A sustainable grid infrastructure for Europe

Summary of the Open Workshop on e-Infrastructures

Heidelberg, Germany, April 19 – 20, 2007

Introduction

The series of open e-IRG workshops supports the e-IRG activities by enabling and stimulating the discussion of e-infrastructure related topics with the community across thematic and country borders. Experts on various areas are getting together regularly to explore open issues and questions for enabling easy and cost-effective shared use of distributed electronic resources across Europe and beyond, based on sustainable e-infrastructures. The main theme of the workshop in Heidelberg was on "A sustainable grid infrastructure for Europe", and the Workshop Announcement proposed to discuss the following topics:

- **Topic 1: Towards a European e-infrastructure.**

It is our belief that we have successfully built local, national and community e-infrastructures until now, and might have got some good ideas on how to proceed on a European level. We want to share these ideas.

- **Topic 2: Sustainability for e-Infrastructures.**

It is our belief that, to create a sustainable e-infrastructure for Europe, we have to consider economic and social aspects as well. We want to learn from the experience of large institutions, industry, and the Internet.

- **Topic 3: Bridging the gap between academia and industry.**

It is our belief that a European e-infrastructure should be of interest for both research and industry. We want to learn when requirements are different and lead to different infrastructures, and when they are similar, so that research and industry can benefit from a common e-infrastructure.

The workshop was hosted by EML, the European Media Lab, on behalf of the German Federal Ministry of Education and Research. Details can be found at: http://www.e-irg.org/meetings/2007-DE/workshop.html.

Topic 1: Towards a European e-Infrastructure

In launching the partnership for growth and jobs as a new start for the Lisbon strategy, the 2005 European Council called knowledge and innovation the engines of sustainable growth and stated that it is essential to build a fully inclusive information society, based on the widespread use of information and communication technologies (ICT) in public services, SMEs and households. To get the full benefits from ICT, EU Member States need more ambitious plans to exploit them, reveals the Commission's first annual progress report on i2010.

In this political and economic context, the European driven e-Infrastructure provides one of the largest (in scale) and richest (in terms of integrated technologies) European ICT-based facility that enables researchers across Europe to face today's big challenges, fostering the emergence of a new generation of ICT-based infrastructures for the good of the European and world economy. The e-Infrastructure provides a unique platform that boosts research intensity and enhances innovation capacity across Europe.

There is a common vision for the requirements of a global e-Infrastructure to support the data-driven e-Science revolution that will overtake us in the next 5 to 10 years. Almost all fields of science will generate orders of magnitude more data to capture, manage, mine, analyze and preserve than in the whole of human history. The key elements of this e-Infrastructure are: (1) Service-oriented middleware and high-bandwidth academic research networks; (2) Powerful tools for data analysis, knowledge management and discovery; (3) Open access federation of research repositories containing full text and data.

A key area of concern for the e-Infrastructure agenda is the federation and interoperation of subject and institutional repositories. Technological and social forces make some form of open access to both research papers and research data (arising from publicly funded research) inevitable. However, this is unlikely to be an area with a strong commercial driver, and the research community needs to support emerging standards such as the OAI-ORE protocol that will allow deep interoperability between repositories.

In the future, e-Infrastructures could be commonly used by users from various Research Infrastructures which are essential for developing top-class research activities, both basic and applied. Because of their ability to assemble a 'critical mass' of people and investment, they contribute to national, regional and European economic development. They also boost – through the development of skills, technologies and knowledge – the EU's chances of achieving its Lisbon Agenda, which is to ensure job creation and sustainable growth in what European leaders came to call the 'knowledge-based society'. Among the areas where Research Infrastructures are most prominent in Europe are specialised archives, libraries and databases and all the 'virtual' infrastructures, where scientists can share data and carry out their work across the Internet and through virtual office spaces. The process of creating an instrument for helping to identify those projects that are crucial for the scientific community in Europe has arrived to its first milestone. Europe's first ever Roadmap of large scale research facilities/research infrastructures, the ESFRI Roadmap (done in cooperation with e-IRG), has been published in autumn 2006.

During the Heidelberg workshop, several European infrastructure initiatives and projects have been presented, among them EGEE (Enabling Grids for E-sciencE), DEISA (Distributed European Infrastructure for Supercomputing Applications), and HET (HPC in Europe Taskforce), and their lessons learned and recommendations for building and operating e-infrastructures are included in this document. One key requirement in this context for the future and further advancements of these grids is sustainability. Already today, many scientific applications depend on production grid infrastructures (such as EGEE and DEISA). New scientific collaborations have been formed thanks to the advancements of grids, and business and industry are getting more and more interested.

