

DTI's Technology Programme and UK e-Science community's contribution

Purpose of document

The Government's investment in e-Science has culminated in a world-leading programme. The UK national infrastructure is recognised as the world's most advanced heterogeneous Grid. The DTI contribution to the e-Science programme has resulted in the engagement of over 70 companies, from SMEs to the largest corporates, and has built close collaboration between University research groups and Industry in a series of flagship projects. ForesightLINK, Issue No 10 Summer 2001, stated: - "If UK industry wants a place in the world of business [Grid] applications, it has to get involved now – at the academic research stage". **Over the past two and a half years the Core e-Science Programme has laid the essential foundations from which further development and exploitation can be made by industry through the Inter-Enterprise Computing (IEC) call.**

This paper aims to inform the IEC call of the strengths of the e-Science programme: -

- the excellent portfolio of projects many developed in close collaboration with industry; (see annex A)
- the commercially attractive re-deployable assets which have been created;
- the well integrated community which has been established;
- and the creation of a new paradigm.

A new generation of e-Science projects, led by industry and funded through the IEC call, will be able to leverage the previous investment and successes, and in the process many of the recommendations from the Lambert Review will be addressed.

Innovation Initiative and e-Science

The Breadth of e-Science

The definition of e-Science, which will certainly evolve into e-Research, is broad. It encompasses many aspects of supporting and undertaking research, and addresses computer supported strategies for collaboratively addressing major intellectual

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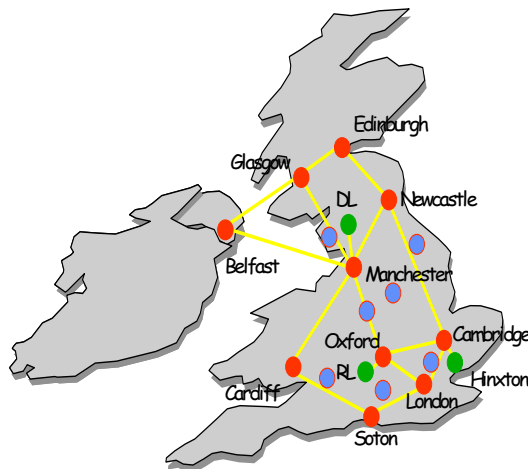
challenges. John Taylor, the previous Director General of the Research Councils, states that e-Science:-

- is about research increasingly done through distributed global collaborations enabled by the Internet (e.g. human genome program, Large Hadron Collider at CERN,..);
- uses very large data collections, terascale computing resources, high performance visualisation, sensors and detectors;
- and enables col-laboratories to be built.

John Taylor states that “e-Science will change the dynamics of how research is done”.

Over the last two and a half years, the e-science Core Programme has begun to create an e-Science infrastructure and has formed a national e-Science Grid as shown in the figure below.

UK e-Science Grid – phase 2



The named places on the map are ‘Regional e-Science Centres’; the remaining locations are ‘e-Science Centres of Excellence’ focusing on modelling (Birmingham / Warwick), networking (UCL), social science (Lancaster), astronomy (Leicester), the environment (Reading) and the operation of a closely coupled local Grid (White Rose Universities).

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The e-Science community has embarked upon an impressive set of projects. A project mapping is available on the national e-science web page (<http://www.nesc.ac.uk/>), and is shown below.

The table in the Appendix presents a selection of projects, which range across many disciplines, and identifies some of the capabilities developed in the projects which have wider applicability and interest.

Re-deployable e-Science Assets

The important assets, developed through substantial investment by RCUK and DTI in the UK e-Science Programme, which will be of interest to industrial collaborators are:-

- generic technologies, capabilities and tools ranging from the theoretical approaches (e.g. to security) to middleware components, some of which have already been developed in close collaboration with industry (eg components from the DAME project); a selection of these ‘components’ are summarised in the table above;
- a large, enthusiastic and highly skilled community¹ that is a rich resource of both R&D leaders and adaptable, mobile technology innovators. Their capability and contribution is internationally recognised, e.g. in leadership of

¹ More than 3600 have visited the National e-Science Institute.

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many working groups at the Global Grid Forum (GGF). This asset is best described as a change of ‘culture’, matched with a novel IT infrastructure which facilitates new opportunities in research, and constitutes the lasting legacy of the programme;

- a resource which industry can call upon consisting of:-
 - an operational infrastructure;
 - a ‘network’ that is capable of outreach, education, training and support²;
 - an operational multi-enterprise multi-technology grid, and web service testbeds³;
 - an established middleware development process now led by the Open Middleware Initiative Institute (OMII).
- well-established collaborative practices, including extensive collaborations with industry, extensive inter-institution projects and national-scale teams developing and supporting e-Infrastructure; these collaborations include richly diverse multi-disciplinary teams, experienced in managing large scale projects, with strong IT research engagement;
- experience in industrial projects that have operated at a sufficient scale to encounter and address some of the major challenges for successful inter-enterprise computing; and have begun to face the issues of robustness, reliability and resilience.

Contributions from UK e-Science community

e-Science alignment to Inter Enterprise Computing call

The UK e-Science community has developed: generic technologies and capabilities; a vibrant, cohesive and sustainable community; an operational national infrastructure and network for outreach, education, dissemination and training; well established practices together with expert knowledge gained from building e-Science projects of a significant scale; and experience of close university/industry collaboration and partnership. This collective experience, knowledge and resource offers the foundation which will be required for the creation of a new generation of industry/academic collaborative projects that will be well aligned to the IEC call.

