to the broader community.</p> <p>The JISC Research Communities Engagement programme will continue to raise awareness of shared e-infrastructure and tools available to researchers. The JISC Virtual Research Environment programme will continue to encourage, facilitate and demonstrate use of shared and local e-infrastructures and tools.</p>
<p><b>R10.</b> Continue the strong focus on creating practices and services for appraisal, curation, federation, and</p>	<p>RCs, HEIs, JISC</p>	<p>Individually, the Research Councils have well established, or are developing, data sharing policies. For example, as part of their Science Information Strategy, NERC has launched a 3 year</p>

<p>long-term access to scientific data.</p>		<p>programme moving towards having the data, systems and services to support the vision of interoperable data for the environmental sciences. ESRC identify that data resources are core to the social science community, and have a clear strategy for their sustainability. ESRC supports data curation and long-term preservation and access through its Economic and Social Data Service (ESDS), an internationally leading, dedicated, national data facility. MRC is reviewing its strategy for 'big data science' including the future development of the Data Support Service.</p> <p>In addition, the RCs and JISC already support a number of activities in support of long-term access to scientific data. For example, the UK <i>PubMed</i> Central Database (<a href="http://ukpmc.ac.uk">http://ukpmc.ac.uk</a>) supported by BBSRC, MRC and the Wellcome Trust offers links to a large number of scientific data sets. JISC is funding the Research Data Management Programme, aimed at building the capacity, support and recognition for research data management and curation within HEIs and research communities. JISC funds the Digital Curation Centre to provide synthesis, dissemination and outreach of good practice, policy and tools.</p> <p><b>Action:</b></p> <p>The RCUK Research Outputs Group (ROG) will work to produce best practice guidelines for the sharing, curation and management of research outputs including data, which will reflect general principles in data sharing while recognising the specific requirements and existing practices in different research disciplines.</p> <p>EPSRC is undertaking a project to develop policy for long term access and management of engineering and physical sciences data.</p>
<p><b>R11.</b> At every opportunity establish and support policies for openness:</p>	<p>RCs, JISC,</p>	<p>Openness remains the general policy of the Research Councils. For example, openness is a key part of NERC's data policy</p>



<p>open-source code, open data, and open courseware.</p>	<p>HEIs</p>	<p><a href="http://www.nerc.ac.uk/research/sites/data/policy.asp">http://www.nerc.ac.uk/research/sites/data/policy.asp</a>). All NERC award-holders are required to ensure that NERC Data Centres are aware of significant datasets generated, or to be compiled, under the award so that their long-term stewardship can be assured or planned. The 2009 RCUK Code of Conduct on the Governance of Good Research (<a href="http://www.rcuk.ac.uk/review/grc/default.htm">http://www.rcuk.ac.uk/review/grc/default.htm</a>) includes specific guidelines on the sharing, openness and preservation of data.</p> <p>Openness underpins the JISC strategy through programmes on Open Education Resources, Open Access, Open Source (via OSS Watch) and programme promoting open data/linked data and open standards.</p> <p><b>Actions:</b></p> <p>RCs to continue to work with HEIs to ensure that openness remains a general policy of publicly-funded research across all disciplines.</p>
<p><b>R12.</b> Place greater emphasis on the overarching goal of establishing capacity for collaborative, international, interdisciplinary team science to occur routinely on IT-enabled platforms provide all the services required by the research teams, and enable them to work together well in all four variations of same and different, time and space.</p>	<p>RCs, HEIs, JISC</p>	<p>The RCs see this recommendation as a feature of success for the other recommendations. Success means there are no barriers to working within, and moving between, all four quadrants as appropriate to the production of world class research.</p> <p>JISC funds a virtual research environment (VRE) programme to provide tools to support interdisciplinary and collaborative research.</p>

## Responses

Brief responses are given below against the embedded recommendations and suggestions of the review (S1 to S59, see Appendix I). The Research Councils and JISC note these issues, alongside the summary recommendations of the report, and will continue to take them on board in future strategy development.