The aim of EGEE is to build on recent advances in Grid technology and develop a service Grid infrastructure, providing researchers in academia and industry with access to major computing and storage resources, independent of their geographic location. EGEE-1 and EGEE-2 concentrate primarily on three core areas: Build a consistent, robust and secure Grid network that will attract and incorporate additional computing resources on demand; continuously improve and maintain the middleware in order to deliver reliable services to users; and attract new users from industry as well as science, and ensure they receive the high standard of training and support they need.

Three years ago, the DEISA project marked the first step towards the deployment and operation of an European HPC infrastructure. DEISA's original motivation was to act as a vector of integration of existing national HPC resources at the continental scale. The DEISA services have been tailored to enable seamless access to a distributed park of leading supercomputing platforms in Europe, as well as its high performance cooperative operation operating on remote distributed data sets.

The High-Performance Computing in Europe Taskforce (HET) was established in June 2006 with the target to draft a strategy for an European HPC Ecosystem with a focus on petaflop computing. One of the recommendations is to develop the different levels in the performance pyramid in a balanced way: enable sufficient top-class resources, but at the same time invest considerably in boosting the collaboration, scaling the software, building the competencies and developing the supporting national/regional infrastructures, with the goal of creating a competitive and sustainable European HPC service.

Finally, the European Grid Initiative (EGI) represents an effort to establish a sustainable grid infrastructure in Europe. For this to happen, a long term perspective for the availability of the grid service model is needed in order to protect the investments of user communities. Driven by the needs and requirements of the research community, it is expected that the EGI enables the next leap in research infrastructures, thereby supporting collaborative scientific discoveries in the European Research Area. The National Grid Initiatives (NGIs) are the main stakeholders of EGI, and are expected to operate the grid infrastructures in each country, while EGI will link existing NGIs and actively support the setup and initiation of new NGIs. The plan for the emerging EGI, built from a federation of NGIs, will provide many managerial, operational and technical challenges. To ensure that the NGIs retain enough flexibility to meet the research needs and priorities of their national user communities it is essential that they are able to deploy the software of their choice provided that it implements the service interfaces required by the EGI. Having service interfaces that conform to defined specifications is essential not only for interoperability with the EGI but also for the development of higher-level services, tools and applications that are essential in promoting adoption by applied end-users.

Lessons Learned

- To achieve sustainability of an e-infrastructure, deepening and enhancing the service that is provided, based in principal on open standards and on multiple and interoperable implementations.
- The evolution towards sustainable service provisioning schemes in the area of grid- and data-based resources appears to be a key step for the e-Infrastructure as indicated by successful past experiences on the connectivity side.
- ‘Build it and they will come’ won’t work. Adoption of e-Infrastructure has been great amongst some technically sophisticated research communities. It has not had broad uptake across the general research community and without this broad buy in further large investments in this work become hard to justify.
- Integration, Integration & Integration: End-user communities will not radically change the way they currently work. For successful adoption e-Infrastructure must be accessible from within the mechanism that they currently use.
- Users need to be supported in their adoption of new practices. This must include training sessions, on-line education materials, helpdesks, consultancy, embedded requirements capturing etc. This is costly, but without it uptake will be slow and limited to the elite.
- There is a need for high-end computing resources in Europe. The level of detail of the computational requirements in different areas of computational science vary, and it is important to carry on the discussion between HPC specialists and scientists to look for optimal solutions. Scalable application development, integration and interoperability with the existing computing centers and competence development are key issues when aiming at efficient usage of HPC facilities.
- It is possible to achieve results in a multinational HPC collaboration with a tight schedule. It requires open attitude and commitment from all the partners. The need for collaboration increases in the future when for example ESFRI roadmap projects start the preparatory projects and construction.

Recommendations

European e-Infrastructures:

- EGI planning needs to move from the operations perspective to be more end-user driven. Successfully operating an infrastructure that is not being used by a broad research community is pointless.
- Build efficient and sustainable governance models for the whole e-Infrastructure as well as for its parts. e.g. networking, data, computing issues need to be dealt with individually and in an integrated way.
- Legal, financial and societal aspects in the context of the e-Infrastructure will need to be addressed more intensively in the future.
- Build stronger liaison between the European Technology Platforms and the e-Infrastructure teams.
- Support interoperability standards for open middleware and access research repositories.

