
# e-IRG Roadmap 2010

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The e-IRG Roadmap 2010 was endorsed by the e-IRG delegates on 23 March 2010. Comments to the document made during the public consultation phase are available at the e-IRG website: http://www.e-irg.eu/publications/roadmap.html

# e-IRG Roadmap 2010

## e-IRG and its mission

The e-Infrastructure Reflection Group (e-IRG) is an inter-governmental policy body comprising government-appointed delegates from thirty-one member states, as well as representatives from the European Commission.

> *The e-IRG mission is to pave the way towards*
> *a general-purpose European e-Infrastructure.*

Here "e-Infrastructure" refers to an open system – comprising services, software components, and network, storage and computing resources – that supports flexible cooperation and optimal use of all electronically available resources. "General-purpose European e-Infrastructure" refers to a common e-Infrastructure that will encompass Europe's existing e-Infrastructure components (including high performance computing, networking and commodity computing services), and will most likely include new components to complement these basic building blocks.

The vision for the research e-Infrastructure outlined in this document has been constructed using a synthesis of data from several channels. The focal points of this ongoing analytical process are the meetings of e-IRG delegates, appointed for their knowledge and expertise in the provision of large-scale e-Infrastructure services and related policy issues. e-IRG meetings aim to reflect on and balance different inputs, including those received from expert consultations, open e-IRG workshops, e-IRG Task Forces on specific issues, and contacts with projects that represent e-Infrastructure users or service providers.

The role of the Roadmap in this process is to provide a vision for the future and to motivate continuing efforts to create links between stakeholders, aiming to maximise the socioeconomic value of common research e-Infrastructure. As the World Wide Web has shown, the junction between research and leading-edge technology is a fertile ground for innovation.

This Roadmap also outlines the role e-IRG intends to play in the ongoing development of e-Infrastructure, and the organisation's plan to expand the scope of its mission once its recommendations have been heard by external stakeholders and followed up at a higher policy level.

Leif Laaksonen, e-IRG Chair

# e-IRG Roadmap 2010

## Executive summary

The fundamental contribution of research e-Infrastructure to European competitiveness is almost universally acknowledged. Sustainable and integrated networking, grid, data and high performance and commodity computing services are now essential tools for 40 million users in research and academia across Europe. The innovation potential fuelled by this large-scale deployment of such advanced services should not be underestimated.

The e-Infrastructure Reflection Group (e-IRG) supports this innovation process. e-IRG is a forum where service providers, technology developers, and existing and new user communities come together to help realise the innovation and inclusivity goals of the i2010 strategy[1].

Increasingly, new and diverse user communities are relying on e-Infrastructure services; as such, the common e-Infrastructure must cater to new and updated requirements. This junction between leading-edge research and the e-Infrastructure that supports it is an area where considerable socio-economic benefits can be realised.

The inclusion of new user communities has also highlighted the importance of providing e-Infrastructure as a service, rather than continuing with a product- or technology-oriented approach. Such service provision should be based on principles and models that allow direct comparison of different technical, organisational and financial paradigms. Adopting this approach will ensure the continued ability of e-Infrastructure to act as an 'innovation engine' and accelerate the transition of leading-edge, research-focused ICT applications into solutions that benefit society as a whole.

Other major trends for the future of e-Infrastructure include the emergence of data-intensive science, the threatening software crisis, and the move towards the concept of computing as a service.

To encourage concrete steps towards addressing these challenges, e-IRG has made a number of recommendations in this document, including calls to:

- Stimulate and support the adoption of an Infrastructure as a Service (IaaS) model.
- Use commodity computing services to bring new users and user communities into contact with other components of e-Infrastructure.
- Improve the interoperability of e-Infrastructure components by pursuing global standardisation efforts.
- Encourage organisational structures and processes that ensure rapid access to European know-how related to exascale computing.
- Reserve resources for developing a blueprint for enabling data-intensive research.
- Encourage a Pan-European effort focused on the impact of new technologies and networking policies on the innovation potential of e-Infrastructure.
- Gather information on the successful commercial uptake of e-Infrastructure-related innovations.
- Support adoption of and access to e-Infrastructure services by new user communities and develop faster mechanisms for targeting resources to popular e-Infrastructure services.
- Facilitate the global contribution of European e-Infrastructure experts by enabling their participation in international roles that include leadership positions requiring long-term commitments.