## Development of Software and e-Science Tools

<p>S11. OMII (Open Middleware Infrastructure Institute) is [...] a model of professional software development and maintenance that needs to expand (Platform for Research Enhancement: Software, page 12).</p>	<p>RCs</p>	<p>In 2010, EPSRC funded the Software Sustainability Institute (SSI) at Edinburgh, Manchester and Southampton to drive the continued improvement and impact of research software. The centre has funding until 2015. As part of the ESRC National Strategic Director grant, funds have been specifically allocated to work with the SSI to enable the SSI to work with and advise the e-social science community.</p>
<p>S12. We suggest creating and sustaining long-term centres for software development and support. They need consistent funding at a significant level [...] (Platform for Research Enhancement: Software, page 12).</p>		
<p>S13. There needs to be a commitment to long-term funding and a recognition that software development and support is at least as important to modern science as massive accelerators and telescopes (Platform for Research Enhancement: Software, page 12).</p>		
<p>S14. Going forward to build on such accomplishments in the initial e-Science Programme, we suggest establishing a process for determining the most important requirements for UK science – distinguishing between needs to</p>		

support UK-created software and UK-needed software. A classic peer review model of projects is NOT appropriate (Platform for Research Enhancement: Software, page 12).

S31. It is important to remember that there are two sides to the investment and adoption issue: (a) What UK e-scientists need, and (b) What UK ICT people produce. There needs to be cooperation and collateral learning between the two. There also needs to be a willingness to use good middleware and application codes produced outside the country and to avoid wasteful not-invented-here attitudes (Investments and Adoption, page 25).

S50. [Further success requires...] incentive structures to reward joint work within and between e-Science application fields and the fields of computer, information, and social science relevant to creating the tools and resources. (What are the future opportunities for UK e-Science?, page 45).

S59. The technologies and practices of e-Science, together with the e-infrastructure on which it rests, must be both a topic as well as an enabler of research and development; and this duality needs to be made synergistic. (Major Conclusions, page 48).



## Career Paths for e-Scientists

<p>S17. [...] it will never be possible for more than a few PhD students to obtain academic posts. However, there is a particular need to ensure that some posts are accessible to e-Researchers (Platform for Research Enhancement: Human Capital, page 15).</p>	<p>HEIs, RCs</p>	<p>Two of the three overarching aims of the Research Councils' Research Career and Diversity Strategy (<a href="http://www.rcuk.ac.uk/rescareer/strategy.htm">http://www.rcuk.ac.uk/rescareer/strategy.htm</a>) are: to ensure that the best potential researchers are attracted into research careers; and, to improve retention of the best researchers by promoting better career development and management of research staff in research organisations.</p> <p>Although the Research Councils planned to include information about e-Science graduates in the Data Document for the review Panel, it was not available. Since e-Science is not a HESA destination classification this information is extremely difficult to collect.</p> <p>The JISC review of ICT support for research models in HEIs will identify and highlight the various roles, and the importance of these roles within institutions, research groups and the research process.</p> <p><b>Actions:</b></p> <p>For future programmes, RCs will look to improve statistic gathering on career progression.</p>
<p>S18. We also urge collection of information on the (mostly non-academic) careers of graduates of e-Science master's and doctoral programmes (Platform for Research Enhancement: Software, page 13).</p>		
<p>S33. There has to be some dedicated funding to ensure continuity in the career path of this group (The Next 5 Years: Provide mid-term career paths for current personnel, page 26).</p>		
<p>S43. [...] leadership quality is one of the many assets the UK e-Science Programme has helped create that should be nurtured and leveraged into the future (In which areas of e-Science is the UK the international leader?, page 39)</p>		

<b>Diversity of e-Science Researchers</b>		
S42. The Panel was surprised and disappointed with the very low participation rate of women in the e-Science Programme [...] We suggest that systematically improving this situation, beginning with primary education, be set as a national goal (How effective is the education and training of e-Science practises and techniques at ensuring sufficient take up and adoption?, page 38).	RCs, HEIs	<p>One of the five aims of the RCUK Research Careers and Diversity Strategy is “to promote diversity within the research workforce at all levels and in the governance of research”.</p> <p><b>Action:</b></p> <p>The RCs will continue to promote diversity across all disciplines.</p>