End-users and e-Infrastructure:

- The outcome of large scale infrastructure projects cannot be guaranteed through ‘top down’, strategic planning alone. Mechanisms need to be put in place so that projects are informed by and able to harness ‘bottom up’ innovation processes that are driven by end-user experimentation and demands.
- To promote adoption amongst end-users there must be a significant investment in support (training, on-line education, helpdesks, consultancy) within each region that can be accessed by all researchers.
- Investment is needed in the client side of the software infrastructure. To date effort has gone on the services – not on the environment and interfaces that users will be using.
- Focus on developing a ‘Social Grid’ along Web 2.0 that will allow researchers to experiment easily.

HPC and e-Infrastructure:

- Establish a “top end” infrastructure consisting of a small number of European HPC facilities to provide extreme computing power for the most demanding computational tasks.
- Emphasise on the development of the full HPC ecosystem, including local infrastructure, national and regional facilities, top-level European computing capabilities and the interoperability of their services.
- Address the key issues in building software that allows exploiting the performance potential of petascale machines in a coherent, efficient, scalable and sustainable manner. In addition, supporting work for educating new people in computational science is of utmost importance.

ESFRI and e-IRG:

- The e-Infrastructure has to address the common ICT-based needs of the new RIs that are identified in the relevant roadmap of the European Strategy Forum for Research Infrastructures (ESFRI).
- The revision of the ESFRI Roadmap should be based on a policy document developed and agreed with intergovernmental organisations and other bodies such as e-IRG and different research communities.

Topic 2: Sustainability for e-Infrastructures

An example of building a sustainable European grid service is the UK’s National Grid Service (NGS) which grew out of early experience in the UK e-Science programme. The Mission of the NGS is to provide coherent electronic access for UK researchers to all computational and data based resources and facilities required to carry out their research, independent of resource or researcher location. To achieve this, the NGS leads the deployment and operation of a common grid production infrastructure to support ICT based research. A Support Centre for the NGS was created during the summer of 2004 and the NGS full production service started in September of that year. Today, the NGS consists of 10 partner institutions and has several thousand registered users, over 500 of which have applied for compute and data storage resources on the central service.

Despite the success of the last 4 years, several challenges remain, not least that of agreeing and promoting a shared vision of a common research infrastructure expanded to include all significant resources and services, many of which have previously not identified the implied integration as a benefit and may see it as a threat. Lack of user confidence in the long term future of any infrastructure makes defining this vision more difficult in the context of the ongoing struggle for resources. Continued and growing success in the area of shared and common research infrastructure depends critically upon the acknowledgement by key stakeholders of their responsibility to help define and support such an activity.

The community has been slow to get to grips with the sustainability challenges posed by the widespread adoption of e-Infrastructure. An important example is the impact of a potentially vast increase in both the numbers and types of research resources (data, services, learning objects, etc.). The accumulation, sharing and re-use of resources lies at the heart of the e-Research vision. However, it seems that responses to the support and financial issues this raises have yet to be factored into planning for e-Infrastructure sustainability. A fundamental question that needs to be addressed is how resources originating in time-limited projects can be curated and managed so that they remain viable for re-use in the long term. In particular, in a landscape of multiplying, diverse and distributed resources, where the necessary effort and expertise will come from, and what funding models are most appropriate to pay for it.

A key aspect of grid technology is to share in a transparent way the computing resources that are provided by various participants. This efficient multiplexing and use of economies of scale has been a main driving force in the development and acceptance of grid technology. In our study, we consider grids that result from different organizations contributing resources in a common pool and hence incurring the corresponding cost in the anticipation of the future gains from sharing. There has been so far no careful study of the effects of particular sharing policies defined by the grid system manager to the total size of the final facility resulting from the contributions of the various participants. There is a strong influence of the type of sharing policy to the decisions of the participants regarding resource provisioning to the common pool, and hence it greatly influences sustainability.

In Grids optimal resource allocation has to be carried out in two dimensions. One is the maximization of the utilization of technical resources. The aim in this dimension is – independently of the economic incentive structure – to carry out a load balancing on heterogeneous and distributed computational resources. This guarantees that all resources are used and no resources are "wasted" while being idle. In contrary to this allocation paradigm the economic resource allocation is aligning the deployment of resources along the economic utility of the individual Grid nodes. Mechanisms like Multi-attribute Combinatorial Exchanges enable an incentive compatible, efficient, individual rational and computational tractable way of allocating these resources.