1 http://ec.europa.eu/information_society/eeurope/i2010/key_documents/index_en.htm

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# e-IRG Roadmap 2010

## *Acknowledgements and background*

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- 15th May 2009 in Prague, Czech Republic
- 17th June 2009 in Prague, Czech Republic
- 16th October 2009 in Uppsala, Sweden

Progress of the e-IRG Roadmap was also discussed in most of the 2009 e-IRG board meetings. The contents of the document underwent a public consultation between 21st December 2009 and 31st January 2010. The received comments and the e-IRG responses to them are available on the e-IRG website at http://www.e-irg.eu/roadmap/.

The editorial process has also relied on the specific groups and individuals acknowledged below:

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# 1 Introduction

The crucial importance of research e-Infrastructure for European competitiveness has been stated several times, perhaps most prominently in a recent European Commission communication to the European Parliament[2]. The communication noted that "e-Infrastructures make a major contribution to the objectives of the i2010 strategy" and reiterated that despite the challenging economic situation, it is

> *"now more important than ever to explore 'innovative funding for a wide range of infrastructure projects, including transport, energy and high-technology networks...'[3]"*

The sustainability of e-Infrastructure services must be guaranteed if user communities are to rely on them in the long term. The growing requirements of new and existing user communities compel continual reassessment of all components of the e-Infrastructure service portfolio, including the structure of interactions between users and service providers. As e-Infrastructure services and technologies continue to change, new opportunities and challenges will keep on emerging.

While it is nearly impossible to predict the development of technologies in detail, a general process of adaptation to new technologies can be described. This process includes developing organisational and financial principles, models and working methods for infrastructure use and resulting innovation.

This document presents e-IRG's vision of the path towards sustainable European e-Infrastructure services. It details the ways in which Europe can optimally benefit from the opportunities introduced by fundamental changes to e-Infrastructure user communities, technologies, and services.

e-IRG already makes important contributions towards this goal, providing a forum for analysing different approaches to technology adaptation, making recommendations where possible, and ensuring that knowledge related to e-Infrastructure is readily accessible in all e-IRG member states.

e-IRG will also consolidate Europe's unique position in the global arena and provide an easily identifiable European contact point for issues related to e-Infrastructure.

2 COM(2009) 108

3 A quote from COM(2008) 800 as referenced in COM(2009) 108

# 2 A view on e-Infrastructure and trends

## *2.1 The role of e-Infrastructure in ICT innovation*

The research community has traditionally been the first customer – and often also the developer – of new information and communication technology (ICT) components and services. The close interaction between users, providers and developers of new technologies and services often instigates the creation of new service components and interfaces. For example, the e-IRG Data Management Task Force and the ESFRI preparatory phase projects have both indicated a need to add data-related services to the e-Infrastructure model. However, advance definition of the new services required is challenging, and the innovation process can be impaired if these new services are prematurely formalised or structured.

In the e-Infrastructure domain, technology upgrades are usually driven by the requirements of advanced users, rather than the need to optimise a commercial business opportunity. Research e-Infrastructure user communities often have very specific, challenging needs more sophisticated than those of the general ICT market; as such it is often impossible to fulfil these needs using commercially available off-the-shelf components in standard configurations.

Hence any new e-Infrastructure technology is immediately used in a multitude of ways, on different operational scales, for different scientific processes, and under very close scrutiny. User communities and service providers constantly analyse how the new technology fulfils its promises and clarify any adjustments needed to render the service a better fit with user requirements. This process accelerates the technology adaptation cycle. Thus e-Infrastructure often acts as an innovation engine, accelerating ICT-related innovation in society as a whole. Open communication between the users and providers of any new technology allows both groups to develop a rapid and realistic picture of the benefits and drawbacks of the technology in question.