### Training for e-Scientists

<p><b>S36.</b> Furthermore, efforts to create Doctoral Training Centres, developing systematic curricula for e-Science, must be carefully fostered. (The Next 5 Years: Community building and training, page 27).</p>	RCs, HEIs	<p>These recommendations are related to R9.</p> <p>The Research Councils are committed to enhancing the quality and output of the UK research base through training the next generation of world-class researchers, including in e-science methods and tools. For example, ESRC have set out a national strategy to improve the skills base in quantitative methods, which includes computationally data intensive research. It is a key priority for ESRC to up skill early/mid</p>
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<p><b>S41.</b> [...] e-Science tools must become fully embedded in undergraduate and post-graduate programmes if the technologies are to become part of the mainstream of research practice (How effective is the education and training of e-Science practises and techniques at ensuring sufficient take up and adoption?, page 37).</p>		<p>career researchers to utilise these tools. The MRC supports biomedical informatics fellowships aimed at creating a skilled workforce in the fields of bioinformatics, neuroinformatics, health informatics and computational biology.</p> <p><b>Actions:</b></p> <p>Subject to the CSR, ESRC will make funds available for training through the e-Social Science strategy; these will provide support for materials and events.</p> <p>Subject to the CSR, ESRC will seek to embed e-Social Science within National Centre for Research Methods (NCRM) Nodes; 30% of an NCRM Node budget is allocated towards training and capacity building.</p>
<p><b>S51.</b> [Further success requires...] educational and training mechanisms to enhance human capacity to both create and use e-Science environments. (What are the future opportunities for UK e-Science?, page 45).</p>		

### Links to High Performance Computing

<p><b>S34.</b> [...] bridges need to be built [to the HPC community] and mutually beneficial projects implemented (The Next 5 Years: Build Stronger Bridges to the HPC community, page 26).</p>	<p>RCs, HEIs</p>	<p>The Software Sustainability Institute is a national focal point for research software users and developers across the e-Science and HPC communities.</p> <p>The aims of the yearly e-Science All Hands Meetings include greater international engagement and collaboration with computational and</p>
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<p><b>S54.</b> There is need for greater involvement with the HPC community (What are the future opportunities for UK e-Science?, page 45).</p>		<p>HPC communities.</p>

### International Links

<p><b>S15.</b> Wider connections to the rest of the world [also] need to be established (Platform for Research Enhancement: Software, page 13).</p>	<p>RCs, HEIs</p>	<p>The RCUK International Strategy published in 2010 identifies the RCs aims in international collaboration. The RCs continue to fund the international mobility of academics via a number of schemes.</p> <p>Malcolm Atkinson, the e-Science envoy, has been an important participant in international activities, for example the EU e-Infrastructure Reflection Group.</p> <p>The aims of the yearly e-Science All Hands Meetings include greater international engagement and collaboration with computational and HPC communities.</p>
<p><b>S52.</b> [Further success requires...] mechanisms for the UK research community to routinely participate in, and often lead, global-scale science projects (What are the future opportunities for UK e-Science?, page 45).</p>		



## Community Building and Networking

	RCs, HEIs	Current EPSRC funding for the All Hands network, including yearly All Hands Meetings, runs until 2011.
<p>S35. The current project has established some very effective organisations, the National and Regional e-Science Centres, and the yearly All Hands Meetings. These need to be continued, evolved and broadened (The Next 5 Years: Community Building and Training, page 27).</p>		<p>Building self-supporting communities underpin many of the JISC programmes including Research Community Engagement, VREs and Research Data Management. This is seen as an essential component of sustaining the outputs of these programmes.</p> <p>Actions:</p> <p>All Hands Foundation to review and identify a strategy for the funding of yearly All Hands Meetings in 2010.</p>
<p>S37. There has to be a dedicated knowledge transfer organisation that deals with disseminating “how-to” information within the e-Science community and would provide help in jump-starting new science projects. Grants should be rewarded, not punished, for reusing existing components (The Next 5 Years: Systematic dissemination of best practice, page 27).</p>		<p>A Digital Social Research community website will be launched in 2010 as a focus for community development and liaison.</p>

## Appendix I: Embedded recommendations and suggestions pertinent to R1-R12

Page numbers refer to the *Microsoft Word* version of the report.

**R1. Establish organisation and management structures that continue to treat e-Science as a designated strategic initiative spanning all Research Councils and having ongoing designated funding:**

S9. The Programme should not be viewed as a one-shot, five-year project, but rather as a long-term strategy that needs to be continuously refined and carried forward indefinitely as a more permanent crosscutting Programme with real authority and resources (Responses to Evidence Framework questions, page vii).

S10. We suggest a hierarchy of small but energetic, value-adding coordinating and leveraging organisations for e-Science (Responses to Evidence Framework questions, page vii).