In the state of the art in economic Grid all mechanisms are developed that enable a two-tiered allocation of Grid resources. In the first tier of these markets, service consumers can trade with service providers about their service needs. Service providers then act on a second market tier – the resource market – where they purchase the resources they need in order to carry out the services. These two markets are interrelated through the price that is determined in the first tier. State of the art in this research field is that incentive compatible, efficient and individual rational allocation mechanisms are identified. However, these mechanisms are very complex to compute for a large number of market participants and hence not applicable on large-scale setups.

Lessons Learned:

- Large scale infrastructure development is a socio-technical process. Projects succeed because they are able to mobilise a socio-technical constituency – an alignment of technical components, standards, etc (the technical infrastructure) and stakeholder interests (the social infrastructure).
- New infrastructures are disruptive. There will be winners and losers as existing socio-technical constituencies are challenged. There may be uncertainty as rival visions and technical solutions emerge and are contested by different stakeholders.
- It is important to balance “something for everyone” with high profile leading exploitation (“winners”).
- Success will depend on stakeholders’ capacity to negotiate a balance between their individual interests. This may be accompanied by a process of technical consolidation characterized by gateways that make rival solutions interoperable.
- Reaching out to new communities has proven extremely difficult for innovative infrastructure service providers in the absence of targeted programmes and/or key visionaries.
- The decision by an organization on how many resources to contribute in the common resource pool is greatly influenced by the resource sharing policy that will be deployed in the future when the system will operate. The problem of choosing such a policy which optimizes the performance of the system assuming a given amount of resources may not be optimal overall, since it does not take into account its effect on the strategies of the participants during the resource provisioning phase.
- Sharing policies that guarantee to a Grid contributor priority in using his contributed resources in case of congestion seem to have better performance overall. Optimal policies that result in large system sizes and efficient sharing may be obtained by including some internal money transfers, i.e. an internal market mechanism for resource contributors to be compensated by free-riders.
- In case of sequential participation where the Grid “players” join one after the other, the incentives to attract the participants at the various stages of the system build-up should be carefully thought. These incentives should be expressed by different rules for sharing the common pool. Also some initial external contribution to the pool may speed up participation.

Recommendations:

Government and funding agency stakeholders:

- Governments and funding agencies need to drive development of a shared vision for the future, engaging key stakeholders. Strong strategic commitment from, and coordination between, funding agencies and key user communities are an important driver for the current infrastructure development.
- Governments and funding agencies must make clear the strategic requirement that resources and infrastructures integrate and interoperate and thereby drive the development of an agreed and shared vision for the future. Possible mechanisms include: high level policy statements; requirements on ongoing or new funding; creation of explicit new bodies or organisations; and new targeted funding.
- A mechanism for developing and sustaining confidence in the emerging infrastructure is required. Several models are possible: a federation of existing infrastructures, the creation of a new umbrella organisation, or an independent body. Strategic support is the key, however, some sustained financial commitment may be required.

User and provider stakeholders:

- Joining the infrastructure, as user or provider, must become easier, justifiable and self sustaining. Stringent requirements on performance and availability may only be relevant to a small subset of the infrastructure.
- The policy for operating and sharing the common infrastructure should be defined and made publicly known to the participants before they decide on their contributions. A well-designed policy may provide more incentives for contribution and decrease free-riding tendencies.
- Work with, and for, key users, provide user focused services, and balance high profile winners and "something for everyone".
- Build community demand by tailoring dissemination of benefits for different audiences and increasing efforts in education and training, and learning the lessons from the rapid adoption of technologies such as Web 2.0.

General considerations:

- Key stakeholders have to agree what infrastructure they want (and how they expect it to be funded). Steering of strategic policy associated with some sustained core funding is required.
- Plan for sustainability by developing new and more sophisticated metrics for impact measurement.
- Work with stakeholders to define new funding models and the technical mechanisms necessary to make them work in practice.

Economic and social considerations:

- Besides technical standardization, efforts for the development of economic standards and interaction schemes (based on Web Services or other SOA concepts) should be fostered for the practical utilization of future e-Infrastructures.
- Efforts for starting real-life pilots for Grid business models and Grid markets should be fostered, where researchers from computer science, economics and business administration commonly work on dynamic, economically sound and vertically integrated business concepts for the dynamic utilization of Grid and other e-Infrastructures.
- Sharing policies for common infrastructures should be carefully designed to reward participants that contributed more to the common resource pool. This may be done by assigning priorities and better performance in proportion to the resources contributed, and possibly by including internal payments (i.e. an internal mechanism for resource contributors to be compensated by others who contribute less resources).
- With regard to commercialization of grids, more research effort should be devoted to combine the communities that do research in the technical allocation and conceptualization of Grids with the economic allocation in Grids.