The success of this approach is exemplified in the networking arena, where National Research and Education Networks (NRENs) collaborate under the GÉANT label, serving over 40 million users in 34 European countries. This collaboration has lead to several innovations in the regular networking market as well as in the research world.

Figure 1[4] illustrates a conceptual model of the role of e-Infrastructure in ICT innovation. It shows how innovation in scientific network infrastructures has primary effects on innovation in the general networking market and in generic application services and specific ICT-applications.

4 Based on experiences and observations from a networking, research, and large-scale piloting project 'GigaPort Next Generation Network' in the Netherlands (2004-2008) http://www.surfnet.nl/en/innovatie/gigaport/Pages/Default.aspx

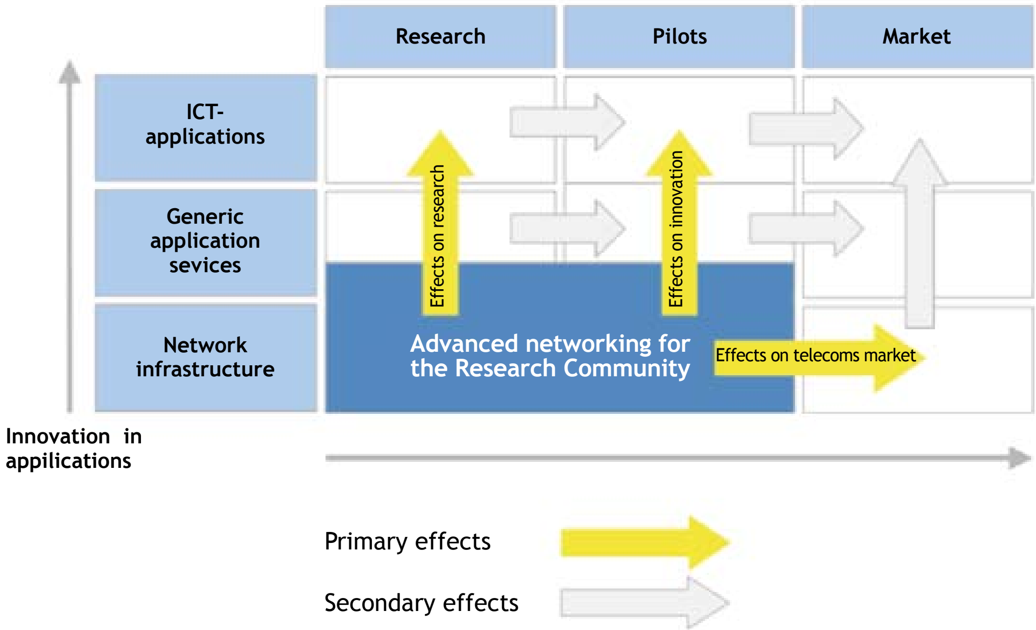



***Figure 1:*** *Example of the impact of infrastructure innovation*

## *2.2 A move to service-orientation*

There is a growing trend away from delivery of e-Infrastructure as a technology or product in favour of delivery as a service. Networking has long been viewed as supplying a Pan-European service rather than a product, but this is not always the case in other fields. For instance, in many cases the users of compute-intensive applications have also helped to develop the infrastructures they use. In high energy physics (HEP), for example, users are also resource owners, often maintaining and operating their own computing centres. As a result, the HEP user community has been strongly involved in middleware development, hardware selection, and operating system support (often coordinated by grid computing projects), instead of pursuing the "computing as a service" model.

However, the users of e-Infrastructure are becoming increasingly diverse, encompassing smaller groups without dedicated IT infrastructure or support, and as such the move towards a service orientation needs to be accelerated for all e-Infrastructure components.

A related policy issue is the commoditisation of e-Infrastructure services. Commoditisation[5] occurs when goods or services from different vendors become practically impossible to distinguish, based on their technical features, for users in a particular market.