Additionality

The investment from RCUK and the DTI, hitherto, has led to the development of the *springboard* described in the section above, but since the technology has not reached maturity, and many of the software standards and concepts are still under

² The outreach, training, education and support is available from the e-Science Institute and the 15 e-Science centres.

³ The testbeds are operated by the e-Science centres and extend into other institutions and internationally.

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development, the focus has been on e-Science pilot projects which aim to be ‘proof-of-principle’ rather than near-market. The IEC fund is required to enable the capabilities which the community possesses to be exploited fully, and for there to be industrial roll-out. Industry, still collaborating closely with academia, should take the lead in a new generation of e-Science projects funded from the IEC call which will realise the full potential of this new paradigm.

The DTI investment will be used to pass the following *thresholds*:

1. *Dependability thresholds* –before use of novel large-scale distributed IT systems in modern businesses can be widespread, there must be investment to ensure appropriate intensive testing is made before deployment.
2. *Usability thresholds* – investment is needed to ensure high-level notations appropriate for direct use by the business user are supplied, and supported by tools and semantically rich infrastructures, in order to use the current technology transparently to support inter-enterprise, compute intensive or data intensive activities.
3. *Technical challenges* – almost all highly profitable investments will involve attaining novel computational, data curation or communication techniques ahead of competitors in order to establish new business processes, and investment is needed to enable UK companies to gather the necessary skills and resources to operate effectively.

Exploitation

The IEC funding will allow further development in key areas and the ‘transfer’ of technology and expertise from the e-Science academic community to UK industry, and the subsequent dissemination and exploitation in the commercial world.

Risk

The UK e-Science programme has: established a good track record, delivered a world-leading heterogeneous infrastructure, an excellent portfolio of projects, and created an impressive knowledge base. Projects which build on this foundation avoid the risk of failure associated with creating new technology and developing new consortia from scratch.

The Community

The UK e-Science community is committed to working with industry to exploit the results and deliverables from the current phase of the e-Science programme into the next generation of projects.

Conclusions

The e-Science Core Programme has been very successful and has: an excellent portfolio of projects (many developed in close collaboration with industry), commercially attractive re-deployable assets and skills, a well integrated community, a well established knowledge base, an operational infrastructure, and has created a new paradigm.

This offers an excellent foundation for a new set of projects, led by industry, and funded through the Inter-Enterprise Computing call.

Annex A

Level 3 Technology Areas – basic infrastructure development		
Technology Area	Technology Area Overview	Projects
Auditing	Development of technologies for tracking GRID resource usage	<ul style="list-style-type: none"> myGRID: Directly Supporting the E-Scientist (http://www.mygrid.org.uk/) Security Aspects of the EU DataGrid (http://web.comlab.ox.ac.uk/oucl/research/grants/bx.html) Middleware services and Tools for managing Resource Sharing in Virtual Organisations (http://www.neresc.ac.uk/projects/GridMIST/index.html)
Authentication & Authorisation	Technologies for handling the security of GRID resources, authorising users and identifying levels of access	<ul style="list-style-type: none"> The Grid for UK Particle Physics (http://www.gridpp.ac.uk/) e-Demand: A demand-led Grid Based Architecture for dependable e-Science (http://www.dur.ac.uk/e-demand/) Security Aspects of the EU DataGrid (http://web.comlab.ox.ac.uk/oucl/research/grants/bx.html)
Brokering	Technologies for distributing GRID tasks to GRID resources	<ul style="list-style-type: none"> The Grid for UK Particle Physics (http://www.gridpp.ac.uk/) EPIC - e-Science Portal at Imperial College (http://www.lesc.ic.ac.uk/projects/epic.html) Middleware services and Tools for managing Resource Sharing in Virtual Organisations (http://www.neresc.ac.uk/projects/GridMIST/index.html) GRENADe - Grid-Enabled Desktop Environments (http://www.sve.man.ac.uk/Research/AtoZ/GRENADe)
Collaboration and Remote Instrument Services	Technologies for the control of remote instruments for collaborative use	<ul style="list-style-type: none"> Remote Microscopy (http://www-em.materials.ox.ac.uk/research/remote/index.htm) Structure-Property Mapping: Combination Chemistry & the Grid (http://www.soton.ac.uk/~echem/main%20page.html) Visualisation Middleware for e-Science (http://www.gridoutreach.org.uk/docs/pilots/visual.htm) Telemedicine on the Grid (http://www.escience.cam.ac.uk/projects/telem.html) iX-Grid (http://www.esnw.ac.uk/n-projects.shtml) An e-Science resource for High Throughput Protein Crystallography (http://www.e-htpx.ac.uk/) Op3D-Grid (http://www.esnw.ac.uk/n-projects.shtml)
Co-scheduling	Technologies for handling parallelised GRID jobs across resources	<ul style="list-style-type: none"> The Grid for UK Particle Physics (http://www.gridpp.ac.uk/) Effective Multi-User and Multi-Job Resource Utilisation (http://www.lesc.ic.ac.uk/projects/optimize.html) EPIC - e-Science Portal at Imperial College (http://www.lesc.ic.ac.uk/projects/epic.html) OSCAR-G: Management and Use of Large Clusters within and between Virtual Organisations (http://www.lesc.ic.ac.uk/projects/oscar-g.html) Sun Data and Compute Grids (http://www.epcc.ed.ac.uk/sungrid) e-Demand: A demand-led Grid Based Architecture for dependable e-Science (http://www.dur.ac.uk/e-demand/) Distance CFD Supercomputing for Industry (http://www.escience.cam.ac.uk/projects/cfd/) GRENADe - Grid-Enabled Desktop Environments (http://www.sve.man.ac.uk/Research/AtoZ/GRENADe)
Data Access Services	Technologies for providing access to distributed GRID-based data stores	<ul style="list-style-type: none"> The Grid for UK Particle Physics (http://www.gridpp.ac.uk/) BioMedical Research Informatics Delivered by Grid Enabled Services Cardiovascular Functional Genomics - An integrated distributed database facility (http://www.brc.dcs.gla.ac.uk/projects/bridges/) AstroGrid (http://www.astrogrid.org) Open Grid Services Architecture - Data Access and Integration Services

