



Grid R&D Vision and Roadmap

Summary Report

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Summary

The term Grid was coined in the mid-1990's¹ to describe a technological vision of a shared computing infrastructure for researchers. This vision was later refined and described the Grid as an infrastructure for *"coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organisations"*. Recently the Network of Excellence CoreGRID (<http://www.coregrid.net/>) produced a definition of Grid as a fully distributed, dynamically reconfigurable, scalable and autonomous infrastructure to provide location independent, pervasive, reliable, secure and efficient access to a coordinated set of services encapsulating and virtualising resources (computing power, storage, instruments, data, etc.) in order to generate knowledge.

A service in the most general sense is something, usually one or more software components, which responds to client requests. An electronic bookstore application is a service. The database component of the bookstore provides a data base service to the bookstore. Thus high level, abstract services may be recursively decomposed into lower level constituent services. In general the term should be qualified or its meaning made obvious through context.

The grid component is a super class of object that represents every managed entity, whether physical or logical, within a grid. Grid components are recursive, in that they may be aggregated to form other grid components, or decomposed into their constituent grid components.

Examples of grid components include, but are not necessarily limited to traditional resources such as servers, switches, disks, arrays and routers, resources such as a software distribution or perhaps data etc.. Whether a grid component is viewed as a service or as a resource and depends on context.

Grid is a vision and not a technology and the Grid vision embraces technology issues, human factors and administrative issues. A Grid roadmap will need to address all of these issues if the Grid vision is to be realised. The ultimate goal of the Grid vision is of an economy where resources can be used, shared and traded and is the backbone infrastructure for future research, commerce and industry. This vision is usually referred to as a service economy with the sharing and trading of resources via services.

The vision is

of a world-leading Grid utility of resources, tools and applications that is a key enabler for European Research, Industry and Commerce.

In order to provide such a Grid utility robust European middleware, with strong interoperability is needed. To realise the Grid vision a roadmap is proposed.

Roadmap goals: establish the European Union as

the centre-of-excellence in Grid middleware research technologies and tools in the short to medium term and thereby creating an EU Grid technological base [short term is regarded as within 2 years, medium term within 2 to 5 years and long term beyond 5 years];

the centre-of-excellence in Grid applications design, development, deployment, hosting and use in the medium term and thus developing the EU Grid technological base and laying the foundation for widespread use of Grid technological exploitation; and

having a world leading Grid service utility for the research community, industry and commerce in the medium to long term that is the means by which the EU can trade resources and services across the EU and globally.

1 Globus: A Metacomputing Infrastructure Toolkit. I. Foster, C. Kesselman. Intl J. Supercomputer Applications, 11(2), 115-128, 1997

2 The Anatomy of the Grid: Enabling Scalable Virtual Organisations. I Foster, C Kesselman and S Tucke. International Journal of High Performance Computing Applications, 15(3), 200-222, 2001

The goals to realise the vision can be implemented by headline recommendations with EU programmes acting as an enabler for the

- Creation of Grid research, development and education programmes in all Member States tailored to the needs of each member state and across the EU in the short term and thus creating a Grid service technology culture across Member States and laying the scientific and technological foundations for widespread Grid deployment;
- Establishment of global standard-based and interoperable middleware technologies in the short to medium term and thus enabling National programmes to develop their strengths and let the EU pool its expertise and take advantage of National strengths;
- Development of a virtual service economy for trading resources and services in the medium to long term and thus establishing the EU as the centre for service economy technologies, applications and business processes with consequent benefits to EU research, business and commerce.

EU programmes have an important strategic role across Member States and in particular

- EU to act as a catalyst for the co-ordination of activities between National Grid funding programmes in the short to long term and thus to leverage the National Grid investments and enable the transfer of expertise across the EU and thereby establishing the EU as the centre for Grid technology and applications.

These headline recommendations provide the theme for EU programmes in the short, medium and long term. Detailed recommendations are set out in section Recommendations. There are a total of 28 recommendations and to enable such a vision and roadmap requires co ordination across and action by, a large number of bodies e.g. the EC, the Member States, SSAs for FP7, ETPs, the grid research community and the industrial providers.

Objectives

The development of a Grid utility requires the development of a network infrastructure to support Grid provision, Grid middleware technologies that enable Grid deployment, tools for creating Grid applications and the development of strategic applications for Grid utilities to pilot and demonstrate Grid capabilities and thus accelerate Grid technology adoption.

The development of a network infrastructure for the EU is outside the scope of this roadmap and its existence will be assumed. It can be argued that a network infrastructure such as Géant will expand and evolve to meet user demands and thus foster a user community keen to use Grid services ensuring development of the necessary infrastructure. Furthermore, it is important that any underlying infrastructure evolves to meet an established need rather than attempting to predict future need.

The roadmap will focus on the key basic Grid software technologies and research and development themes that will form the user experience of the Grid.

The basic Grid technologies are

- Grid middleware that enables secure, authenticated and accountable access;
- Grid middleware architectures for robust, resilient and quality-of-service based services;
- Grid application technologies (e.g. brokerage, work flow, indexing etc);
- Grid user access technologies for Grid resources (e.g. portals, portlets, etc).

Many of these basic Grid technologies are well covered in the current project portfolio in National and EU research programmes. The focus on these basic technologies in the roadmap is a short to medium term theme as many of the foundational elements of these technologies have been developed.

The rapid development of Grid middleware has resulted in the deployment and active use of a number of middleware packages with the consequence that the deployment of a middleware platform in the short term is difficult to achieve. (It is probably impossible at this early stage of the Grid development lifecycle to define the ideal middleware platform.) The roadmap proposes a focus on inter-operability rather than the specification and development of a particular middleware platform; the development of a European middleware platform is likely to inhibit the long-term development of global Grid infrastructure.

The rapid development of Grid middleware has also resulted in a number of legacy Grid middleware communities that rely on early middleware systems (e.g. those user groups using Globus GT2.x). A roadmap will (necessarily) address the creation of one inter-operable Grid platform in the medium term and thus a short-term migration pathway for these legacy middleware communities is necessary. A focus for the roadmap proposal is the creation of a single Grid community using a single inter-operable infrastructure which is a shared resource for European research, industry and commerce.

The development of applications is an important theme in the roadmap, as applications will hasten the deployment of Grid infrastructures and the adoption of Grid technology. It is important that Grid is viewed as an enabling technology. The roadmap proposes the development of pilots of increasing complexity.

It is clear that web-service based middleware will be the foundation of Grid middleware infrastructures in the short to medium term and the roadmap proposes a focus on web-service based middleware.

The objectives can be summarised as:

- Develop a comprehensive, coherent and innovative roadmap outlining the strategic R&D directions for the future of European Grid research.
- Integrate the findings of previous and current Grid projects and take into account the long-term goals of national Grid programmes of Member States.
- Incorporate the collective view of members of the GridCoord Consortium regarding the long term future of European Grid development.
- Make recommendations for the funding bodies regarding the actions towards the implementation of suggested strategies.

Methodology

The presented document outlining the roadmap of Grid R&D is based on the recommendations suggested by the GridCoord Consortium, namely by focusing on the following topics:

- formulate a vision for European Grid research;
- produce a view on the rationale for future investments in Grid based research and take-up, both from the National and EU perspectives;
- show the common issues and challenges in different communities;
- make thought provoking recommendations.

During the preparation of this document we took into account the findings of previous and current Grid projects, the opinion of experts groups such as Next Generation Grids, ISTAG, NESSI, GridStart etc.

The Roadmap also incorporates the findings of interviews and discussions with numerous representatives of IT industry and academia regarding their rôle and involvement in the future of the European Grid effort. In these interviews we focused on identifying the requirements and actions that might help to increase the presence of industry and business in the Grid effort and widen the adoption of Grid technologies.

The Roadmap is the result of collective effort. This document has been revised and updated regularly by all members of the consortium. Drafts of the Roadmap have been circulated for comments among the members of GridCoord Consortium and in wider academic circles in order to verify the ideas presented in the document.

Grid Classification and Users

There are several classifications of grid. For example, at the highest level computational Grids and data Grids with additional sub classifications such as collaboration Grids involving multiple organisations and individuals, security domains, protocols, discovery mechanisms, etc.; enterprise Grids involving the complete life cycle of service deployment, provision, management, and decommissioning where the multiple domains are either absent or highly integrated, at least at a political level; and cluster Grids aiming at high performance/throughput computing which tend to be static, rather than dynamic like the above.

Another way of categorising Grids is according to their geographical distribution, their organisational scope and resource ownership which distinguish between cluster Grids, campus Grids, enterprise Grids, and global Grids. A cluster Grid contains resources located at one site within one organisation, and belonging to a single owner. A campus Grid differs from a cluster Grid in that its resources belong to multiple owners. Unlike campus Grids, enterprise Grids contain resources located at multiple sites. Finally, global Grids contain resources from multiple organisations.

Given the wide diversity of grid types, the different origins and developments of grids and the different user groups exploiting grids an essential and important activity is the integration of Grids into a unified entity. The different grid types currently being developed and deploy plus the experience and implementation efforts are contributing to the wider development and exploitation of grid technology; essentially each grid type is contributing to a bigger picture and therefore plays a role of contributing to the roadmap and vision as described in this document. For example, enterprise grids play a role within organisations in promoting and exploiting grid technology which then has to be incorporated within the wider scenario, thus interoperability becomes a unifying and critical issue which enable such grid knowledge to be employed and built upon.

As discussed later interoperability and consolidation of grid middleware becomes an essential and demanding requirement. The task involves facilitating the development and porting of application level services such as job submission, data services, virtual organisation management, accounting and portals to develop tighter interoperability between different grid types. As a result there will be greater application level portability and the utilisation of grids will be simplified. This will require the re engineering of software components rather than developing new technology. Efforts such as the Open

Middleware Infrastructure Institute (OMII) have an important and leading role to play in this activity. The current efforts to develop a repository of quality assured grid services running on existing major grid infrastructures such as EGEE, Unicore and Globus as part of OMII-Europe is an important contribution to interoperability. For new projects interoperability can be promoted by requiring project proposals to define in detail the technology they will use and defining how it adheres to global accepted standards or to state their plans to ensure global interoperability.