Topic 3: Bridging the gap between academia and industry

Many European infrastructure projects contain an industrial component. The CoreGRID Network of Excellence, for example, aims at strengthening and advancing scientific and technological excellence in the area of Grid technologies. It has established links with the industry thanks to the Industrial Advisory Board and a dedicated fellowship programme to let researchers conduct their research activities closely with the Industry.

As another example, the EGEE consortium is serving both the e-Science community and diverse business sectors. In its Annual Report of the Industry Forum an analysis of the evolving situation in Europe and recommendations for consideration by e-IRG are presented. These recommendations are intended to reduce the gap between e-Science and e-Business so that the on-going transfer of knowledge and technology performed by EC co-funded projects can be better focused and result in establishing new services and business opportunities.

In many areas, computing Grids are now widespread in industry, both as compute Grids for sectors such as finance and oil and gas, but also as the basis for major ‘cloud service providers’, including the five major Cloud Platform companies – Google, Amazon, Yahoo, eBay and Microsoft. All have 100’s of thousands of servers distributed in data centres around the world and proprietary systems that perform job scheduling, data sharing and cluster management that are operating 24/7 each day of the year. Companies like Amazon are experimenting with interesting new Cloud Services such as their S3 data storage service and their EC2 computing service. At present, such companies see that their proprietary solution for their infrastructure gives them a competitive advantage so there is no motivation for them to agree on anything but the simplest Grid standards. In some areas, such as security, there is no competitive advantage to having a proprietary security solution so we are seeing interoperability between different solutions such as Google ID, Microsoft Passport, Liberty Alliance and Open ID. For inter-organizational Grids, security solutions are now possible but there is at present little commercial demand for such Virtual Organizations that are required by the research community.

The usage of HPC resources in Grid environments both for research and industry is of great interest in many countries today. A number of projects aim to extend their reach beyond the research field and attract industrial usage. Important ones to be mentioned here are EGEE at a European level and D-Grid in Germany. D-Grid is aiming at a sustained infrastructure open for industry. First successes were achieved in the InGrid project which is part of D-Grid. Similarly, in the frame of the INCITE program, DoE in the US encourages usage of HPC also for industry.

Not many working concepts are currently operating on a long term commitment in this field. The French nuclear research agency (CEA), for example, has set up a specific cooperation with industry for the long term usage of computational resources. These activities have not yet created a general Grid approach for industrial usage of HPC. Other centres across the world have set up special programs to encourage industrial usage of their resources, e.g. HLRS in Germany which has set up a public private partnership with T-Systems and Porsche in 1996, to provide all industrial users access to research infrastructure in a seamless way.

Last but not least, an opportunity of general importance, far beyond but often including e-Infrastructures, is for the public sector to procure R&D services, called pre-commercial procurement. Pre-commercial procurement is about public sector procuring research and development services in view of acquiring solutions to tackle strategic public sector challenges. Areas of public interest from health through education to inclusion and security represent a large part of the EU economy and around 48% of the EU GDP. With a public purchasing demand of 1700 billion euros per year it is clear that closing the gap between public sector needs and private sector R&D would have a direct impact not only on the long term efficiency and effectiveness of the public sector, but also on the competitiveness of European industry. Europe can indeed still do better in terms of innovation performance compared to major competitors. Long time to market and fragmentation of public demand are key reasons why industrial activity directed towards the public sector lacks a strong single European market for the development of new innovative products that can improve public services.

Challenges such as the increasing competition on a global scale, the ageing population, climate change, energy efficiency and security – will require significant quality improvements in public services in a sustainable and cost effective way. These improvements can be best achieved through mid to long term strategic transformations in ways services are acquired, developed and delivered and by making use of the latest inventions and innovations. This will often require more than just purchasing of commercially available products and services. It will require strategies for procurement that include procuring research and/or development of new solutions and technologies that do not yet exist and that will outperform the solutions available on the market.