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		<p>(http://www.ogsadai.org.uk)</p> <ul style="list-style-type: none"> Data Query Processing (http://www.ogsadai.org.uk/dqp/) Op3D-Grid (http://www.esnw.ac.uk/n-projects.shtml) e-Diamond: Digital Mammography (http://www.ediamond.ox.ac.uk/) First Data Investigation on the Grid - FirstDIG (http://www.epcc.ed.ac.uk/~firstdig/)
Data Cataloguing and Provenance	Technologies for handling the creation of data, tracking the life-time of data including who, when and where data is created, modified and accessed. GRID-based content management	<ul style="list-style-type: none"> The Grid for UK Particle Physics (http://www.gridpp.ac.uk/) AstroGrid (http://www.astrogrid.org) Structure-Property Mapping: Combination Chemistry & the Grid (http://www.soton.ac.uk/~echem/main%20page.html) myGRID: Directly Supporting the E-Scientist (http://www.mygrid.org.uk/) Grid Based Medical Devices for Everyday Health (http://www.gridoutreach.org.uk/docs/pilots/meddev.htm) e-PROTEIN: A distributed pipeline for structural-based proteome annotation using GRID technology (http://www.e-protein.org/res_intro.html) The Gene Ontology Annotation Tool (http://www.esnw.ac.uk/n-projects.shtml) 3D OPT Microscopy Grid: Bringing the Grid to the Biomedical workbench (http://www.gridoutreach.org.uk/docs/pilots/3dopt.htm)
Fault Management	Technologies for identifying and accommodating errors and faults to provide a resilient GRID infrastructure	<ul style="list-style-type: none"> The Grid for UK Particle Physics (http://www.gridpp.ac.uk/) e-Demand: A demand-led Grid Based Architecture for dependable e-Science (http://www.dur.ac.uk/e-demand/) GridWeaver: Exploring Automated Configuration and Management for Grid Computing Fabrics (http://www.gridweaver.org/)
Global Event Services	Technologies for handling event-based communications between GRID resources	<ul style="list-style-type: none"> Effective Multi-User and Multi-Job Resource Utilisation (http://www.lesc.ic.ac.uk/projects/optimize.html) Grid Based Medical Devices for Everyday Health (http://www.gridoutreach.org.uk/docs/pilots/meddev.htm) OSCAR-G: Management and Use of Large Clusters within and between Virtual Organisations (http://www.lesc.ic.ac.uk/projects/oscar-g.html) Performance-based Middleware for Grid Computing (http://www.dcs.warwick.ac.uk/~hpsg/) GRENADÉ - Grid-Enabled Desktop Environments (http://www.sve.man.ac.uk/Research/AtoZ/GRENADÉ)
Grid Information Service	Underlying infrastructure for the GRID – containing technologies for registering and discovery of GRID services and their properties (such as quality of service, performance indicators, current availability status etc.)	<ul style="list-style-type: none"> The Grid for UK Particle Physics (http://www.gridpp.ac.uk/) Effective Multi-User and Multi-Job Resource Utilisation (http://www.lesc.ic.ac.uk/projects/optimize.html) Middleware services and Tools for managing Resource Sharing in Virtual Organisations (http://www.neresc.ac.uk/projects/GridMIST/index.html) GRENADÉ - Grid-Enabled Desktop Environments (http://www.sve.man.ac.uk/Research/AtoZ/GRENADÉ) BioQuery: A Bioinformatics Source Querying Environment (http://www.esnw.ac.uk/n-projects.shtml)
Global Queuing	Technologies for handling queue management of messages and GRID tasks or jobs	<ul style="list-style-type: none"> The Grid for UK Particle Physics (http://www.gridpp.ac.uk/) GRENADÉ - Grid-Enabled Desktop Environments (http://www.sve.man.ac.uk/Research/AtoZ/GRENADÉ)
Monitoring	Technologies for monitoring the performance and availability of GRID resources and network bandwidth	<ul style="list-style-type: none"> The Grid for UK Particle Physics (http://www.gridpp.ac.uk/) Performance-based Middleware for Grid Computing (http://www.dcs.warwick.ac.uk/~hpsg/) A Scalable Monitoring Platform for the GRID (http://www.cl.cam.ac.uk/users/iap10/)
QoS Dependability	Technologies for ensuring the quality of server ensuring the dependability	<ul style="list-style-type: none"> The Grid for UK Particle Physics (http://www.gridpp.ac.uk/) e-Demand: A demand-led Grid Based Architecture for dependable e-Science