The users of grids range widely in IT ability and as such the effort to use grids must be adapted accordingly. Communities such as HPC grid users are in the vanguard of user communities as they have the experience of dealing with the substantial challenges of state of the art technology and the dedicated effort and frustration it requires. The demands of the users varies with the disciplines and, for example, if grids are to be universally available and widely used then the effort to use grids and exploit them must be made as simple as possible for a user. Thus the work on portals and user interfaces becomes the essential tool and requirement in this area. This, in turn, is linked to education and training and requires universities as well as industry to improve education and training in grid technology. The EU project ICEAGE has laid the foundations for much of the work in this area but this needs to be sustained over a long period of time to ensure users of all type, disciplines etc. are trained and educated in the exploitation of grid technology.

Strategic Workshops: Conclusions and Lessons Learnt

As part of the Gridcoord process of finding out more about grid up take and utilisation a number of workshops were held. Further details can be found in Annex E. The lessons to be learned from the workshop are:

- Industry embraces the concept of Grid but is following a different path than research in order to meet user demands and in order to minimise software development risks.
- Both legal and technical problems have made it so far difficult to show any large-scale successes of industrial Grid usage.
- The workshop has stimulated intense discussions among the participants, and thus did successfully contribute to the goals of the project. However, these workshops have to be continued to keep the communication between industry and public research going on.

Grid Programmes in the European Union

Grid Programmes in European Union Member States

There are more than 15 National Grid initiatives on Grid-based research within the European Union which provide a wealth of funding approaches, programme frameworks, innovative algorithms, software and methodologies for Grid technology. Annex A provides a brief overview of these programmes.

In the current phase of the Grid development lifecycle, the focus of Grid development has been on network infrastructure, middleware development, enhancement and testing, foundation toolsets for Grid application development and early-adopter/pioneering applications. This strategy is to provide the key technology to enable larger-scale Grid development and deployment. This is reflected in the funding strategies in most Member States that have invested in Grid; initially, providing a means for Grid implementation and piloting; developing, evaluating and deploying middleware on network infrastructures; and then funding pilot applications in both research and business domains.

The importance of National Grid programmes cannot be over stated. The Grid vision will be built incrementally and the need to create a broad and diverse user group is of critical importance to this vision. This broad and diverse user group is essential if the EU is to capitalise on its market size, to influence the direction of Grid technology in the short to medium term and to offer Grid services in the long term.

European Union Funded Grid Projects

The EU has funded a broad and diverse range of projects, as outlined in Annex B. The projects address specific technologies, broader technology issues, and specialist and general Grid communities. The projects also cover short, medium and long-term objectives of the Grid vision. The projects have purely research elements and elements with industrial and commercial involvement.

These projects provide a good technology spread and provide a good basis for building a sustainable Grid community within the EU.

EU and Global Research Communities

The EU has funded a broad range of research communities, as outlined in Annex C. Again, these research communities provide a good technology spread, with short, medium and long term focus, and involve both research and industry. These research communities have an important rôle to play in the development of the Grid within the EU and provide a focus for co-ordination of Grid activities.

In addition, there are many global research communities that are important to EU Grid activities. Annex D presents an overview of the important global research communities. These research communities again address the full range of objectives in the Grid with short, medium and long-term vision.

Summary

The National programmes of the EU states have taken a variety of approaches and are at different stages of development. Some National programmes have taken an academic approach while others are more business focused. These differences are to be expected and indeed may be regarded as a strength of the EU programme portfolio where National programmes are focusing on the strengths of their National economic and business base.

The current Grid programmes are establishing the fundamentals required for the Grid vision: developing the required Grid middleware, the application technologies for Grid systems and the first generation of Grid applications. This phase is establishing the underlying technological base as defined in roadmap objective recommendation 1. This short-term requirement is thus well covered by a number of National Grid programmes and by EU funding.

It is important to the EU academic community and industrial economy that all Member States fully participate in the development of a pan-European Grid culture. This Grid culture must be grounded in the needs of individual Member States. A short-term objective for the EU is to ensure that Grid programmes are realised in all Member States and that they address the particular need and capabilities of those Member States. A mechanism for encouraging development and to spread best practice programme and project approaches is prudent. For example, some limited EU funding might be provided to enable well-developed Grid initiatives to mentor emerging programmes and thus accelerate those programmes and make best use of pan-European funding.

The EU funded projects and research communities provide a good base for the development of Grid technology in the EU. The Grid vision is a diverse one. It is difficult and has been a problem in the GridCoord project to create an accurate picture of the technologies that projects are addressing and thus to identify programme weaknesses and gaps. A mechanism is necessary to catalogue and record the technology areas that projects and communities are addressing to enable best-practice to be identified and to enable more targeted funding for areas that are unresourced.

It is vitally important that EU researchers and industry take an active part in the global research communities as these communities will shape the global Grid vision, establish technology standards and address the issues of global Grid service provision. A mechanism to encourage and sustain EU researcher involvement is prudent—this might, for example, be a project funding requirement to plan and cost project involvement in the global Grid communities thus providing a platform for an EU voice in these communities.

A Rationale for Funding the Grid Vision

The Grid vision provides a powerful mechanism for European integration. It provides a means by which the EU research, commerce and industry bases can co-operate and share resources. Grid by its nature is an enabler for research, commerce and industry because they are increasingly collaborative, resource sharing, and multi-site and often multinational.

A realisation of the Grid vision would permit EU Member States to

- co-operate more effectively in academic research;
- co-operate more effectively in pan-European industrial and commercial undertakings;
- share cost-effectively the diverse intellectual and economic strengths of Member States;
- share and collaborate cost-effectively globally;
- share resources available across Member States;
- share resources more effectively globally;
- ease the integration of new Member States into the Union;

This will provide the EU with significant benefits in technology and resource sharing with consequent cost savings, improvements in productivity and effectiveness.

The realisation of the vision would enable the capabilities of EU researchers, business and the scale of the EU economy to meet the challenges of a changing global economy.

To obtain the advantages of the Grid vision the EU needs to

- encourage the development of a pan-European Grid culture in members states;
- encourage the creation of Grid co-ordination organisations in each member state to provide a focus for each state and to provide a means by which negotiations between Member States can take place;
- encourage the creation of an inter-operable Grid utility based on localised (member state) resources.

The EU and the Global Grid Vision

Grid is a global vision with Grid research and development efforts across the world (see also Annex F). The EU must view its research and development effort in Grid computing as being an integral part of this global vision, and the global research and development effort. The National Grid programmes, the EU funded projects and EU funded research communities provide a means whereby the EU research can participate in the global Grid vision and ensure an EU voice in the global Grid community.

The EU must pursue a global presence for its Grid technology base and ensure the National programmes and EU funded projects and research communities are active in the global research and development communities. To achieve these goals the EU should

- support an EU presence in international standards, interoperability and development groups and thus provide a European voice in global Grid discussions ; for example, by making participation in conferences such as GGF a requirement in project proposals;
- enable EU technology and applications to be presented at global Grid events; for example, by funding technology showcases at major Grid events, such as SC06, SC07 etc ;
- ensure that EU projects pursue technology built to global standards and are required to demonstrate this global interoperability; for example, by requiring project proposals to define in detail the technology they will use and defining how it adheres to global accepted standards or to state their plans to ensure global interoperability;
- ensure that EU projects have a global perspective by enabling the collaboration with projects in other National programmes; for example, by requiring projects to name other projects which are potential collaborators and planning the involvement in the projects.

The Grid R&D Challenge

Vision

The vision is of a world-leading Grid utility of resources, tools and applications that is a key enabler for European Research, Industry and Commerce.

Purpose

The Grid utility enables Europe to create a dynamic, efficient virtual service economy of resources and client applications for European Research, Industry and Commerce.

This vision is of an infrastructure that enables

- Research to be conducted more efficiently, reduces its costs, facilitates collaboration, increases the scale of the research challenges that can be tackled and is an enabler for pan-European collaboration, and therefore enables Europe to sustain and increase its world leading research base;
- Industry to control its costs, increase its productivity, to innovate and diversify, improve its ability to collaborate and co-operate and provides a means of pan-European trading services and resources, and therefore enables Europe to sustain and increase its high-value industrial sector;
- Commerce to develop and innovate, to trade resources and services and is the basis for a pan-European cyber service economy, and therefore provides a dynamic, innovative wealth creating sector for Europe;
- The infrastructure will provide both commercial and research services and enable the use and inter-operation of not-for-profit resources with profit based services and provide a bridge between the research, industrial and commercial sectors.

Resources

The Grid utility enables the secure collaborative sharing of National, pan-European and global resources and thus creates dynamic and efficient Research, Industrial, and Commercial sectors. The vision is of a Grid utility of resources that

- Provides on-demand, secure, efficient, resilient, robust and quality of service (QoS) focused hosting environments for services which can be on a commercial or non-for-profit basis;
- Provides on-demand, secure, efficient, resilient, robust and QoS focused storage capabilities which can be on a commercial or not-for-profit basis;
- Provides on-demand, secure, efficient, resilient, robust and QoS focused communication capabilities which can be on a commercial or not-for-profit basis;
- Provides on-demand, secure, efficient, resilient, robust and QoS focused computation capabilities which can be on a commercial or not for profit basis;
- Provides on-demand, secure, efficient, resilient, robust and QoS focused service indexing and cataloguing capabilities;
- Are accessible transparently and simply to a user with a minimum of infrastructure technical expertise required;
- Can be searched and inspected transparently and simply to enable users to identify resources they require.

The resources will be a mixed economy of public provision for community-based services for the research and non-commercial user, and for-profit provision from private companies and publicly funded organisation creating a resource marketplace where resource usage can be purchased on demand. This mixed economy will inter-operate to permit research, community, industrial and commercial users to collaborate and share resources and thus create a dynamic and efficient service economy.

Tools

The Grid utility provides tools that make its use transparent to the end-user and application and enables the administration, monitoring, management and deployment of resources, tools and applications.

This vision is of a Grid utility of tools that provides

- Standard mechanisms and formats for describing resource capabilities, resource quality of service, resource usage policies, resource availability and resource service agreement policies which enables resource services to be defined, created, advertised and used.
- Standard mechanisms and formats for describing service capabilities, service quality of service, service usage policies, service availability and service agreement policies which enable services to be defined, created, advertised and used.
- Secure mechanisms for dynamic registration of resources and services that enables capabilities to be inspected and searched and resources/services to be located;
- Secure mechanisms for the definition, management and monitoring of service registration that enables the secure management of hosting environments;
- Mechanisms that enable on-demand discovery, negotiation, resource access and use of resources and services and thus provide the basic requirements for a service-based trading economy;
- Secure mechanisms for the automatic monitoring of deployed services;
- Secure mechanisms for infrastructure definition and that performs automatic deployment and update of that infrastructure of resources and services;
- Secure mechanisms for the management and administration of services and resources, and thus makes large-scale services deployments possible;
- Secure mechanisms for autonomic control, configuration and update of deployed services;
- Mechanisms that enable the establishment, negotiation and arbitration of service agreements;
- Mechanisms that enable the brokering for the use and access to resources and services;
- A transparent programming model for application development that enables applications based on discovery of resources/services, automatic partitioning to enable parallel execution, automatic data movement, automatic choice of best autonomic control of execution and the negotiation of service use;
- Mechanisms for efficient, resilient, robust and QoS focused execution of Grid applications;
- A convertible and exchangeable Grid currency with agreed and standardised mechanism for defining and resource/service cost;
- A currency clearing system that enables resource/service payment to be effected.