Commoditisation of computing services is in the users' interest: it makes the supply of services transparent, removes unnecessary lock-in situations, and enables economies of scale, making large-scale deployment of external services more attractive. These external services are often supplied on a commercial basis and may in some cases compete with the dedicated internal services provided by research e-Infrastructure. Companies offering large-scale external services are often able to allocate significant resources towards developing and refin-

5 http://en.wikipedia.org/wiki/Commodity.

ing new service implementations and integrating these with existing IT infrastructure, thus perhaps increasing the advantage of these services over solutions offered specifically by the research e-Infrastructure domain.

A challenge for research e-Infrastructure is therefore to represent users' interests in the commoditisation process by a) promoting standards for commodity computing and b) advising when a switch to commodity services would be appropriate. Premature adoption of a commodity service could hinder future research activities; for example, switching to a commercial offering that does not comply with commodity standards could result in vendor lock-ins due to proprietary interfaces. Such a scenario should be prevented by user-controlled commoditisation. However, attempting to maintain dedicated solutions that directly compete with commercial solutions may waste resources, which could be as harmful as vendor lock-ins in terms of the ability of an e-Infrastructure to meet the advanced requirements of its user communities in the long term.

Current financing models are not sufficiently transparent to allow comparisons between commodity and dedicated e-Infrastructure services, which complicates decision-making based on costs and benefits. Legal compliance issues – such as those related to non-proliferation[6] – can be even more complicated in environments that mix dedicated e-Infrastructure resources with commodity offerings.

## *2.3 Paradigm shifts*

While improvement in the price/performance ratio of technical components is likely to continue, this seemingly linear development may hide fundamental paradigm shifts in the methods used to maintain this trend. Changes on the underlying implementation level may cause some surprises in the development of the leading-edge software systems typical to research e-Infrastructure.

Many of the technologies that underpin e-Infrastructure are on the brink of fundamental change. New developments are replacing older technologies in the networking (lambda networking and the deployment of "dark fiber" connections), high performance computing (massively parallel architectures), and commodity computing domains (virtualisation).

### 2.3.1 The data deluge

Perhaps the most important paradigm shift will come from the spread of data-intensive science, which will have enormous impact on the need for e-Infrastructure services. Large amounts of data are created not only by state-of-the-art scientific instruments and computers, but also by processing and collating archived data.

While the headlines are occupied by the unprecedented capacity of new research instruments and the massive computing capacity needed to handle their outputs, the changing and increasingly important role of data is rarely noticed. Indeed, it seems the only hints of this revolutionary issue are the mentions of heights of hypothetical stacks of DVDs, intended to illustrate massive amounts of "raw, passive fuel" for science.

However, the shift from traditional methodology to data-intensive science – sometimes called the *4th Research Paradigm* – is making data an active component in the scientific process.

6 For example, the issue of non-proliferation in grid computing environments has been studied in a recent paper "Problem description for non-proliferation issues in Grids" by W. Juling, K.Schauerhammer, M. Spiro, K. Ullmann, D. Vandromme.

This shift is also changing the way most research is planned, conducted, communicated and evaluated.

This new paradigm is based on access to and analysis of large amounts of new and existing data in innovative combinations. This data can be the result of work by different groups of researchers, working concurrently with or independently from the researchers who gathered the originally information.

Use of data by unknown parties for purposes not initially anticipated creates a number of data management challenges. Long-term data storage, curation and certification are just the tip of the iceberg. For example, a so-called Digital Data Deluge is expected to result from the ease with which large quantities of new data can be created. Managing this deluge is even more difficult in this rapidly changing and new environment.

### 2.3.2 The threat of a "software crisis'

One technical development with a clear policy impact is the so-called "software crisis," caused by the technical challenge of harnessing the very large number (hundreds of thousands) of processing units used in supercomputing applications. This challenge is growing as the number of cores in multi-core computing architectures continues to increase. The International Exascale Software Project[7] is a global initiative instigated to address this challenge; however, such a fundamental paradigm shift may require broader, proactive policy changes. For example, European funding policies may need to be adjusted to enable research e-Infrastructure services, and the applications using them, to more readily adopt new architectures and programming techniques, without compromising stability and reliability.