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	and resilience of GRID infrastructures	<p>(http://www.dur.ac.uk/e-demand/)</p> <ul style="list-style-type: none"> • GRID Resource Scheduling (http://www.cs.ucl.ac.uk/research/grs/) • Performance-based Middleware for Grid Computing (http://www.dcs.warwick.ac.uk/~hpsg/) • A Scalable Monitoring Platform for the GRID (http://www.cl.cam.ac.uk/users/iap10/)
Resource Access Services	Technologies for accessing and utilising GRID based resources	<ul style="list-style-type: none"> • The Grid for UK Particle Physics (http://www.gridpp.ac.uk/) • AstroGrid (http://www.astrogrid.org)
Security and Privacy	Technologies for ensuring data integrity and trust of GRID resources for data sensitive tasks	<ul style="list-style-type: none"> • The Grid for UK Particle Physics (http://www.gridpp.ac.uk/) • e-Demand: A demand-led Grid Based Architecture for dependable e-Science (http://www.dur.ac.uk/e-demand/) • Security Aspects of the EU DataGrid (http://web.comlab.ox.ac.uk/oucl/research/grants/bx.html)

Level 2 Technology Areas – high level toolkits		
Technology Area	Technology Area Overview	Projects
Collaboration Toolkits	Toolkits for development GRID based large-scale collaborative environments	<ul style="list-style-type: none"> • The RealityGrid - a tool for investigating condensed matter & materials (http://www.realitygrid.org/information.html) • Structure-Property Mapping: Combination Chemistry & the Grid (http://www.soton.ac.uk/~echem/main%20page.html) • Environmental e-Science IRC: Linking Environmental e-Science in the lab and in the Field (http://www.gridoutreach.org.uk/docs/pilots/equator.htm) • Environment from the molecular level: an e-Science proposal for modelling the atomistic processes involved in environmental issues. (http://www.esc.cam.ac.uk/eminerals/) • Grid Enabled Optimisation & Design Search for Engineering (http://www.geodise.org/) • MYGRID: Directly Supporting the E-Scientist (http://www.mygrid.org.uk/) • Grid enabled knowledge services: collaborative problem solving environments in medical informatics (http://www.gridoutreach.org.uk/docs/pilots/griden.htm) • Collaborative Advanced Knowledge Technologies in the grid. (http://www.aktors.org/coacting) • MIAS-Grid. A Medical Image and Signal Research Grid (http://www.gridoutreach.org.uk/docs/pilots/mias.htm) • UTOPIA (http://www.esnw.ac.uk/n-projects.shtml) • Open Grid Services Architecture - Data Access and Integration Services (http://www.ogsadai.org.uk) • Visualisation Middleware for e-Science (http://www.gridoutreach.org.uk/docs/pilots/visual.htm) • A Co-operative Clinical e-Science Framework (http://www.clinical-escience.org/) • Telemedicine on the Grid (http://www.escience.cam.ac.uk/projects/telemed.html) • iX-Grid (http://www.esnw.ac.uk/n-projects.shtml) • Collaborative Virtual Teams (http://www.wesc.ac.uk/projects/covite/index.html) • e-Demand: A demand-led Grid Based Architecture for dependable e-Science (http://www.dur.ac.uk/e-demand/) • Electromagnetic Scattering by Aircraft (http://www.escience.cam.ac.uk/projects/emgrid/) • Application of GRID techniques to the monitoring and management of key data associated with major Civil Engineering Sites (http://www.soton.ac.uk/~gcivil) • Op3D-Grid (http://www.esnw.ac.uk/n-projects.shtml) • First Data Investigation on the Grid - FirstDIG (http://www.epcc.ed.ac.uk/~firstdig/)
Data Management Services	Toolkits for handling large scale	<ul style="list-style-type: none"> • Distributed Aircraft Maintenance Environment (http://www.cs.york.ac.uk/dame)