The tools will be a mixed economy of open-source and propriety tools that inter-operate based on agreed, open standards that enable competition in tool and service provision to enable a dynamic service economy to develop. Governments, the European Union and Global inter-government organisations will need to provide regulatory management, auditing and control of the infrastructure.

- A Grid utility of tools requires additional non-technological issues to be addressed:
- A framework that defines the responsibilities of Governments and inter-Governmental bodies in a virtual service trading environment will be required;
- A framework of organisations will be required to create administer, regulate, index and manage the service economy will be required;
- A legal framework will be required to enable the trans-boundary provision, regulation and enforcement of service provision.
- Easy to setup and maintain tools and middleware, that makes to a large extent the Grid transparent for the user.
- Scalable tools that by their architectural design are prepared to be used in a large scale systems with several thousand participants and resources.

Applications

The vision is of a Grid utility of applications that provides

- Transparent, on-demand and accountable access to resources;
- A transparent and automatic mechanism for the execution of applications.

Recommendations

The Grid technology area is evolving rapidly and thus a long term, definitive collection of recommendations is not feasible and perhaps not desirable. The definition of a technology roadmap is possible for the short to medium term but is much more difficult for the medium to long term. The recommendations outlined below are more definite for issues in the short term and more general for issues in the medium to long term where the affect of technology changes are more difficult to predict. The vision below sets a goal for Grid in the medium to long term and is followed by headline recommendations that enable the maturity of the vision to be assessed.

The Vision

The vision is of a world-leading Grid utility of resources, tools and applications that is a key enabler for European Research, Industry and Commerce.

Roadmap Milestones and Headline Recommendations

To realise the Grid vision a Roadmap is proposed with three goals/milestones that aim to establish the European Union as

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| <i>the centre-of-excellence in Grid middleware research technologies and tools in the short to medium term and thereby creating a EU Grid technological base (short term is regarded as within 2 years, medium term within 2 to 5 years and long term beyond 5 years);</i> | <i>Milestone 1</i> |
| <i>the centre-of-excellence in Grid applications design, development, deployment, hosting and use in the medium term and thus developing the EU Grid technological base and laying the foundation for widespread use of Grid technological exploitation; and</i> | <i>Milestone 2</i> |
| <i>having a world leading Grid service utility for the research community, industry and commerce in the medium to long term that is the means by which the EU can trade resources and services across the EU and globally.</i> | <i>Milestone 3</i> |

The goals to realise the vision can be implemented by headline recommendations (RM) with EU programmes acting as an enabler for the

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| <i>creation of Grid research, development and education programmes in all Member States tailored to the needs of each member state and across the EU in the short term and thus creating a Grid service technology culture across Member States and laying the scientific and technological foundations for widespread Grid deployment;</i> | <i>RM1</i> |
| <i>establishment of global standard-based and interoperable middleware technologies in the short to medium term and thus enabling National programmes to develop their strengths and let the EU pool its expertise and take advantage of National strengths;</i> | <i>RM2</i> |
| <i>development of a virtual service economy for trading resources and services in the medium to long term and thus establishing the EU as the centre for service economy technologies, applications and business processes with consequent benefits to EU research, business and commerce.</i> | <i>RM3</i> |

EU programmes have an important strategic role across Member States and in particular

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| <i>EU to act as a catalyst for the co-ordination of activities between National Grid funding programmes in the short to long term and thus to leverage the National Grid investments and enable the transfer of expertise across the EU and thereby establishing the EU as the centre for Grid technology and applications.</i> | <i>RM4</i> |
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These headline recommendations provide the theme for EU programmes in the short, medium and long term.

Milestone M1 – Short Term Recommendations

The well-developed National Grid programmes within the EU address the short-term priority recommendation RM 1 (and thus milestone M1) and thus large-scale investment in this area is not necessary. However, there is a need to foster the development of Grid programmes across EU Member States in order to take full advantage of the EU's technology base and the potential scale of a EU service economy. Further, there is a need to foster greater adoption of emerging Grid standards and to focus on inter-operability of different Grid middleware solutions in order to make best long-term use of current funding. To achieve this, the roadmap envisages in the short term:

Reviewing Progress, Identifying Issues and Co-ordinating Funding

- **R1** - A requirement to publish for EU funded projects a definition of the technology areas that projects and research communities are addressing. This will enable best practice to be identified, reduce duplication of effort and help identify under-resourced areas. A lightweight approach is recommended with, for example, a web site collating a cross-referenced list for all projects that are funded. In the medium term a Grid technology ontology might be developed to provide a standard mechanism for describing technology.
- **R2** - A requirement to publish an annual list of outstanding technology issues in Grid computing. It is important that such a list be developed as a global effort and the EU might provide a focus for global efforts in this area.

Establishing an EU wide Grid Technology Culture

- **R3** - A programme to foster the development of National programmes with support for experience and technology from established National Grid programmes to emerging National Grid programmes. A lightweight approach is recommended with, for example, limited strategic funding for National programmes to mentor emerging programmes.

Establishing a Long-Term and Globally Sustainable Grid Technology Base

- **R4** - A requirement on all EU funded Grid programmes to use (global) standards-based middleware technologies or to address the seamless inter-operability with global middleware technologies. A lightweight approach is recommended with, for example, project review criteria assessing the sustainability of the proposed technical approach with respect to evolving standards and inter-operability with those standards.
- **R5** - A requirement on all EU funded Grid projects to participate in the global Grid vision and be active in standardisation, Grid forums and in global collaborations. A lightweight approach is recommended with a requirement, for example, at review stage for projects to be assessed on their collaboration in the global vision and inclusion of global partners that will be part of the project.
- **R6** - A limited funding programme is prudent to enable researchers to be active in global standardisation and inter-operability forums to ensure a EU voice in such efforts.
- **R7** - A requirement on EU funded applications development to stress the long-term sustainability of the technical approach. A lightweight approach is recommended with, for example, project assessment criteria that review such sustainability with respect to R2 and R5.

Steps towards the Global Grid Vision

- **R8** - A requirement on all EU funded application development to address their integration within a virtual service economy. A lightweight approach is recommended with, for example, project review criteria assessing the proposed approach with respect to its suitability for inclusion in a virtual resource and service trading environment.
- **R9** - A research programme on multi-authority security and authentication.
- **R10** - The EU to encourage the identification of a Grid co-ordination body for each National domain. These will be necessary to have a single point of contact for National Grid programmes and National infrastructures. A EU-wide co-ordination body is not recommended and does not seem necessary.

Ensuring the Sustainability of Current Grid Efforts

- **R11** - A (short term and focused) programme to assist in the migration of Grid applications deemed important to the medium to long term EU research, business or commerce base from legacy based middleware to emerging middleware standards and thus to create an applications base for a Grid service economy vision. The projects selected should be assessed with respect to R2 to R6.
- **R12** - A programme to create cross-border Research Grids based on two or more established National Grid R&D initiatives and infrastructures. Linking these infrastructures will create clusters of Research Grids throughout Europe and will promote the European Grid technological base.

Milestone M2 – The Medium Term Recommendations

In the medium term the goal is to establish the EU as a centre-of-excellence in service middleware packages and standards, development tools, service development techniques, service deployment, service hosting and e-infrastructure applications development. This goal aims to lay the foundation of a service economy by establishing a technological base to sustain it, the software necessary to enable its creation and a user demand to drive a service economy creation. To achieve this, the roadmap recommends in the medium term

Reviewing Progress, Identifying Issues and Co-ordinating Funding

- **R13** - A short, focused review of the roadmap and vision. A lightweight approach is recommended that might, for example, be an international workshop on the technology challenges. Such an approach would again focus the EU roadmap on the global issues and challenges.

Establishing a Long-Term and Globally Sustainable Grid Technology Base

- **R14** - The creation of a managed middleware repository for EU projects. This repository will act for EU projects and co-ordinate its efforts with EU National and global efforts in this area. It is important that this does not create a European middleware standard but provides a focus for the support of and technology transfer to the global Grid efforts. A lightweight approach is recommended with the EU body providing a means by which the National efforts in this area can work more closely and reduce duplication.

Technology Necessary to Implement the Grid Service Vision

- **R15** - A research programme that focuses on application support tools to make service-economy applications easier to develop and maintain. These programmes should build on the work that is a result of the EU NextGrid and CoreGrid projects.
- **R16** - A research programme that focuses on the management, maintenance and evolution of large-scale distributed, multi-authority service infrastructures.
- **R17** - A research programme that focuses on providing robust and resilient service infrastructures.
- **R18** - A research programme on the definition, provision and auto-negotiation of service agreement.
- **R19** - A research programme for advance resource, data, network usage monitoring.
- **R20** - A research programme on autonomic control of service-oriented architectures.
- **R21** - A research programme to create area focused ontologies and mechanisms for advanced searching and service discovery using semantic mechanisms.

Steps towards the Global Grid Service Vision

- **R22** - The creation of focused application programmes across all research disciplines and across National boundaries. In particular, emphasis should be outside the Science and Engineering domains which are early adopters of Grid technology and well funded currently.

Economic, Social and Security Impacts of the Grid Vision

- **R23** - The creation of a research programme that considers the financial and security issues of multi-authority service trading infrastructures.
- **R24** - The creation of a research programme to consider the legal and security aspects of multi-national service provision.
- **R25** - The creation of a research programme to consider the economic and economic security issues of a multi-national service economy.

The recommendations are not intended to imply individual funded programmes but to outline the technology issues that should guide the selection of programmes. Thus, the management of multi-authority, service-based infrastructures would fit with a programme that considers robust service-based infrastructures.