### 2.3.3 Knowledge resources related to paradigm shifts

e-IRG leverages knowledge from numerous ICT projects and initiatives in addition to expertise from its own expert network. At time of writing, e-IRG is also in contact with technology surveys including:

- The Future Internet Research & Experimentation (FIRE)[8] initiative, which published a draft version of its White Paper[9] that details use cases and lists initiatives working towards the network of the future.
- The Partnership for Advanced Computing in Europe (PRACE) project, which is establishing the European high performance computing (HPC) service, has published several documents[10] addressing subjects from procurement strategies for the HPC service through to user requirements matched with actual and possible future computing systems.
- The European Science Foundation's Lincei initiative[11] and the International Exascale Software Project, which both study the status and development of HPC software for present and future supercomputing systems with a very large number of processors.

7 http://www.exascale.org/

8 http://cordis.europa.eu/fp7/ict/fire/

9 http://www.ict-fireworks.eu/publications/papers.html

10 http://www.prace-project.eu/documents/public-deliverables-1/

11 http://tinyurl.com/ydbessl or http://preview.tinyurl.com/ydbessl

## 2.4 From e-Infrastructure components to e-Infrastructure service components

From the users' point of view, e-Infrastructure should provide a seamlessly interacting service. However, for historical and practical reasons, this service has been divided into components.

For example, the HPC service is provided in a relatively centralised manner from a limited number of large-scale installations. In contrast, the networking service must account for diverse geographical constraints and organisational models, both of which vary between countries and between campus networks within countries. The commodity computing service model seems to be least constrained by external factors. However, this freedom may have made it more challenging to reach consensus about fundamental technical, financial and organisational structures that affect the benefits, working models, and the investments required by different commodity computing stakeholders.

Details of the vision for the data management service will continue to emerge as advanced data services are launched and understanding of the processes and policies governing their use continues to evolve. HPC and grid services already incorporate data storage solutions, and there is a large body of expertise in the digital library community. However, the role of data in the scientific process is rapidly changing, and truly innovative data-related services may evolve in a way that does not complement or integrate with existing solutions and services – especially if these legacy solutions impose constraints that limit the benefits that can be achieved by efficient e-Infrastructure support for data-intensive science.

Sustainable models for the provision of these four key services – networking, HPC, commodity computing, and data management – are well on the way to being defined, but construction of a coherent model for e-Infrastructure as a service will require their close coordination. Due to its composition and mandate, e-IRG provides a natural forum for enabling and optimising this coordination, as well as facilitating parallel engagement with user communities.

The key issues in each of the infrastructure components are as follows:

### 2.4.1 Networking services

Networking services are entering an era characterised by the broad uptake of a new hybrid model enabling the use of lightpaths in parallel with IP-based[12] services. This move from the "best effort IP[13]" model will create new opportunities to optimise the quality of service provided to high-end users, especially once these services are integrated with existing e-Infrastructure services. On the other hand, an ability to accurately prioritise, measure and potentially invoice user traffic may prevent the kind of fortuitous innovation enabled by the "Internet traffic is free"[14] model.

This feature of "normal" IP traffic has extended also to the initial pilot and testing stages of ventures aiming to utilise these innovations. It is thus important to develop usage policies that a) strike a balance between optimal allocation of and accounting for on-demand lightpath-networking resources, and b) provide room for bottom-up activities that feed the innovation ecosystem. A related technical challenge will be enabling user-controlled dynamic lightpath networking.

12 IP refers to Internet Protocol, the basic general-purpose protocol used when sending data packets via the Internet.

13 "Best effort IP" provides no guaranteed quality of service.

14 Or if not free, at least even relatively demanding large-scale usage did not require advance authorisation.

In the networking arena, user communities are increasingly heterogeneous, often comprising academia, public and private research institutes, corporations, and non-profit organisations cooperating in public-private partnerships. Access to the same network infrastructure is essential to the success of such collaborations and supports transfer of application and service concepts from the research network into the commercial domain. Thus there is an increasing need for new governance principles and methods targeted to managing and financing the mixed use of network infrastructures.