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	<p>data sets.</p>	<ul style="list-style-type: none"> • Structure-Property Mapping: Combination Chemistry & the Grid (http://www.soton.ac.uk/~echem/main%20page.html) • Data Query Processing (http://www.ogsadai.org.uk/dqp/) • Environment from the molecular level: an e-Science proposal for modelling the atomistic processes involved in environmental issues. (http://www.esc.cam.ac.uk/eminerals/) • Grid Enabled Optimisation & Design Search for Engineering (http://www.geodise.org/) • MYGRID: Directly Supporting the E-Scientist (http://www.mygrid.org.uk/) • Discovery Net: An e-Science test Bed for High Throughput Informatics (http://www.discovery-on-the.net/) • 3D OPT Microscopy Grid: Bringing the Grid to the Biomedical workbench (http://www.gridoutreach.org.uk/docs/pilots/3dopt.htm) • GRID Resource Scheduling (http://www.cs.ucl.ac.uk/research/grs/) • Software Applications for Data Management (http://web.comlab.ox.ac.uk/oucl/research/grants/c5.html) • MIAS-Grid. A Medical Image and Signal Research Grid (http://www.gridoutreach.org.uk/docs/pilots/mias.htm) • A problem solving environment for global biodiversity: prototype and demonstrator (http://www.bdworld.org/index.php) • A GRID Database for biomolecular simulations (http://www.biosimgrid.org/) • Open Grid Services Architecture - Data Access and Integration Services (http://www.ogsadai.org.uk) • A Co-operative Clinical e-Science Framework (http://www.clinical-escience.org/) • National Cosmology Grid and Remote Visualisation (http://www.escience.cam.ac.uk/projects/cosmos.html) • GODIVA: Grid for Ocean Diagnostics, Interactive Visualisation and Analysis (http://www.nerc-essc.ac.uk/las) • The NERC Datagrid (http://www.e-science.clrc.ac.uk/web/projects/nercdatagrid) • VideoWorks for the Grid (http://www.videoworks.ac.uk) • Distance CFD Supercomputing for Industry (http://www.escience.cam.ac.uk/projects/cfd/) • Application of GRID techniques to the monitoring and management of key data associated with major Civil Engineering Sites (http://www.soton.ac.uk/~gcivil) • Grid Enabled Integrated Earth system model (http://www.lesc.ic.ac.uk/projects/genie.html) • Op3D-Grid (http://www.esnw.ac.uk/n-projects.shtml) • e-Diamond: Digital Mammography (http://www.ediamond.ox.ac.uk/) • BioQuery: A Bioinformatics Source Querying Environment (http://www.esnw.ac.uk/n-projects.shtml) • Climate Prediction dot com (Centre Industrial) (http://www.climateprediction.com) • First Data Investigation on the Grid - FirstDIG (http://www.epcc.ed.ac.uk/~firstdig/) • Mouse Atlas Database (http://genex.hgu.mrc.ac.uk/)
<p>Data Mining and Analysis Services</p>	<p>Toolkits for handling data mining, data extraction and data analysis of large scale distributed datasets using GRID technologies.</p>	<ul style="list-style-type: none"> • AstroGrid (http://www.astrogrid.org) • Distributed Aircraft Maintenance Environment (http://www.cs.york.ac.uk/dame) • Grid Enabled Optimisation & Design Search for Engineering (http://www.geodise.org/) • myGRID: Directly Supporting the E-Scientist (http://www.mygrid.org.uk/) • Discovery Net: An e-Science test Bed for High Throughput Informatics (http://www.discovery-on-the.net/) • Software Applications for Data Management (http://web.comlab.ox.ac.uk/oucl/research/grants/c5.html) • Effective Multi-User and Multi-Job Resource Utilisation (http://www.lesc.ic.ac.uk/projects/optimize.html)

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		<ul style="list-style-type: none"> • Grid Based Medical Devices for Everyday Health (http://www.gridoutreach.org.uk/docs/pilots/meddev.htm) • MIAS-Grid. A Medical Image and Signal Research Grid (http://www.gridoutreach.org.uk/docs/pilots/mias.htm) • A problem solving environment for global biodiversity: prototype and demonstrator (http://www.bdworld.org/index.php) • e-PROTEIN: A distributed pipeline for structural-based proteome annotation using GRID technology (http://www.e-protein.org/res_intro.html) • A GRID Database for biomolecular simulations (http://www.biosimgrid.org/) • BioMedical Research Informatics Delivered by Grid Enabled Services Cardiovascular Functional Genomics - An integrated distributed database facility (http://www.brc.dcs.gla.ac.uk/projects/bridges/) • The NERC Datagrid (http://www.e-science.clrc.ac.uk/web/projects/nercdatagrid) • VideoWorks for the Grid (http://www.videoworks.ac.uk) • Application of GRID techniques to the monitoring and management of key data associated with major Civil Engineering Sites (http://www.soton.ac.uk/~gcivil) • Grid Enabled Integrated Earth system model (http://www.lesc.ic.ac.uk/projects/genie.html) • Op3D-Grid (http://www.esnw.ac.uk/n-projects.shtml) • e-Diamond: Digital Mammography (http://www.ediamond.ox.ac.uk/) • GEDDM - Grid Enabled Distributed Data Mining and Conversion of Unstructured Data (http://www.qub.ac.uk/escience/projects.php#geddm) • GeneGrid (http://www.qub.ac.uk/escience/projects/genegrid/) • BioQuery: A Bioinformatics Source Querying Environment (http://www.esnw.ac.uk/n-projects.shtml) • Climate Prediction dot com (Centre Industrial) (http://www.climateprediction.com) • First Data Investigation on the Grid - FirstDIG (http://www.epcc.ed.ac.uk/~firstdig/) • Mouse Atlas Database (http://genex.hgu.mrc.ac.uk/)
Grid Administration Services	Toolkits for administering GRID resources	<ul style="list-style-type: none"> • The Grid for UK Particle Physics (http://www.gridpp.ac.uk/) • Effective Multi-User and Multi-Job Resource Utilisation (http://www.lesc.ic.ac.uk/projects/optimize.html) • OSCAR-G: Management and Use of Large Clusters within and between Virtual Organisations (http://www.lesc.ic.ac.uk/projects/oscar-g.html) • Middleware services and Tools for managing Resource Sharing in Virtual Organisations (http://www.neresc.ac.uk/projects/GridMIST/index.html) • Sun Data and Compute Grids (http://www.epcc.ed.ac.uk/sungrid) • Performance-based Middleware for Grid Computing (http://www.dcs.warwick.ac.uk/~hpsg/) • A Scalable Monitoring Platform for the GRID (http://www.cl.cam.ac.uk/users/iap10/) • Collaborative Virtual Teams (http://www.wesc.ac.uk/projects/covite/index.html) • GridWeaver: Exploring Automated Configuration and Management for Grid Computing Fabrics (http://www.gridweaver.org/) • GRENADE - Grid-Enabled Desktop Environments (http://www.sve.man.ac.uk/Research/AtoZ/GRENADE)
Instrument Management Services	Toolkits of remote control and management of networked scientific instruments	<ul style="list-style-type: none"> • Remote Microscopy (http://www-em.materials.ox.ac.uk/research/remote/index.htm) • Structure-Property Mapping: Combination Chemistry & the Grid (http://www.soton.ac.uk/~echem/main%20page.html) • Grid Based Medical Devices for Everyday Health (http://www.gridoutreach.org.uk/docs/pilots/meddev.htm) • Telemedicine on the Grid (http://www.escience.cam.ac.uk/projects/telemed.html)