Milestone M3 – The Long Term Recommendations

The goal in the long term is to establish the EU as possessing the world leading Grid service infrastructure that is fundamental to the everyday activities of the research community, industry and commerce. This infrastructure will be the focus of resource sharing, service provision and National and multi-national collaboration. It will be the means by which the EU technology and business bases trade resources and services across the EU and globally.

The medium term recommendation development will have established the underlying technologies and the focus in the medium to long term is on deploying and using a service-trading infrastructure. There will be remaining technology challenges but it is difficult at this stage to identify what they will be

To achieve this goal the roadmap envisages in the long term

Creating the Global Grid Vision

- **R26** - The creation of advanced user-focused applications that can take advantage of the robust, domain-aware service-based infrastructure that can be deployed across EU National boundaries.

Making the Grid Vision Work.

- **R27** -The creation of a service infrastructure authority that will co-ordinate EU service infrastructures with global service infrastructures.
- **R28** -The creation of necessary financial, security and administrative regulations to enable the deployment of multi-national service-based infrastructures.

To enable such a vision and roadmap requires co ordination across and action by, a large number of bodies e.g. the EC, the Member States, SSAs for FP7, ETPs, the grid research community and the industrial providers. Appended to each of the bodies are the recommendations which are most appropriate to their particular interests.

The decision makers in the

- EC
 - √ *R1, R2, R3, R4 to R7 to R10, R13, R15 to R21, R23 to R25, R26 to R28;*
- SSAs for FP7
 - √ *R1, R2, R3, R15 to R22, R26, R27;*
- MS programmes
 - √ *R3, R7, R10, R11, R12, R22, R26, R27, R28], ETPs [R1, R2, R3, R22, R23 to R25;*
- Grid research community in general
 - √ *R9, R15 to R21;*
- and the industrial providers
 - √ *R11, R12, R22, R23 to R25, R28.*

ANNEX A – A Summary of National Programmes

Austria

In Austria, the Federal Ministry for Education, Science and Culture (bm:bwk) started funding the AustrianGrid project in 2004. The main goal of this project is the realisation of a Grid that is used for the development of Grid-specific applications and tools in order to demonstrate the benefits of such approaches for scientific applications. Austrian Grid has to be seen as a first step for achieving the long-term goal of increasing the Austrian competence in Grid Computing. Thereby not only academic institutions are addressed but also other research facilities and industry.

At the moment a national strategy is discussed. The possible implementation of recommendations and roadmap milestones presented in this report (ref. Section 7) will also be part of this process. Decisions concerning funding and research of the next phase of the AustrianGrid are envisaged for autumn 2006 with respect to national interests and the further development of the European Research Area..

France

The general French public funding scheme is governed by the new central research funding agency ANR (reorganised in 2005). This unique entry point is exhibiting several major programs that include Grid.

Fundamental research: These programs address long-term, mostly academic research, and they are managed in close collaboration with other national research bodies: CNRS, INRIA, CEA, etc. The main programs in the area of Grids are the Data Masses Program, and the High-Performance Computing and Grids Program. In both programs, the projects range from very fundamental ones about specialised algorithmic or programming methods for large-scale Grids, to more applied ones, like massive computing or using Grids to break major challenges in data management. A transversal program on Security is also proposed, where specific aspects of Grid research can be supported.

Research transfer: Another set of programs are devoted to transferring academic results to industry. The projects range from exploratory ones, still close to academia, to competitive ones, ready to be exploited by industry. They usually involve industrial partners, from start-ups to major companies. As far as Grids are concerned, such programs have been launched in the field of Network and Telecommunication and in Software Technology.

A special mention should be made about the national Grid'5000 Project. This is a large collaborative research effort developing a large-scale, nation-wide infrastructure for Grid research, eScience and cyber-infrastructures. The Grid'5000 project aims at building a highly reconfigurable, controllable and monitorable experimental Grid platform gathering 9 sites and featuring a total of 5000 CPUs. This collaborative research effort is funded by many sources: the French Ministry of Research, INRIA, CNRS, local universities and several regional councils. The total funding can be estimated at 7.5 MEuros for hardware equipment. It should be stressed that the goal is to build a large instrument for Grid Research, very much in the sense of particle physics or astrophysics, and not to develop a production tool. The experiments include all the computing layers: applications, algorithms, runtime, middleware, operating systems, and network protocols. A number of industrial companies have also expressed interest in using this instrument to experiment with their latest prototypes, and the platform is open to international collaboration.

Germany

In Germany, a coherent Grid strategy was established in 2005 when the first D-Grid projects (www.d-grid.de) were started. In the initial phase of D-Grid, one integration project and six community projects from different scientific disciplines are funded by the Federal Ministry of Education and Research. The integration project aims at providing a basic Grid infrastructure across Germany based on existing software solutions.

Additional generic developments and research results from the community projects will be successively integrated and supported by the integration project. This process is accompanied by a D-Grid Steering Committee that monitors and controls the research, development and deployment of the Grid middleware. The long-term goal of D-Grid is a take-over by industry and service providers that shall offer

Grid and E-Science services to the scientific communities, similar to Internet providers offering network bandwidth today.

With respect to the recommendations and roadmap milestones presented in this report (ref. Section 7), the D-Grid initiative aims at implementing goals M.1 and M.2, namely to establish centres of excellence in Grid middleware research and Grid applications design and deployment - however at a national scale. For the future, it is expected that the existing Grid middleware will be improved for further robustness and that it will be deployed not only in academic environments but also in industrial settings.

Hungary

The vision in Hungary is to carry on Grid related R&D in four main directions. The first direction is related with the Hungarian ClusterGrid that is a unique Grid solution in Europe enabling the interconnection of teaching lab PCs of higher educational institutions into a nation-wide Grid for the night shift and for the weekends. The further development of this Grid to include large data centres is a high priority. The second direction is further developing HunGrid, the Hungarian VO of EGEE. This infrastructure is basically offered for the scientists of the Hungarian Academy of Sciences. The third direction aims at creating a service-oriented Grid that can be used by industry. Finally, the desktop Grid concept is generalised and further developed towards a generic Grid infrastructure concept that can be used at every level in scientific, commercial and government institutions.

In a long term all these four kinds of Grid infrastructures should be interoperable and hence a key R&D issue in Hungary is Grid interoperability. A national funding roadmap is in development by Government, Academy and several companies. The Hungarian vision is deeply embedded in the European vision; all the Hungarian projects should strongly collaborate with European projects having similar objectives.

Education of the Grid concept and technology is also an important part of the Hungarian Grid vision. The Grid technology is already taught at several universities at the MSc level and Hungary plays the role of the regional training centre for the Central and South-East European regions.

Italy

In the period 2002–2005, the Italian Ministry of Research invested 8.1 M€ in the national research project FIRB GRID.IT mainly devoted to create a solid and coherent framework for research and applications of Grid Computing in Italy. In order to provide a solid coordination framework and to promote the exploitation of Grid in all possible domains the Italian Minister has launched the recent Grid Technology Platform Initiative. The first steps of this process are to: consolidate the middleware components, so far spontaneously developed by independent R&D projects, into a general platform of Grid services coherent and interoperable, increasingly adhering to International Standards and made available under a common Open Source licence; and start a series of pilot projects to exploit this Grid services platform at Industrial Service level.

The Consortium for the Open Middleware Enabling Grid Applications (c-OMEGA) will allow Italy to maintain the current level of drive in Grid developments and effectively collaborate with other similar initiatives, as those adopted by US (NMI) and UK (OMII).

The Netherlands

The Dutch developments on Grid infrastructures and e-Science are taking a rapid momentum to achieve a comprehensive environment focused on the take-up of academic and non-academic applications. The three major initiatives providing the road ahead are:

- Fibre-optical broadband infrastructure and communication services: SURFnet 6
- Virtual laboratory middleware for e-sciences: VL-e
- Nationwide Grid-based e-Science infrastructure: BIGGRID,

While both SURFnet 6 and VL-e have been launched as projects in 2004 and have been reported in the state-of-the-art publication of GRIDCOORD, BIGGRID is a project to be launched in the course of 2006. It strengthens the international position of the Netherlands in many scientific areas. BIGGRID encompasses data storage facilities and data processing services, enabled by Grid services with a budget of 30 M€ over a four-year period.

The roadmap for future development is governed by the following few key issues.

- How does the rise of Grid infrastructure impact the requirements for future generation supercomputers for scientific purposes? This question is relevant for technical domains as well as for organisational structures and has a comparable European dimension.
- To what extent do we have to allow non-academic and non-scientific users to make use of publicly funded Grid infrastructure. How can we improve non-academic take-up while ensuring availability for scientific R&D?
- How can we turn academic and scientific applications of Grid infrastructure into non-academic applications for the public sector and the commercial sector?

Poland

Announced in 1999, The PIONIER Programme (Polish Optical Internet - Advanced Applications, Services and Technologies for the Information Society, 2000-2006) envisaged the attainment of three strategic objectives:

- Construction of the broadband optical Internet. Today Polish research community has access to a leading-edge transmission infrastructure, with current transmission capacities matching those of GÉANT2 and other leading research networks in the world. Actually, with $n \times 10\text{Gbit/s}$ transmission, twenty one MANs, more than 700 academic institutions connected and over 4500 km fibre lines available, this is the largest National Research and Education Networks (NRENs) owned infrastructure of this type in the world.
- Development and verification of pilot services and applications for the Information Society, creating a base for new developments in: eScience, eLearning, eHealth, government and local administration as well as industry and business services. Several Grid projects were launched under this initiative.
- Creation of competitive conditions for active software development for new applications and services in the Information Society.

Recently preparation has started to launch the PIONIER2 Programme, which will be focused around service platforms for various eScience, eGovernment and eHealth domains.

Spain

Research on Grids is mentioned in the Spanish National Research Plan (the current one spanning from 2004 to 2007) in relation with its applications to e-Science and the need for infrastructures to support Grid-based computations. However, no explicit research line has been set up which focus solely on Grid development or applications. In spite of this, the NRP recognises Grid computing as instrumental for future development of several scientific and technological areas. Recently, a committee was set up and endowed with the task of writing a roadmap to clarify how e-Science (for which Grid-based technology is seen as a must) can foster the development of several scientific areas and which additional actions are needed. The result of this effort is a report entitled White Book on e-Science in Spain, which, among other things, lists a series of recommendations to policy makers. Understandably, they do not match exactly those put forth in this report, but some of them do coincide or overlap: R10 appears as the recommendation to establish a national contact point for international coordination; R3 is partially mentioned as the recommendation to pay attention to other countries with well-established Grid programs; the spirit of R13 is also present with the recommendation of establishing repositories aiming at spreading research results; since the importance of participating in the definition of international standards is acknowledged, R4, R5 and R6 are (indirectly) also part of the White Book.