S32. A continuing investment at least at the current level over the next 5 years could easily grow [involvement in the e-Science community] by at least a factor of 10. This should happen in the research community, in linked industry, and in society as a whole (The Next 5 Years: Dramatically expand community involvement, page 26).

S47. [Further success requires...] the funding of the research communities, particularly those relevant to grand/key challenges, to use and benefit from the e-Science environment in a high-quality and transformative way (What are the future opportunities for UK e-Science?, page 45).

S58. A more permanent crosscutting programme with real authority and resources continues to be important. We are suggesting a hierarchy of small but energetic, value-adding coordinating and leveraging organisations for e-Science [...] (How did the Programme Strategy affect the outputs from UK e- Science?, page 47).

**R2. Establish more systematic and better supported mechanisms, including targeted funding, to nurture collaboration and bi-directional knowledge transfer between academia and industry in the creation, provisioning, and application of e-Science:**

S8. [...] the established platform of e-Science not only could scale to broader use, but also could move to more transformative impact (Future considerations, page vi).

S49. [Further success requires...] programmes for the systematic transfers of the fruits of both types of research listed above into innovative systems and processes that benefit all facets of society, including the environment and the economy (What are the future opportunities for UK e-Science?, page 45).

S55. [There is need for] more systematic interaction with industry (What are the future opportunities for UK e-Science?, page 45).

### **R3. Sustain and strengthen the RCUK network of e-Science Centres:**

S1. The Programme has been successful at creating shared software tools, ontologies, and standards work. It is important to continue to sustain long-term centres for such developments (Current Status of the Programme and its Impacts, page v).

S5. Important e-Science research facilities that have extra-ordinary levels of utilisation by their respective communities and high status within their communities need to be provided with continuous, sustained funding [...] (Current Status of the Programme and its Impacts, page v).

### **R4. Sustain the operational e-infrastructure for e-Science created to the present:**

S2. Hardware investments [...] are no longer impressive national resources and should be re-examined for alternative, cost-effective ways of providing superior storage and computational power (Current Status of the Programme and its Impacts, page v).

S4. Some heavily used services created and supported by the Programme include the National Grid Service, Access Grid, and the Digital Curation Centre; however, there is no plan for long-term basic support outside of R&D project budgets, so we advise revisiting the decisions on which services need to be provided specially or can be procured commercially, and then making a strategic plan in collaboration with the research community, service industry, and government (Current Status of the Programme and its Impacts, page v).

S6. The current hierarchy of centres and resources allows a more gradual evolution of the system and support infrastructure and should be maintained (Future considerations, page vi).

S23. It is important to sustain essential operations for use by all. [...] We advise starting an effort to revisit the decisions on which categories and specific services need to be provided specially or can be procured commercially, and then make a strategic plan working together with the research community, service industry and government (Platform for Research Enhancement: Services, page 17).

S24. We do urge re-examining the intensity (number and speed) of practical links as requirements increase exponentially for remote computing, visualisation, and especially data storage (Sustaining Requirements and Resources: Superior networking, page 23).

S25. There needs to be continued investment to ensure resources are shared and scheduled responsively (Sustaining Requirements and Resources: Distributed computing, page 23).

S27. [...] we recommend that efforts [on federation and sharing of compute resources], including enhanced capacity and function of distributed storage, be sustained and expanded (Sustaining Requirements and Resources: GRID architecture, page 24).

S38. The current e-Science Programme has been very successful in planting the seeds of a stable and robust system. This should not only be preserved, but systematically grown and evolved over the next ten years, placing new, large scale facilities and resources at the appropriate levels of this hierarchy (The Next 5 Years: Stable hierarchical distribution of resources, page 27).

S39. We note the very important role that JISC has played in piloting and supporting e-infrastructure for the university community and suggest that the JISC role be expanded, better funded, and better linked at the highest levels of the Research Councils (Stretching the Vision and Elevating the Response, page 33).

S40. The physical infrastructure needs significant expansion to support communication and information needs as well as the traditional computational pressures. Long-term sustainability and continuous improvement of the infrastructure is a major challenge that needs to be addressed (Are the present infrastructure and communication channels sufficient?, page 36)

S45. [Further success requires...] the creation, enhancement and sustaining of application-driven, shared e-infrastructure and comprehensive services developed collaboratively between technologists and users using iterative design methods (What are the future opportunities for UK e-Science?, page 44).