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		<ul style="list-style-type: none"> • iX-Grid (http://www.esnw.ac.uk/n-projects.shtml) • An e-Science resource for High Throughput Protein Crystallography (http://www.e-htpx.ac.uk/) • Op3D-Grid (http://www.esnw.ac.uk/n-projects.shtml)
Market Economy Services	Toolkits for managing economic models of use of GRID resources	<ul style="list-style-type: none"> • A market for Computational Services (http://www.lesc.ic.ac.uk/projects/markets.html) • The Grid for UK Particle Physics (http://www.gridpp.ac.uk/) • OSCAR-G: Management and Use of Large Clusters within and between Virtual Organisations (http://www.lesc.ic.ac.uk/projects/oscar-g.html) • Middleware services and Tools for managing Resource Sharing in Virtual Organisations (http://www.neresc.ac.uk/projects/GridMIST/index.html) • G-Ship: Product Description for Ship Motion Analysis using Grid Technologies (http://www.soton.ac.uk/~gship)
Scheduling Monitoring Diagnostic Services	Toolkits for management of GRID based scheduling including monitoring of resource availability and diagnosing problems	<ul style="list-style-type: none"> • GRID Resource Scheduling (http://www.cs.ucl.ac.uk/research/grs/) • Effective Multi-User and Multi-Job Resource Utilisation (http://www.lesc.ic.ac.uk/projects/optimise.html) • Environmental e-Science IRC: Linking Environmental e-Science in the lab and in the Field (http://www.gridoutreach.org.uk/docs/pilots/equator.htm) • EPIC - e-Science Portal at Imperial College (http://www.lesc.ic.ac.uk/projects/epic.html) • OSCAR-G: Management and Use of Large Clusters within and between Virtual Organisations (http://www.lesc.ic.ac.uk/projects/oscar-g.html) • Sun Data and Compute Grids (http://www.epcc.ed.ac.uk/sungrid) • A Scalable Monitoring Platform for the GRID (http://www.cl.cam.ac.uk/users/iap10/) • GRENADE - Grid-Enabled Desktop Environments (http://www.sve.man.ac.uk/Research/AtoZ/GRENADE)
Virtual or Immersive Environment Services	Toolkits for Virtual Reality manipulation of data and management of GRID resources	<ul style="list-style-type: none"> • The RealityGrid - a tool for investigating condensed matter & materials (http://www.realitygrid.org/information.html) • Telemedicine on the Grid (http://www.escience.cam.ac.uk/projects/telemed.html) • iX-Grid (http://www.esnw.ac.uk/n-projects.shtml) • e-Demand: A demand-led Grid Based Architecture for dependable e-Science (http://www.dur.ac.uk/e-demand/)
Visualisation Services	Toolkits for visualisation of large data-sets and complex analyses	<ul style="list-style-type: none"> • Environment from the molecular level: an e-Science proposal for modelling the atomistic processes involved in environmental issues. (http://www.esc.cam.ac.uk/eminerals/) • e-Demand: A demand-led Grid Based Architecture for dependable e-Science (http://www.dur.ac.uk/e-demand/) • The RealityGrid - a tool for investigating condensed matter & materials (http://www.realitygrid.org/information.html) • Discovery Net: An e-Science test Bed for High Throughput Informatics (http://www.discovery-on-the.net/) • Collaborative Advanced Knowledge Technologies in the grid. (http://www.aktors.org/coakting) • UTOPIA (http://www.esnw.ac.uk/n-projects.shtml) • Visualisation Middleware for e-Science (http://www.gridoutreach.org.uk/docs/pilots/visual.htm) • 3D OPT Microscopy Grid: Bringing the Grid to the Biomedical workbench (http://www.gridoutreach.org.uk/docs/pilots/3dopt.htm) • National Cosmology Grid and Remote Visualisation (http://www.escience.cam.ac.uk/projects/cosmos.html) • GODIVA: Grid for Ocean Diagnostics, Interactive Visualisation and Analysis (http://www.nerc-essc.ac.uk/las) • Application of GRID techniques to the monitoring and management of key data associated with major Civil Engineering Sites (http://www.soton.ac.uk/~gcivil) • Op3D-Grid