Notwithstanding, it is still uncertain up to what point this report will influence upcoming project calls or the definition of the new NRP. This is due not only to being a report made by a consultative committee, but also to recent changes in the Ministry of Education and Science which caused relevant decision makers to be replaced.

Sweden

In Sweden, SNIC (=Swedish National Infrastructure for Computing) has a development mission for computing. Its earlier strategy dates from 2003 but is now (spring 2006) being replaced with a new "Landscape" document with visions and roadmaps for 2006-2009. In this document it is stated that "Grid computing is a key technology in the further development of the SNIC infrastructure for the Swedish research community". Also that it is vital to continue the ongoing build-up of the whole range of Grid computing research and development activities, including basic Grid computing research, middleware development and Grid applications. Among developments foreseen are middleware-independent

resource brokering solutions, research on market-based Grid economies, distributed Grid-wide fair share scheduling, Grid security issues, distributed databases and data replication.

To achieve wide spread use of Grid, high priority should be given to making the Grid more user-friendly. Also the tools for managing Grid systems have to be further developed. The goal is that at the end of the three-year period all SNIC-resources will be Grid-enabled.

Sweden is expected to fully participate in the international collaborations that drive the Grid development.

This is also expected to include a Nordic level activity of joining forces of National Grid Infrastructures.

A new manager is being recruited for SNIC to take the co-ordination role of implementing the new strategy.

UK

The UK e-Science programme was launched in July 2001 and in the subsequent 5 years over £250 M of new funding was invested in the basic e-Science infrastructure as well as e-Science projects in academia, industry and commerce.

In April 2006 the e-Science entered a new phase with projects being funded through the UK's seven Research Councils and the infrastructure being enhanced and maintained by the Joint Information Strategy Committee (JISC). The Research Councils co-operate through a new Strategy Advisory Team. The JISC e-Infrastructure Programme builds on the work arising from the e-Science Core Programme, and the OST (Office of Science and Technology) e-Infrastructure Roadmap initiative and will be working closely with the e-Science Strategy Advisory Team.

The Vision for the JISC e-Infrastructure Programme follows the initial five year investment in the UK e-Science infrastructure, which is being developed with other partners to expand the uptake and effective use of the e-Infrastructure from early adopters and researchers across disciplines.

Its two main objectives are:

- To have enhanced and consolidated the current technologies;
- To have established sustainable communities of use.

ANNEX B – European Union Funded Grid Projects

The EU Framework Programme is currently funding a range of projects in the Grid area which include:

NextGrid is focusing on the underlying technologies of the Next Generation Grid, aiming to deliver a new Grid architecture by the end of the decade. The work addresses security and business models, taking into account requirements from sectors such as finance and media.

CoreGrid is a network of excellence addressing the longer term Grid research, creating the foundations for the next-generation Grids toward 2010 and beyond.

Akogrimo is developing mobile Grid architectures and services for dynamic virtual organisations in pilot applications in e-Health and e-Learning.

SIMDAT is developing generic Grid technologies for industry in the areas of data integration, collaboration and knowledge discovery in sectors such as aerospace, automotive, pharmacology and meteorology.

K-WF Grid: A Knowledge-based Workflow System for Grid Applications (K-Wf Grid) addresses the need for a better infrastructure for the future Grid environment.

UniGrids is addressing the inter-operability between Globus and UNICORE.

HPC4U: The goal of the HPC4U project (Highly Predictable Cluster for Internet Grids) is to provide an application-transparent and software-only solution of a reliable Resource Management System.

inteliGrid: A goal of the project is to develop Grid technologies to provide an interoperability platform for engineering.

OntoGrid: The OntoGrid project will produce the technological infrastructure for the rapid prototyping and development of knowledge-intensive distributed open services for the Semantic Grid.

DataMining Grid: The project aims to develop tools and services for deploying data mining applications on the Grid.

Provenance: The Provenance project aims to design, conceive and implement industrial strength open provenance architecture for Grid systems, and to deploy and evaluate it in complex Grid applications, namely aerospace engineering and organ transplant management.

SENSORIA: The goal of the project is software engineering for service-oriented overlay computers, engineering of service-oriented overlay computers, context-adaptive, personalised global services applied to e-business, automotive systems, telecommunications.

MOBIUS: The Mobility, Ubiquity and Security project focuses on trust and security for small devices as parts of global computers, uses the Proof Carrying Code paradigm on Java-enabled global computer case studies.

AEOLUS: The project Algorithmic Principles for Building Efficient Overlay Computers aims to develop the algorithmic principles to enable transparent and efficient access to the resources of an internet-based global computer. It addresses also communication between wireless and mobile nodes and builds sample services as proof-of-concept.

Gridstart (<http://www.gridstart.org>) project has published an “IST Projects’ Inventory and Roadmap” document in which an inventory of FP5 projects was made and a roadmap for future grids was presented. The Inventory contains three types of information. First, a method for the categorisation of projects’ activities is presented along with the method for collecting the necessary information. Then, the survey of GRIDSTART cluster projects and the additional ten projects from the 8th call of the 5th IST Framework Programme is introduced. Finally, results of the analyses of all of the projects are compared. One of the goals of the inventory was to constitute a background for the Grid Roadmap. This document provides a clear basis for a Grid Roadmap and it includes information useful in order to recommend collaborations between relevant projects these days, knowledge of technology and applications (for “technology push” vs. “application pull” analysis – and the status of the Grid development in Europe along with its major trends and directions in the 5th programme. By analysing the history of Grid computing and the current developments, a general roadmap of European Grid technology with the potential to dramatically change the way Scientific Research is done, both in Europe and elsewhere, was elaborated. The conclusion of the report was that there is a broad interest, of both Grid developers and application end users, to drive the Grid forward and exploit all of the possibilities that were presented in the early Grid vision. Many aims have already been reached, and we expect an even more interesting future where many more people will profit from Grids and the idea of resource sharing.

EGEE: The Enabling Grids for E-science (EGEE) project is funded by the European Commission and aims to build on recent advances in grid technology and develop a service grid infrastructure which is available to scientists 24 hours a day. It focuses on three core areas: building a consistent, robust and secure Grid network that will attract additional computing resources; continuously improvement and maintenance of the middleware in order to deliver a reliable service to users; and attracting new users from industry as well as science and ensure they receive the high standard of training and support they need.

DEISA is a consortium of leading national supercomputing centres that currently deploys and operates a persistent, production quality, distributed supercomputing environment with continental scope. The purpose of this FP6 funded research infrastructure is to enable scientific discovery across a broad spectrum of science and technology, by enhancing and reinforcing European capabilities in the area of high performance computing. This becomes possible through a deep integration of existing national high-end platforms, tightly coupled by a dedicated network and supported by innovative system and grid software.

FP6 – IST Call 5 - Starting Summer 2006

IP proposals (Information is available on the web: http://cordis.europa.eu/ist/grids/ip_proposal.htm)

The IP (Integrated Projects) proposals have a strong orientation towards both industrial and societal use of Grids as well as pushing the frontiers of Grids and Grid technologies. The former places a realistic emphasis on integrating state-of-the-art technologies to develop prototype Grids and their validation and testing through a wide range of application test-beds, with proper attention paid to key issues for industry acceptance such as security, ease of use, etc. There is a clear emphasis in the proposals on applying to Grids and further developing within the Grids context, semantic, web services, and agent technologies.

XtreemOS: This proposal seeks to extend the Linux operating system to Grid environments and virtual organisation contexts. It proposes to design, implement and evaluate a Grid operating system. Many results will be made available and supported as open-source. The proposal considers applications in the areas of aerospace, energy, telecoms, business, multimedia, computer graphics, and finance. The potential impact is high, bringing Grids forward to a wider general audience. The approach of moving middleware components to the operating system level is innovative and significantly beyond the state-of-the-art. The project covers the full value chain including use cases. There is significant SME involvement. The Chinese partners will facilitate the dissemination and distribution in East Asia, strengthening the competitiveness of the EU-led open-source product in the competitive global market. In particular, the involvement of a Chinese distributor opens the East Asia markets for the project’s results.

Project coordinator: Caisse des dépôts et consignations; contact person: Mr Jean-Noël FORGET

BEinGRID: This proposal seeks to undertake 19 business experiment pilots designed to implement and deploy Grid solutions in a broad spectrum of European business sectors. A knowledge and tool repository will also be developed consisting of Grid service components and best practices to support European businesses with the take-up of Grid. The proposed work will start with available Grid tools and then later bringing in newer tools and this should enhance the potential impact. The focus is on integrating existing Grid technologies and filling in any gaps to facilitate Grid take-up by business and industry. The proposal is strongly focused on exploitation with dissemination and exploitation being inherent to many of the planned activities. SMEs are strongly represented. The Chinese partner is an end-user in one of the experiments.

Project coordinator: AtosOrigin; contact person: Mr Santi RISTOL

BREIN: This proposal seeks to develop a user-centric Grid framework by applying agent technologies and semantic web technologies, with the aim of providing businesses with a means of deploying Grids to solve their specific business problems. The proposal will contribute towards closing the gap between high-level business security requirements and low-level security policies. Business management of Stuttgart Airport is addressed as an application. The proposal will have strategic impact on service providers by developing tools that improve their supply chain. SMEs are well represented.

Project coordinator: Telefónica Investigación y Desarrollo; contact person: Mr Antonio SANCHEZ

STREP proposals (Information is available on the web: http://cordis.europa.eu/ist/grids/strep_proposal.htm)

The STREP (Specific Targeted Research Projects) proposals invited to negotiations (and listed below) address a broad range of new functionality and enhancement of present Grid technologies and services, including research on and development of: knowledge and data sharing in Grid environments, methods and metrics to support service level agreements (SLA) negotiations, interfaces and portals to access Grid resources, trust, security and privacy policy enforcement, Grid economies and business models, pervasive and network-centric middleware, agent-based approaches for service orchestration and configuration, network-aware scheduling, self-healing and adaptive enterprise service Grids, Grid-enabled workflows and collaboration in virtual organisations, new Grid architectures, distributed approaches to resource publishing and retrieval, real-time aspects and Quality of Service in Grid environments, Grid programming models, licensing schemes for the Grid, generic Grid application components, and Grid services for Ambient Intelligence applications. The Grid architectures, systems, tools, models methods and solutions to be developed will be tested and applied in many application cases in business, industrial and scientific domains. These include healthcare, business supply chains, collaborative learning, home multimedia, on-line gaming, biochemistry, seismic imaging, genetics research, and simulations in the automotive industry.