### 2.4.2 High Performance Computing services

The creation of an enduring HPC service will have an important impact on European competitiveness. High performance computing has long been a key enabling technology for optimising product and process designs in both academia and industry, often directly addressing grand challenges such as energy, health and mobility. A persistent HPC service will also help to train university students, such that when today's high-end HPC systems become affordable enough to be acquired by small- and medium-sized enterprises (SMEs), there will be no shortage of skilled workers able to use these tools efficiently.

As mentioned earlier, the technological basis of HPC services is changing as several assumptions related to the design of efficient application software are challenged. The move to massively parallel "*multi-core*" architectures may require a thorough re-examination of the large number of software suites in use today.

### 2.4.3 Commodity computing services

The concept of commodity computing services will soon encompass solutions offered by grid and data grid computing, cloud computing, and cluster and cycle-scavenging systems[15]. Users value commodity computing services based on their flexibility and ability to offer rapid access to resources; these features reduce the opportunity cost of accessing resources beyond the personal workstation[16]. Rather than enabling a completely new kind of problem-solving, commodity computing will improve efficiency of the research process. For example, delays caused by the procurement and installation of new computers in the local IT infrastructure can be greatly reduced.

In addition to this facilitating and enabling role, commodity computing services will also become the most common point of first contact with e-Infrastructure for many researchers. Thus, in addition to providing commodity computing services, providers must also be able to identify opportunities for researchers to benefit from other resources and services in the e-Infrastructure palette.

On the policy level, the key challenge for commodity computing is the creation of transparency by setting standard requirements – for performance and reliability, for example – and agreeing on methods for accurately comparing the actual cost of different solutions. Currently methods for calculating the costs of various computing solutions vary between countries and between organisations. This poses challenges for economical decision-making.

The technical interoperability of different computing solutions also needs to be improved. Once interoperability has been achieved, standardisation will allow interoper-

15 The exact definition of commodity computing varies. For the purposes of this discussion, it is enough to use a relatively informal definition that separates commodity computing from HPC based on characteristics such as tightly vs. loosely coupled execution of parallel processes.

16 There are notable exceptions to this. For example, in HEP computing where the volume of data is such that managing large number calculations and reliably storing results becomes a key issue.

ability to be measured or codified, facilitating its use as criteria in public procurement processes, for example.

Commoditisation that best serves users and achieves required levels of interoperability can be most effectively reached by approach from several angles, rather than by relying on an individual solution. At minimum, these approaches should consist of simultaneous:

- Monitoring of the development of *de facto* standards to ensure that the investment in formal standardisation efforts is justified by their impact
- Pursuit of formal standardisation processes, with an emphasis on those standards organisations seen as relevant by stakeholders
- Testing and development of third-party interoperability[17]
- Development of policy actions aimed at clearly distinguishing the roles of software, solution and service providers.

Like HPC, commodity computing on the organisational level is in the process of being consolidated across Europe. Clarifying and strengthening the role of National Grid Initiatives (NGIs) will create a network that can efficiently support any scientific discipline that needs to use or share e-science resources beyond those locally available.

### 2.4.4 Data-related services

Data management is crucial to most research disciplines and as such it may be possible to map different data-related requirements to a common set of basic services. This is reflected in the recently published ESFRI roadmap update,[18] which states that

> *"Access to and common exchange of data is a prerequisite for the fruitful utilisation of the possibilities offered to the Humanities and Social Sciences by the emerging technologies."*

There has been an explosion in the volume and complexity of human knowledge available through the Internet. The models, algorithms and technical innovations that manage all this data are increasingly numerous and advanced. The population using these advanced e-Infrastructure technologies has grown by several orders of magnitude.