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		<p>(http://www.esnw.ac.uk/n-projects.shtml)</p> <ul style="list-style-type: none"> e-Diamond: Digital Mammography (http://www.ediamond.ox.ac.uk) BioMedical Research Informatics Delivered by Grid Enabled Services Cardiovascular Functional Genomics - An integrated distributed database facility (http://www.brc.dcs.gla.ac.uk/projects/bridges/)
Workflow Services	Toolkits for management of workflows for data and computational resources	<ul style="list-style-type: none"> Workflow Optimisation Services for e-Science Applications (http://www.wesc.ac.uk/projects/dipso/index.html) Grid Enabled Optimisation & Design Search for Engineering (http://www.geodise.org/) myGRID: Directly Supporting the E-Scientist (http://www.mygrid.org.uk/)

Level 1 Technology Areas – Services		
Technology Area	Technology Area Overview	Projects
Application Services	Domain specific services	<ul style="list-style-type: none"> GridCast (http://www.qub.ac.uk/escience/projects/gridcast/) The Grid for UK Particle Physics (http://www.gridpp.ac.uk/) AstroGrid (http://www.astrogrid.org) Distributed Aircraft Maintenance Environment (http://www.cs.york.ac.uk/dame) The RealityGrid - a tool for investigating condensed matter & materials (http://www.realitygrid.org/information.html) Structure-Property Mapping: Combination Chemistry & the Grid (http://www.soton.ac.uk/~echem/main%20page.html) Environmental e-Science IRC: Linking Environmental e-Science in the lab and in the Field (http://www.gridoutreach.org.uk/docs/pilots/equator.htm) Environment from the molecular level: an e-Science proposal for modelling the atomistic processes involved in environmental issues. (http://www.esc.cam.ac.uk/eminerals/) Grid Enabled Optimisation & Design Search for Engineering (http://www.geodise.org/) myGRID: Directly Supporting the E-Scientist (http://www.mygrid.org.uk/) Discovery Net: An e-Science test Bed for High Throughput Informatics (http://www.discovery-on-the.net/) Grid enabled knowledge services: collaborative problem solving environments in medical informatics (http://www.gridoutreach.org.uk/docs/pilots/griden.htm) 3D OPT Microscopy Grid: Bringing the Grid to the Biomedical workbench (http://www.gridoutreach.org.uk/docs/pilots/3dopt.htm) Biology of ageing e-science integration and simulation system (http://www.basis.ncl.ac.uk/) Grid Based Medical Devices for Everyday Health (http://www.gridoutreach.org.uk/docs/pilots/meddev.htm) MIAS-Grid. A Medical Image and Signal Research Grid (http://www.gridoutreach.org.uk/docs/pilots/mias.htm) A problem solving environment for global biodiversity: prototype and demonstrator (http://www.bdworld.org/index.php) Grid Enabled Electromagnetic Optimisation (http://www.soton.ac.uk/~gridem) e-PROTEIN: A distributed pipeline for structural-based proteome annotation using GRID technology (http://www.e-protein.org/res_intro.html) EPIC - e-Science Portal at Imperial College (http://www.lesc.ic.ac.uk/projects/epic.html) A Co-operative Clinical e-Science Framework (http://www.clinical-escience.org/) National Cosmology Grid and Remote Visualisation (http://www.escience.cam.ac.uk/projects/cosmos.html) GODIVA: Grid for Ocean Diagnostics, Interactive Visualisation and Analysis (http://www.nerc-essc.ac.uk/las) VideoWorks for the Grid (http://www.videoworks.ac.uk) Collaborative Virtual Teams (http://www.wesc.ac.uk/projects/covite/index.html) e-Demand: A demand-led Grid Based Architecture for dependable e-Science