KnowARC: The proposal develops a high performance, robust and easy to use Grid-based solution for know-how sharing between virtual organisations, based on the Advanced Resource Connector (ARC) middleware. The work focuses on building industrial quality, standards-compliant, interoperable Grid foundations for know-how sharing services for business and society. The work will be validated in applications in healthcare, genetics research, and simulations in the automotive industry.

Project coordinator: University of Oslo; contact person: Prof. Farid OULD-SAADA

AssessGrid: This proposal fosters the adoption of risk management into the Grid, focusing on the development and integration of methods, metrics and analysis tools enabling Service Level Agreement (SLA) negotiations. The proposal addresses risk awareness and management, self-organising, fault-tolerant actions and capacity planning, closing the gap between the development of SLAs as concept and as a widely accepted tool for commercial Grid uptake. The results will support all Grid actors by increasing the transparency, reliability, and trustiness as well as providing a solid foundation for planning and management of Grid activities.

Project coordinator: Universität Paderborn (Germany); contact person: Dr Odej KAO

A-WARE: The proposal develops a stable and commercially exploitable technology able to give easy access to Grid resources via a web thin-client approach based on user-friendly interfaces, hiding the complexity of the underlying Grid middleware. The proposal is based on the Grid portal EnginFrame and on Unicore/GS technologies. Particular care will be put on simplifying the deployment of the Grid under typical industrial scenarios, including issues such as Intranet security, AAA, SLAs, QoS, single-sign-on systems, etc. Validation will be undertaken in the fluid dynamic applications (automotive, aerospace, oil and gas), defence, and electronics.

Project coordinator: CINECA - High Performance System Division; contact person: Paolo MALFETTI

QosCosGrid: This proposal develops core Grid technology capable of providing quasi-opportunistic supercomputing (QOS) Grid services and technology that will enable users to develop applications with supercomputing requirements without the need to deploy supercomputers themselves. The proposal covers the topics of Grid middleware and services, Grid access and use, Grid-based applications, and Grid economics. Validation will be undertaken in the application areas stellar dynamics and evolution, biochemistry, ecological evolution, gene regulation networks, and business supply chains.

Project coordinator: University of Ulster; contact person: Dr Stephen ROBINSON

GridTrust: The objective of this proposal is to develop the technology to manage trust and security for the Next Generation Grid from the requirement level down to the application, middleware and foundation levels. The work will focus on linking trust, security and privacy requirements with policies, trust and security properties in dynamic virtual organisations, and trust-based autonomic security management, taking into account aspects such as self-organisation, self-management, self-adaptation and evolvability. The emphasis will be on models and tools to assist in reasoning about trust and security properties along the Next Generation Grid architecture. Inter-enterprise knowledge management and distributed authoring will be used as test cases to validate the results.

Project coordinator: CETIC; contact person: Mr Philippe MASSONET

GridEcon: This proposal addresses Grid business models and Grid economics, working on the development of solutions and extensions to Grid technology for economics-aware Grid applications so that Grid business models can be implemented. It will advance the state-of-the-art in the financial and economic aspects related to large-scale Grid deployment. The proposal defines micro-economic models for resource sharing across organisations and analyse new paradigms of accounting and settlement in the utility service model. Business applications, seismic imaging, and storage Grids will be used to validate the results.

Project coordinator: International University in Germany; contact person: Dr Jörn ALTMANN

GREEDIA: The proposal creates a platform for design and deployment of secure applications support for mobile devices to be integrated in the Grid. The work will advance the SYMBIAN mobile operating system to exploit Grid opportunities. Both desktop and mobile terminals will be addressed. The focus is on business services which mainly demand access to and sharing of large amounts of distributed annotated numerical and multimedia content, referred to as media-rich content. As an application, integration of media-rich content devices to Grid will be considered.

Project coordinator: ATC - Athens Technology Center; contact person: Dr Nikos SARRIS

ARGUGRID: The proposal addresses the development of an agent based approach to the configuration and orchestration of resources and services in Grids environments. The work will provide a new model for programming the Grid at a semantic, knowledge-based level of abstraction. Validation of the intended models will be undertaken against e-business application scenarios. The proposal employs virtual organisation representation, utility maximisation, web services, and agent architectures.

Project coordinator: Imperial College; contact person: Dr Francesca TONI

SORMA: This proposal deals with the development of methods and tools for an efficient market-based allocation of resources, through a self-organising resource management system, using market-driven models supported by extensions for Grid infrastructures. Topics addressed include open Grid markets, economics-driven Grid middleware, and intelligent tools. Brokerage of resources over the Grid will benefit Grid consumers, resource owners, outsourcing providers, and new intermediaries.

Project coordinator: Universität Karlsruhe; contact person: Dr Dirk NEUMANN

Chemomentum: This proposal seeks to develop a Grid services based environment to enable innovative research by providing a Grid-enabled workflow centric workbench to support decision making processes. Based on UNICORE enhancements, the work will focus on a workflow engine for execution of complex, multi-step, multi-site workflows on the Grid. A web service enabled user database will provide for simple remote management of users and roles, and Grid complexity will be hidden by providing an easy to use user interface. Applications in biochemistry, drug design, and eco-toxicology will be used for validation.

Project coordinator: Warsaw University; contact person: Dr Piotr BALA

Edutain@Grid: The proposal focuses on the development of real-time online interactive applications, aiming at reducing the development and hosting costs, fostering business and societal uptake of the Grid. Applications in online gaming and e-learning will be used for validation. The proposal will devise and implement a development, hosting and run-time environment for the full value chain: application developer, provider, distributor, host, customer, and market broker. An innovative architecture will separate the business level from the Grid management functionality, bridging the gap between them.

Project coordinator: Universität Innsbruck; contact person: Prof. Thomas FAHRINGER

g-Eclipse: This proposal aims to provide an integrated environment for Grid users, operators and developers on top of the Eclipse framework, and to allow for easy adaptation by new Grid applications. Compared to the world-wide-web, g-Eclipse will be the “web-browser” for the more complex “world wide Grid”, thus helping to make Grid less complex and to broaden its take-up. The developed software platform will consist of underlying Grid components and integrated plug-ins. The proposal fosters an open source community to ensure the sustainability of the g-Eclipse framework.

Project coordinator: Forschungszentrum Karlsruhe GmbH; contact person: Dr Harald KORNMAYER

Grid4All: The objective of this proposal is to bring Grid computing to millions of users beyond the academic and industrial communities. It combines elements of peer-to-peer and Grid technologies in a form of an open Grid middleware framework. Secure peer-to-peer techniques will be used to federate large numbers of small-scale resources into large-scale Grids. The proposal addresses the areas of autonomic software, Grid economics, and semantics. The result will be a Grid system pooling the offerings available within large amounts of cheap resources that are able to satisfy demand spikes. Proof-of-concept applications are foreseen in such domains as collaborative learning, home multimedia, SMEs and supply chains, and virtual organisations.

Project coordinator: France Telecom R&D MAPS/AMS; Contact person: Ms Ruby KRISHNASWAMY

GridCOMP: This proposal aims to develop a standard and domain-independent Grid component platform for developing efficient Grid applications, supporting dependability and security. Non-functional aspects will be covered that allow components to be seamlessly executed with minimal programmer intervention, thus implementing the invisible Grid concept. A prototype implementation, based on existing open source Grid-enabled middleware, will be used to experiment, demonstrate and assess the platform features through some relevant case studies. Compatibility and interoperability with existing standards will be addressed.

Project coordinator: GEIE-ERCIM; contact person: Mr Bruno LE DANTEC

ANNEX C – Grid related initiatives

In this section we analyse the findings of several Grid related road mapping initiatives in the light of the first wave of Grid projects. The aim of this study is to identify synergies with similar projects, learn from the accumulated experience and to provide a critical appreciation of results. This analysis is based on published documents but we have also conducted discussions with the leaders of individual projects especially within the UK e-Science community regarding their vision for the future of the Grid.

e-IRG (eInfrastructure Reflection Group): Objectives of e-IRG (<http://www.e-irg.org/>) can be summarised as:

- Coordinate on the European level the introduction of a (Grid-based) infrastructure for e-Science.
- Draft a Roadmap for the European e-Infrastructures (the current version can be found at

<http://www.e-irg.org/roadmap/eIRG-roadmap.pdf>)

- Establish a forum for the exchange of Grid-related ideas.
- Give input to other policy drafting bodies e.g. ESFRI, NREN PC etc.
- Formulate guidelines/policies for EU collaboration with the international community.
- Bring together national best practice with EU projects and initiatives.

NGG (Next Generation Grid) Expert Group

NGG (Next Generation Grid) Expert Group The main objective of the NGG (<http://www.cordis.lu/ist/grids/ngg.htm>) initiative is to identify potential European Research priorities for Next Generation Grid(s) 2005 - 2010 and beyond. There were several phases of this effort namely NGG1, NGG2, and NGG3. The aim of NGG1 running from January 2003 to July 2003 was to bring together the leading experts in the field of Grid research and industry and to define the research agenda and measures to achieve the identified requirements.

Three perspectives are defined in the NGG1 Report to envision next generation Grids: The end-user vision in which the simplicity of the Grid is exemplified; the architectural vision of a large-scale, self-organising network; and the software vision of a programmable system. Each of these visions is described in detail to support the assignment of priorities to the research agenda.

NGG2 running from January 2004 to July 2004, revised the NGG1 vision in the light of results of the first wave of Grid projects by taking into account the new requirements, identified issues and emerging technologies.

The next phase of NGG (NGG3) was launched in September 2005. In their report, published in January 2006, the NGG3 group defined the scientific and technological requirements necessary to evolve Grids towards the wider and more ambitious vision of Service Oriented Knowledge Utilities (SOKU). The SOKU vision identifies a flexible, powerful and cost-efficient way of building, operating and evolving IT intensive solutions for use by businesses, science and society. It builds on existing industry practices, trends and emerging technologies and gives the rules and methods for combining them into an ecosystem that promotes collaboration and self-organisation.

Ecolead: The main objective of Ecolead (European Collaborative Networked Organisations Leadership Initiative <http://www.ecolead.org>) is to develop a toolset that can create and run Virtual Organisations.