S53. The comprehensive services mentioned [above] need to include integrated high-performance computing, data stewardship and access, visualisation and human interaction capabilities, scholarly communication environments, virtual research environments, and online instrumentation. Processes need to be established to guide and sustain the creation of a shared e-infrastructure on which project-specific software can be easily tailored (What are the future opportunities for UK e-Science?, page 45).

S56. There is need to establish models for long-term funding and support of critical components of e-infrastructure: networking, HPC, data and information repositories, open software development and hardening, and training programmes to build human capacity to use and support e-infrastructure (What are the future opportunities for UK e-Science?, page 45).

**R6. Continue funding policies that strongly encourage or require the creation and adoption of shared e-infrastructure:**

S46. [Further success requires...] the alignment of a variety of stakeholders (Research Councils, JISC, Large Facilities Capital Fund, Technology Strategy Board, Higher Education Funding Councils, universities, private philanthropy, industry, and international research funding agencies) to jointly co-fund, in ways consistent with their various missions, a sustained and continuously improving e-infrastructure as a platform for e-Science (What are the future opportunities for UK e-Science?, page 44).

**R8. Encourage and support even greater leadership by the social science research community in the adoption of e-Science methods:**

S48. [Further success requires...] the funding of technical and social science research communities for which e-Science is an object of research (What are the future opportunities for UK e-Science?, page 45).

**R9. Develop a dual strategy that both (1) accelerates the adoption of e-Science methods in the “mainstream market” of researchers; and (2) refreshes the investments in the “early market” to produce the next wave of innovation in e-Science services and application:**

S29. Decisions need to be made on how much further to push the [development of semantic technologies] and what needs to be done to cross the broad chasm (Sustaining Requirements and Resources: Semantic technologies, page 25).

S30. Crossing the chasm requires a different sort of support and drive than staying with the visionaries [...] Staff who understand the technology (often researchers in their own right), can talk to scientists, and solve problems [...] must be available in an ongoing way. [...] We are urging larger and more permanent organisations which may not be part of university research departments (Investments and Adoption, page 25).

S44. The pioneers of e-Science have built a community, e-Science centres, and training opportunities and have contributed to the creation of e-infrastructure and its adoption [...] The best of these activities need to be identified and supported in a competitive way to move forward in innovation and to attract and support more practitioners (What are the future opportunities for UK e-Science?, page 44).

S57. There is need for a strategy to span the chasm between early adopters and the mainstream research community (What are the future opportunities for UK e-Science?, page 45).

## **R10. Continue the strong focus on creating practices and services for appraisal, curation, federation, and long-term access to scientific data:**

S3. [...] the Programme [...] needs more extensive planning for large-scale support of storage or federation of data resources as data grows exponentially (Current Status of the Programme and its Impacts, page v).

S7. Data-intensive computational technologies are evolving extremely rapidly, and establishing a shared, national support centre to take an exploratory role would be a very cost-efficient way to approach this inevitable shift (Future considerations, page vi).

S16. We strongly urge a top down analysis of what are now the most cost-effective means of providing basic storage and computation (Platform for Research Enhancement: Software, page 13).

S19. There must be broad planning for what [data] should be saved and how it will be made accessible and usable over time (Platform for Research Enhancement: Data Information and Stewardship, page 16).

S20. To enable future cross-disciplinary research, the programme needs to ensure pieces are saved in the disciplines, even though they may be considered of limited future use to the discipline (Platform for Research Enhancement: Data Information and Stewardship, page 16).

S21. There is also a need for an information and knowledge strategy too, including linked ontologies, standards, and metadata stability (Platform for Research Enhancement: Data Information and Stewardship, page 16).

S22. [...] there must be a very serious look at the expectations for fast, exponential growth of data that are created and the value of the information to be conserved. There is an inevitable conflict between saving results and doing new work, so there should be overt and transparent decisions (Platform for Research Enhancement: Data Information and Stewardship, page 16).

S26. There needs to be renewed examination of the distributed storage opportunities, including massive storage clusters (many petabytes at minimum) that would support preservation and long-term access to data and information (Sustaining Requirements and Resources: Distributed computing, page 23).

S28. [...] security still has to be addressed in the context of sharing data and e-Infrastructure, particularly the relationship between commercial security strategies and the research communities current practice (Sustaining Requirements and Resources: Data curation, sharing and management, page 25).