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		<ul style="list-style-type: none"> (http://www.dur.ac.uk/e-demand/) • Electromagnetic Scattering by Aircraft (http://www.escience.cam.ac.uk/projects/emgrid/) • Distance CFD Supercomputing for Industry (http://www.escience.cam.ac.uk/projects/cfd/) • An e-Science resource for High Throughput Protein Crystallography (http://www.e-htpx.ac.uk/) • Application of GRID techniques to the monitoring and management of key data associated with major Civil Engineering Sites (http://www.soton.ac.uk/~gcivil) • G-Yacht - Application of GRID Technology for Computational Performance Prediction of Racing Yachts (http://www.soton.ac.uk/~gyacht) • Grid Enabled Integrated Earth system model (http://www.lesc.ic.ac.uk/projects/genie.html) • Op3D-Grid (http://www.esnw.ac.uk/n-projects.shtml) • e-Diamond: Digital Mammography (http://www.ediamond.ox.ac.uk/) • BioQuery: A Bioinformatics Source Querying Environment (http://www.esnw.ac.uk/n-projects.shtml) • Climate Prediction dot com (Centre Industrial) (http://www.climateprediction.com)
Grid Computational Services	High Performance Distributed Computational Services	<ul style="list-style-type: none"> • The Grid for UK Particle Physics (http://www.gridpp.ac.uk/) • AstroGrid (http://www.astrogrid.org) • The RealityGrid - a tool for investigating condensed matter & materials (http://www.realitygrid.org/information.html) • Environment from the molecular level: an e-Science proposal for modelling the atomistic processes involved in environmental issues. (http://www.esc.cam.ac.uk/eminerals/) • 3D OPT Microscopy Grid: Bringing the Grid to the Biomedical workbench (http://www.gridoutreach.org.uk/docs/pilots/3dopt.htm) • Biology of ageing e-science integration and simulation system (http://www.basis.ncl.ac.uk/) • Dynamic Brain Atlas (http://www-ipg.umds.ac.uk/d.hill/IXI/Dynamic_Brain_Atlas.html) • Grid Enabled Electromagnetic Optimisation (http://www.soton.ac.uk/~gridem) • A GRID Database for biomolecular simulations (http://www.biosimgrid.org/) • OSCAR-G: Management and Use of Large Clusters within and between Virtual Organisations (http://www.lesc.ic.ac.uk/projects/oscar-g.html) • Middleware services and Tools for managing Resource Sharing in Virtual Organisations (http://www.neresc.ac.uk/projects/GridMIST/index.html) • Sun Data and Compute Grids (http://www.epcc.ed.ac.uk/sungrid) • A Scalable Monitoring Platform for the GRID (http://www.cl.cam.ac.uk/users/iap10/) • GODIVA: Grid for Ocean Diagnostics, Interactive Visualisation and Analysis (http://www.nerc-essc.ac.uk/las) • Electromagnetic Scattering by Aircraft (http://www.escience.cam.ac.uk/projects/emgrid/) • Distance CFD Supercomputing for Industry (http://www.soton.ac.uk/~gcivil) • GridWeaver: Exploring Automated Configuration and Management for Grid Computing Fabrics (http://www.gridweaver.org/) • Grid Enabled Integrated Earth system model (http://www.lesc.ic.ac.uk/projects/genie.html)
Domain/ Task Ontologies and Metadata	Services for data/knowledge mangament	<ul style="list-style-type: none"> • Distributed Aircraft Maintenance Environment (http://www.cs.york.ac.uk/dame) • Environment from the molecular level: an e-Science proposal for modelling the atomistic processes involved in environmental issues. (http://www.esc.cam.ac.uk/eminerals/) • Grid Enabled Optimisation & Design Search for Engineering (http://www.geodise.org/) • myGRID: Directly Supporting the E-Scientist (http://www.mygrid.org.uk/)

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		<ul style="list-style-type: none"> • Discovery Net: An e-Science test Bed for High Throughput Informatics (http://www.discovery-on-the.net/) • Grid enabled knowledge services: collaborative problem solving environments in medical informatics (http://www.gridoutreach.org.uk/docs/pilots/griden.htm) • Biology of ageing e-science integration and simulation system (http://www.basis.ncl.ac.uk/) • Collaborative Advanced Knowledge Technologies in the grid. (http://www.aktors.org/coakting) • MIAS-Grid. A Medical Image and Signal Research Grid (http://www.gridoutreach.org.uk/docs/pilots/mias.htm) • Molecular Informatics Standards for the Grid (http://www.escience.cam.ac.uk/projects/mi/) • e-PROTEIN: A distributed pipeline for structural-based proteome annotation using GRID technology (http://www.e-protein.org/res_intro.html) • The Gene Ontology Annotation Tool (http://www.esnw.ac.uk/n-projects.shtml) • A Co-operative Clinical e-Science Framework (http://www.clinical-esience.org/) • VideoWorks for the Grid (http://www.videoworks.ac.uk)
Publication/Archiving Services	Services for publishing and long term storage of information	<ul style="list-style-type: none"> • The NERC Datagrid (http://www.e-science.clrc.ac.uk/web/projects/nercdatagrid)
Problem Solving Environments	Services for collaborative problem solving	<ul style="list-style-type: none"> • Environment from the molecular level: an e-Science proposal for modelling the atomistic processes involved in environmental issues. (http://www.esc.cam.ac.uk/eminerals/) • Grid Enabled Optimisation & Design Search for Engineering (http://www.geodise.org/) • Collaborative Advanced Knowledge Technologies in the grid. (http://www.aktors.org/coakting) • A problem solving environment for global biodiversity: prototype and demonstrator (http://www.bdworld.org/index.php) • EPIC - e-Science Portal at Imperial College (http://www.lesc.ic.ac.uk/projects/epic.html) • G-Ship: Product Description for Ship Motion Analysis using Grid Technologies (http://www.soton.ac.uk/~gship) • UTOPIA (http://www.esnw.ac.uk/n-projects.shtml) • e-Demand: A demand-led Grid Based Architecture for dependable e-Science (http://www.dur.ac.uk/e-demand/) • An e-Science resource for High Throughput Protein Crystallography (http://www.e-htpx.ac.uk/) • G-Yacht - Application of GRID Technology for Computational Performance Prediction of Racing Yachts (http://www.soton.ac.uk/~gyacht) • Grid Enabled Integrated Earth system model (http://www.lesc.ic.ac.uk/projects/genie.html)