- Dynamic VO creation assistance tool
- VO collaboration and performance measurement tool
- Contract negotiation wizard tool
- VO management e-service tool
- Collaborative problem solving support e-services tool
- Advanced collaboration platform for Professional Virtual Communities tool

ESFRI (European Strategy Forum on Research Infrastructures): The key objectives of ESFRI (<http://www.cordis.lu/esfri/>) are to develop a 20 year Roadmap for a service based knowledge economy. The ESFRI's roles are:

- To jointly reflect on the development of strategic policies for pan-European Research Infrastructures;
- To prepare a European Roadmap (with regular updates as different areas mature);
- To act as an incubator for RI projects with pan-European interest.

This initiative has established three Steering Groups for the following communities: Physical Sciences and Engineering, Biological and Medical Sciences, Social Sciences and the Humanities.

ISTAG: The objective of ISTAG (Information Society Technologies Advisory Group) is to offer a coherent view for the European Commission regarding the on the overall strategy to be followed in carrying out the IST thematic priority under the European framework programme for research (<http://www.cordis.lu/ist/istag.htm>). We cite here those aspects of ISTAG activities more closely related to what Grid technologies can provide:

- Interoperable services built on robust middleware based on open standards.
- Systems for the management of privacy, security, access and use.
- The report also mentions some points which are still to be completely fulfilled in Grid technologies, outstandingly:
- Semantics to manage the sharing, integration and distribution of content.
- Open standards to manage the diverse range of technologies and resources (an ongoing OGSA effort).

Both the visions and the identified activities lead to the definition of six research priorities and recommendations aimed at the “development of large-scale resilient and fault-tolerant intermittently connected and mobile distributed systems, driven by the needs of individuals, business and the research community.” The research priorities are:

- Interoperability and integration
- Management of complex software-intensive systems
- Semantics and knowledge
- Software development methodologies, tools, and standards
- Trust, security and privacy
- Societal and commercial acceptance take-up

None of these points fundamentally addresses (or mentions) Grid technology; however, almost of all them (the last being an exceptional case) clearly intersect with what Grids offer today and what they should offer tomorrow. In fact, the ISTAG recommends giving “active support to the development of open standards, including Grids and Web Services and support for the development of open source implementations.”

Nessi (Networked European Software & Services Initiative): The Nessi (<http://www.nessi-europe.com/>) aims to strengthen the industrial involvement in planning the future development of Grid effort. The vision of Strategic Research Agenda for Nessi is centred on the following features of the future Grid:

- awareness
- ubiquity
- trust
- alive
- user-centrality

The awareness of a computer is the basics of semantics, self-awareness and awareness of its context (tackling semantic Grid, physical locations through advanced GIS, architectures and infrastructures like INSPIRE and GMES). Ubiquitous computing, including virtualisation, utility computing, pervasive connectivity, ambient intelligence, etc. Advanced technologies that pave the way to “trust “ built on privacy, identity and dependability.

Advanced technologies that pave the way to “alive software”, including adaptive algorithms, reconfiguration, component engineering, variability management and dynamic Grid. Advanced technologies for user-centric engineering, including requirements and service engineering, usability techniques, vertical down-streaming on user markets with specific needs, like eGov, Health, etc. These components are supported by an integrated roadmap on three technology domains

- infrastructure (mainly software related, Grid services and similar),
- service integration and
- semantics.

These domains are inter-related, and aim to create the holistic framework where high-level services contextualise flexible low-level infrastructures.

ANNEX D – Grid related organisations

GGF (<http://www.ggf.org>) is the community of users, developers, and vendors leading the global standardisation effort for Grid computing. The GGF community consists of thousands of individuals in industry and research, representing over 400 organisations in more than 50 countries. Together they work for the pervasive adoption of Grid computing worldwide. The work of GGF is carried out through community-initiated working groups, which develop best practices and specifications in cooperation with other leading standards organisations, software vendors, and users. GGF is funded through its Sponsor Members, including technology producers and consumers as well as academic and government research institutions. GGF meets as a worldwide community three times annually to share best practices and further develop Grid-related specifications. GGF leads the pervasive adoption of Grid computing in research and industry by:

- defining Grid specifications that lead to broadly adopted standards and interoperable software
- building an international community for the exchange of ideas, experiences, requirements and best practices

GGF played a defining rôle in the development of OGSA (Open Grid Services Architecture) that defines the key elements of Grid environment. The main idea of OGSA is the adoption of Web Services as a foundation technology for the Grid. The aim of the OGS (Open Grid Service Infrastructure) effort was to specify the Grid in terms of Web services, however OGS was not accepted by the community. The draft document produced in 2004 was modified and published as WSRF (Web Services Resource Framework). The WSRF standard was positively received by the community and was implemented in Globus Tk4.0.

As Grids continue to grow and evolve, a strategy of “affiliation” between GGF and geographically dispersed organisations such as the Member States Grid Initiatives is currently considered to be established by GGF. The GGF roadmap identifies a list of OGSA (Open Grid Services Architecture) related specifications that will be developed in the future (source: H. Kishimoto, J. Treadwell. Defining the Grid: A Roadmap for OGSA™ Standards v 1.0, <http://www.ggf.org/documents/GFD.53.pdf>).

OASIS (Organisation for the Advancement of Structured Information Standards): the OASIS (<http://www.oasis-open.org>) consortium covers a wide range of activities centred around XML technologies. OASIS has developed numerous standards and recommendations covering the interoperability and resource management of Grid and utility systems. The main directions of OASIS can be described by the following working groups:

- Adoption Services - adoption of best practices and guidelines for interoperability
- Computing Management - management of distributed resources in the Grid environment; Document-Centric Applications - promoting the XML based document format and exchange
- e-Commerce - development of specifications regarding transactions over the internet
- Law & Government - legal aspects of e-Commerce and data protection
- Localisation - document translations
- Security - development of standards required for e-Commerce
- SOA - documents describing the orchestration and management of distributed services
- Standards Adoption - evaluation and development of new standards, monitoring the adoption and implementation of standards in e-Commerce
- Supply Chain - development of standards and recommendations related to supply chain management
- Web Services - development of XML based communication protocols
- XML Processing - development of standards and APIs for XML document processing

W3C (World Wide Web Consortium): the W3C (<http://www.w3.org/>) has made a major contribution to the development and promotion of Web Services standards. This is a collection of specification documents related to HTTP, XML, SOAP and WSDL. All these elements represent the basis for the Grid environment. In relation to resource discovery in the Grid environment it is important to mention the W3C’s Semantic Web effort that focuses on the development of standards for ontologies, semantic annotation of service descriptions, service registries, composition and orchestration of services. The

standardisation effort of Web services at the W3C can be described by the following categories:

- SOAP 1.2: messaging framework
- XOP+MTOM+RRSHB: optimised message transmission
- WS-Addressing 1.0: message and service addressing information
- WSDL 2.0: service description
- WS-CDL 1.0: choreography description
- XML Schema Patterns for Databinding

From the Grid's perspective the new version of the WSDL specification effort is highly relevant. This work focuses on the development of a generic mechanism that enables semantic annotation of Web services descriptions based on WSDL 2.0 extensions. This task also involves the development of WSDL 2.0 and RDF mapping that is important for semantic discovery. At present there is no specific Grid work group within the W3C, but there is a close collaboration between GGF and W3C regarding Grid standards.

EGA (Enterprise Grid Alliance): The objective EGA (<http://www.gridalliance.org/en/index.asp>) is to develop Grid specifications, standards and solutions for enterprises. Recently the Reference Model was published that describes the key elements of enterprise grids (source: http://www.gridalliance.org/en/WorkGroups/techdownloads_download.asp). The reference model contains the following categories:

- a lexicon of Grid terms
- specification of the main components
- requirements and use cases

In relation to GGF, the scope of EGA is less wide and more focused towards the needs of private enterprises. The main opportunities for collaborations between OGSA and EGA are in defining the common Reference Model and Use cases. The main technical working groups of the consortium are:

- Enterprise Grid Reference Model
- Component Provisioning
- Data Provisioning
- Grid Security
- Utility Accounting

Liberty Alliance: the Liberty Alliance Project (<http://www.projectliberty.org/>) is an alliance of more than 150 companies, non-profit and government organisations from around the globe. The consortium is committed to developing an open standard for federated network identity that supports all current and emerging network devices. Federated identity offers businesses, governments, employees, and consumers a more convenient and secure way to control identity information in today's digital economy, and is a key component in driving the use of e-commerce and personalised data services, as well as Web-based services. Membership is open to all commercial and non-commercial organisations. Members Work Closely Together to:

- Build open standard-based specifications for federated identity and identity-based Web services.
- Drive global identity theft solutions.
- Provide interoperability testing.
- Offer a formal certification program for products utilising Liberty specifications.
- Establish best practices, rules, liabilities, and business guidelines.
- Collaborate with other standards bodies, privacy advocates, and government policy groups.
- Address end user privacy and confidentiality issues.
-

ETSI (European Telecommunications Standards Institute): the ETSI (<http://www.etsi.org/>) is an independent, non-profit organisation, whose mission is to produce telecommunications standards for today and for the future. The European Telecommunications Standards Institute is officially responsible for standardisation of Information and Communication Technologies (ICT) within Europe. These technologies include telecommunications, broadcasting and related areas such as intelligent transportation and medical electronics.

ETSI unites 654 members from 59 countries inside and outside Europe, including manufacturers, network operators, administrations, service providers, research bodies and users - in fact, all the key players in the ICT arena.

ETSI plays a major role in developing a wide range of standards and other technical documentation as Europe's contribution to world-wide ICT standardisation. This activity is supplemented by interoperability testing services and other specialisms. ETSI's prime objective is to support global harmonisation by providing a forum in which all the key players can contribute actively. ETSI is officially recognised by the European Commission and the EFTA secretariat.

ETSI's Members determine the Institute's work programme, allocate resources and approve its deliverables. As a result, ETSI's activities are closely aligned with market needs and there is wide acceptance of its products. ETSI's standards are built on consensus.