Lessons Learned

- The economic benefit from public investment in research infrastructures is clear, according to an impact analysis study for the 7th Framework Programme (FP7): each 1€ of public R&D leads to almost the same amount or more of business R&D investment. While the benefit of e-Infrastructures to science is direct, their benefit to industry is rather indirect and of a longer term nature.
- Production Grid infrastructures still have weaknesses that are not only due to a lack of engineering. There are still many scientific issues to be solved. Grid user communities and computer scientists may learn more from each other.
- Drive standardization only for technologies that have been well explored and that are built on well established and supported commercial standards.
- Without a strong commercial incentive IT companies will only agree to standardize in areas where there is no proprietary advantage or there is customer pressure.
- Simple is better: we must allow researchers to build their loose knit Virtual Organizations without having to make a major middleware installation.
- Legal and economic issues are at least as important in providing services through a Grid environment to industry as technical issues. Ignorance of these issues leads to failure and discourages sustained usage of public research infrastructure.
- Technology speed is a killer for classical business models as the price of any CPU is outperformed by the next generation of CPU which is on the market after at most one year to compete with existing hardware. On the other hand industrial usage is only a side business for research resources which focus on scientific research. Pure general purpose computing Grids based on general industrial usage are therefore hard to sustain economically.
- CPU cycles have become a cheap commodity. The price of one CPU hour is insignificant compared to the other costs that come with simulation – specifically compared to license costs for software. Industry is hence more interested in high level services that require HPC resources. Any business model is driven by software costs rather than by hardware costs.
- Complexity of grid systems raises the need for real-scale experimental platforms where computer scientists can run experiments, observe the distributed systems at large scale, stress the systems using experimental conditions injectors and make precise measurements. This is mandatory to make progress towards the design and the implementation of next-generation Grids for research and industry.
- The industry requires access to Service Infrastructures that can be developed using grid technologies. Most of these infrastructures do not exist yet and we can speculate that such infrastructures will encompass a large variety of distributed systems. Therefore a real-scale experimental platforms that can be reconfigured on demand may be of benefit to the industry to validate business solutions.
- Networking and cooperation between public procurers in the development process of new solutions would typically lead to better interoperability and exchangeability in the public sector and thereby better productivity and lower costs, on one hand, and economies of scale and thereby a better competitive position for the industry, on the other hand.
- When strategically linked with other demand and supply measures such as standardisation, regulations and well functioning venture capital markets – pre-commercial procurement can be geared to contribute directly to the development of important new lead markets for innovative products and services and thereby to the creation of growth and jobs in Europe.

Recommendations

Research infrastructures for businesses:

- Improve coordination between EC funded projects. Each project with business related objective defines its own goals, consortium and timelines. While there is general willingness to come together and discuss their findings, it is difficult to find significant documented evidence on projects indicating their proven solutions to the business sectors. In part this is because projects have to distinguish themselves from others in order to justify their existence but also because there is a natural tendency to restrict the distribution of information which could potentially lead to business opportunities.
- It is necessary to identify mutual interests of HPC@science and HPC@industry in order to see where and how resources can be shared for the benefit of both worlds. It is also necessary to identify a working business model by addressing the economic and legal issues of a mixed usage model that considers the organisational and economical boundary conditions.
- To enable businesses to make use of EGEE and other European infrastructure under a fee-paying arrangement a more flexible approach to the use of the GEANT network for pre-competitive R&D should be developed.
- In addition, develop mechanisms that allow the trading of computing resources, though various research and development actions are in progress. These developments necessarily include aspects of resource accounting and billing; commercial software license policies; security previsions and service level agreements.
- Provide clear information on the business case for e-Infrastructures. Enterprises will only collaborate in building cross-organisation infrastructure components once they are confident that these represent real commercial opportunities. Short, informative and interactive guidance overviews should be offered to businesses that make it easy for them to understand e-Infrastructure benefits and opportunities. Demos should be displayed at events showing case studies that provide a general perspective and alternative views from a research and business perspective.

European Entrepreneurship:

- Facilitate access to knowledge and funds for establishing new companies: Numerous reports indicate that Europe lags behind other regions in terms of business entrepreneurship. EC co-funded projects have created new technologies and opportunities for Europe's young researchers to convert into new businesses. Current high-tech entrepreneurship initiatives that raise awareness among the young researchers involved in Grid projects should be enlarged and supplemented with information about how young entrepreneurs can get access to funds to help them create their own companies. To aid entrepreneurship, public organisations employing researchers should be encouraged to define employment conditions that permit individuals to continue their research while developing business opportunities in parallel.

Reconfigurable e-Infrastructures:

- One speaker suggested to establish reconfigurable e-Infrastructures at the EU level for Grid research to perform experiments and for the industry to experiment on service-oriented utility infrastructures not yet fully defined today, and encourage strong interactions between user communities of reconfigurable and production e-Infrastructures.

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