ANNEX E – Strategic WS: Conclusions & Lessons Learnt

The strategic workshop contributed to the goals of GridCoord in several ways by:

- Improving the information exchange between various funding authorities in the European Union: The workshop has contributed to this goal by having representatives of the European Commission and the German Ministry of Education and Research (BMBF) on the first two days of the workshop in the audience.
- Identifying the current status of Grid computing in industry: based on the presentations given at the workshop, the following conclusions can be drawn:
 - √ *Most (if not all) of the large software companies and software solution providers are aware of the current developments in Grid computing and are actively involved in projects experimenting with this technology. However, smaller companies are struggling with this new technology at the current stage, either because they are lacking fundamental knowledge about Grid computing, or the benefit of this technology for their company and customers is not yet completely clear.*
 - √ *Many large software companies are furthermore offering technologies, which have similar functionality to publicly available Grid software, without calling it "Grid" or without these systems being necessarily single, well integrated environments. Nevertheless, they could/should be regarded as future building blocks for industrial Grid software.*
 - √ *From the presentations given at the workshop, just a single large software vendor declared, that the base technology on which their product relies is similar to Grid computing or Web Services.*
 - √ *There is little impact of Grid computing on the computer hardware development. The only new technology which might have an impact on Grid computing is the hardware support for virtualisation of resources.*
 - √ *Some multi-site companies have an infrastructure which is similar to a Grid infrastructure and which offers similar functionality, without necessarily calling it a "Grid". The vision of Grid computing is already partially reality within a single company (intra-grids).*
 - √ *Grid projects are currently developing or have already developed software systems to manage highly complex software environments. Among the interesting/required features are self-healing and self-organising software, or automatic handling of updates. Research in this area has been considered highly beneficial by many presenters, independent of whether they are related to Grid technology.*
 - √ *From the industrial end-user perspectives, companies have identified many application scenarios which might benefit from Grid computing or Grid technologies. The status of individual application scenarios in various industrial fields is once again correlated to the size of the company. This might be due to two reasons. First, large companies are - contrary to smaller ones - usually located in several sites and have to deal with distributed resources on a different scale, making problems eminent which smaller companies don't have. Second, larger companies have different financial boundary conditions in experimenting with new technologies.*
- Identifying the open problems from an industrial perspective
 - √ *The benefit and impact of Grid computing for industrial environments and industrial customers has not yet been demonstrated at a large scale and for sufficiently different scenarios. This is especially true for scenarios involving small and medium size companies.*
 - √ *There are still open technical problems (security, resource management, Grid-enabled databases). Some of them are at least partially considered to be psychological barriers in industry rather than real technical problems (acceptance problem of the new technology).*
 - √ *Legal issues are of increasing importance for many industry-relevant areas (e.g. financial data, medical data and licensing issues). It is in many scenarios not clear, whether Grid technologies can really cross country borders for all scenarios, due to the different legal system in different countries.*

The lessons to be learned from the workshop are:

- Industry embraces the concept of Grid but is following a different path than research in order to meet user demands and in order to minimise software development risks.
- Both legal and technical problems have made it so far difficult to show any large-scale successes of industrial Grid usage.
- The workshop has stimulated intense discussions among the participants, and thus did successfully contribute to the goals of the project. However, these workshops have to be continued to keep the communication between industry and public research going on.
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ANNEX F – Beyond Europe

While most of the present report deals with matters of EU dimension, a true globalisation of Grid utilities will need expanding it beyond current Member States on to other countries inside and beyond Europe. This step will not be possible without a force directed towards well defined goals and the use of available resources as efficiently as possible. These conditions can be obtained from the coordination among Member States sought by GridCoord and which the recommendations put forth in previous sections aim at. In the following sections we try to shape a possible future scenario in line with the advices given so far.

Vision

Many current trends in Grid development are geared towards making Grid technologies a source of computing power and/or storage. Those efforts, while technically challenging and undoubtedly needed in some scientific fields (i.e., according to some estimations the raw data from the LHC project could fill in all hard disks in the world in just some days), are far from being all the possibilities offered by a fully interconnected world where communication and computer power is “available on tap” [4]. Many such applications (such as “videoconferencing everywhere”) were in the initial view by Foster and Kesselman, and recent Grid-related projects are in fact addressing service-based and service economy issues. Notwithstanding, maybe it is time to review, in the light of these trends, up to what point the current Grid vision has been narrowed over the years, and whether its current re-expansion is enough in order to draw, again, a blueprint for the future of Grid technologies. We propose here a vision which tries to foresee what a future can be expected for the Grid.

Our vision stems from the conviction that the great majority of complex software applications will, in the mid term, be dynamically built by composing services which will be available in an open market of services and resources. In this sense, the Grid might be conceived as a “world-wide utility” populated by self-cooperating services which interact as in a complex and gigantic service-based economy. Those services could be set up by a variety of agents (e.g., software companies, open source developers, but also states and institutions, as a public service for their citizens), and will be available to developers or proxies of them (e.g. software agents), who will choose to use software solutions from different vendors, sold at different prices, with different performance and QoS. This will lead to a new style of application development based on software services, which will in turn need the expansion of existing practice regarding service location, standardisation, semantics of services, certification, and others.

In this style programmers do not start from scratch but build instead new applications by reusing existing off-the-shelf services available in a galaxy of services offered within the Grid. The ecosystem is the set of connections among different services, competing for visibility and adoption (which would help them survive when confronted with other, competing services), and which, notwithstanding, will cooperate when put together in large applications. When a complex service uses smaller services, an association is created between all of them. In this view, mainly for cost reasons, and also in the quest for diversification which would make it possible to survive in a rapidly changing world, it is foreseeable that few companies or organisations would be interested in creating from scratch very complex and diverse software applications. Future business and scientific applications will be built as a complex network of services offered by different providers, on heterogeneous resources, constrained by administrative problems when crossing the borders of different organisations [1].

This view is in line with an intuitive observation: while big, challenging, enterprises (such as, for example, building the largest bridge or tunnel in the world) makes it to the press, the amount of richness these works produce (in terms of salary, goods being transferred, communications which are made easier, and so forth) is very small when compared with what myriads of regular roads, big and small, connecting cities and villages, bring about. A similar comparison can be drawn between big (but scarce) computational efforts geared towards a very precise end and everyday’s cash balance and payroll calculation done in millions of places in the world. Not to imply that big computational efforts are not utterly needed in some areas! However, this need is not be the norm, and few agents would need such a specialised service. Consequently, few companies would survive from providing it, while the dynamic service economy, if conveniently nurtured, would flourish and outgrow the few big, strong dinosaurs.

Roadmap

In order to make this vision a reality it is mandatory to find a definitive answer (towards which we, somewhat daringly, try to point) to some important open questions hereunder reported:

- Who should build the infrastructure on top of which the global utility is built?
 - √ *The creation of a world-wide utility requires the existence of a stable, reliable and secure infrastructure. In order to make an analogy, for example, railways played a crucial part in the Industrial Revolution permitting people and stuff to move around in a fashion previously unheard of, and consequently, permitting the expansion of markets and a drastic reduction of the prices of goods. In a similar way the Information Technology (IT) market is evolving dramatically, driven by the increasing need to reduce operation management costs and to make business processes more and more agile and effective. However, those infrastructures (which should of course consist of more than wires and routers) ought*

to be homogenous across countries and make it easy to cross “administrative boundaries”. Organisations willing to take advantage of services living in the Grid will otherwise be taken aback by the sheer complexity of making a single, trustable international transaction using Grid services.

- √ In order to reach this objective, providing IT services as a set of “utility services” is an emerging paradigm which offers a clear path to follow. As in the case of railroads, in which an important role was played by the national governments with their continuous support to promote the growth of the railroad system, the creation of a utility system will similarly require large and tightly coordinated national and international investments, not only at the scientific level, but also at the political and administrative ones, by establishing grounds to make a common infrastructure (for trust, authentication, quality of service, computer and process roaming, provenance, etc.) possible.
- √ As current network authorities control the evolution of the national and international backbones the future creation of utility authorities responsible for maintaining and ensuring that resources made available by a plethora of providers worldwide (data, software, hardware, instruments, etc.) can be trusted is foreseeable.
- Who should build this infrastructure in third- (fourth-) world countries?
 - √ How can the Global Digital Divide (GDD), the socio-economic difference between countries in their access to the global utility, be worked around? The GDD is seen as an important social/political problem characterised by not having an easy solution. It is true, however, that in many underdeveloped countries complex industries (e.g. oil extraction) have been established. This means that the basic utilities to make them work can be taken there. May something similar be done so that virtual organisations are built with centres in third-world countries as members? There are studies underway which try to find the best (in terms of reliability and economical feasibility) way to make current technology (such as Internet) reach remote areas (e.g., the communities in the Amazon rain forest). There is a hope that providing third-world countries with at least some access to a connected world is not an unfeasible endeavour.
- What should be the standards adopted for the implementation of the software infrastructure?
 - √ The creation of global utility system will require the commoditisation of its components (hardware, software, etc) and this directly implies the need of huge efforts in terms of standardisation. As pointed out before, this is of outmost importance, and the player which makes (and supports conveniently) the first standard to be broadly adopted will have a very strong position for the future: let us recall the case of the GSM standard, now followed in the entire world. If a successful, widely adopted standard for Grid services were devised in Europe, support could (and should) come not only from private companies, but also from governments and European initiatives such as NESSI and their counterparts at the national level.
 - √ On the other hand, and since the usefulness of such a set of standards derives from providing access to a world of Grid services, and the underlying business model is in fact based on the service market, it seems sensible to make those standards open.
- What types of business models (BM) can take advantage of the global utility?
 - √ Another important ingredient to implement the above envisioned world-wide utility is the utility is the definition and the agreement of credible Business Models (BMs), e.g. the need to reach agreements on standardised protocols to build new businesses, on Service Level Agreements, etc. In fact several actors are involved and can take part in the definition and exploitation of the BM:
 - √ **Software companies:** they will not only take advantage from services to build applications, but they will also sell them or, in some cases, allow others to use them for free, and make a profit from consulting.
 - √ **Final users:** following the idea of selling computer power, final applications which use Grid services may have to pay to continue using them. It has to be taken into account that the process of building an application where components are services is not limited to “fishing” the components, as they will continue to “live” in their “ecosystem” after the application is finished.
 - √ **Academy:** in order to make the whole system work seamlessly and with a minimum of human intervention, many ends have still to be polished, ranging from precise definitions of services (so that services able to carry out properly a set of tasks can be automatically discovered and their use negotiated) to making them work 24/7.
- Has Europe the capacity to lead this market?
 - √ The ambitious idea behind the Networked European Software and Services Initiative (NESSI) Technology Platform, which proposes to aid innovation in the services industry up to 2010 and beyond, goes exactly in this direction. Similar initiatives can be fostered in member countries to act as speakers for these countries and to act as interface with each government.

Contribution by Manuel Carro, Domenico Laforenza, Manuel Hermenegildo

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