A new term, data-intensive science, has been coined to describe this trend. In 2009, for example, where one scientific field may have produced publications at a rate of two per minute, in 2020, this same field and its interdisciplinary combinations may produce a flood of published knowledge (articles, analysis results, multimedia and so on) that rivals the volume of raw data produced today. At the same time, the amount and complexity of data that can – and often must – be analysed as part of the research process has similarly grown.

The 2009 e-IRG Data Management Task Force report[19] details the status of data management initiatives, and recommends that current data management practices be augmented by services focusing on metadata[20], quality and interoperability.

17 This means tests and developments done by parties not participating in the development of individual solutions. This could be organised as a service contract, public interoperability test event, or open competition.

18 ftp://ftp.cordis.europa.eu/pub/esfri/docs/esfri_roadmap_2008_update_20090123.pdf

19 Published on the e-IRG Task Force reports page:
http://www.e-irg.eu/index.php?option=com_content&task=view&id=38&Itemid=37

20 Descriptions of the data itself and the services related to it

The rapid growth in data-intensive research will require facilities that combine data and computation; this can be achieved, for example, by providing services that run researchers' computations close to data[21] and by balancing I/O (input-output) capacity with CPU (central processing unit) speed[22]. This may also set new requirements for the architectures of future data networks.

## *2.5 Organisational developments*

The practices of research institutes will change even more dramatically than those of individual researchers. However, this change will be driven less by e-Infrastructure development and more by the increasingly global and competitive research marketplace, which brings new requirements and methods that will steer research activities. This increasing competition will naturally create pressure to use – whenever possible – computing resources that do not require dedicated hardware and personnel investments. These services will be supplied by providers both within and outside the research communities, and their use will be driven by the cost-effectiveness achieved a) through economies of scale and b) by minimisation of the extra capacity needed to accommodate peaks in resource usage.

The role of the common e-Infrastructure in this competitive market is to avoid the risks of the two extremes: ICT resources either managed completely "in-house", or completely outsourced to external providers. Outsourcing to a common e-Infrastructure will likely produce better results than a commercial tendering process since it will provide an organisational interface sympathetic to the issues of research applications and offer researchers a role in governance of the service. As the European e-Infrastructure community distils generic requirements from research use cases, it can feed these findings back to the marketplace, coupled with evidence of a user-base large enough to support the emergence of commercial commodity solutions that can support the original research use case. To accomplish this, the organisational model will need to:

- Address the integration of local/global/outsourced resources
- Account for the use of these resources – including resources like helpdesks
- Be service-oriented across organisational boundaries. For example, permit partial refunds to keep a customer happy, even if the refund concerns services provided by another organisation.

Addressing these challenges requires participation from technology developers, service providers and user communities. The combined efforts of e-IRG and ESFRI will be an important starting point for this process.

21 When computations are performed "close to data", they are performed physically to the place where the data is stored, instead of the traditional approach of moving the data to a location where the computing takes place. This approach minimises inefficiencies caused by bandwidth limitations or network latencies.

22 The issue has been a focus of several scientific papers, including: Gordon. Bell, Tony. Hey, and Alexander S. Szalay. "Beyond the data deluge". Science, 323(5919):1297–1298, March 2009

# 3 Recommendations: Roadmap implementation

To reach the "ideal e-Infrastructure" model presented above, and to enable maximal socio-economic benefits, e-IRG proposes a number of concrete, near-term actions. These e-IRG recommendations are listed below in order of impact and urgency, starting with the highest priority:

## *3.1 Infrastructure as a Service (IaaS)*

The adoption of an Infrastructure as a Service (IaaS) model should be strongly stimulated and supported with the aim of increasing the sustainability of e-Infrastructure and to identify and provide innovative solutions which could find a larger use in society

## *3.2 Commodity computing*

Since commodity computing to run scientific applications is the most common "first e-Infrastructure contact point" for new users and user communities, e-IRG recommends strengthening and clarifying the roles of the National Grid Initiatives and the European Grid Initiative. e-IRG recognises the importance of transparency and compatibility of the organisational and financial models as key factors in maximising the benefits of broad commodisation of computing services for all scientific users.

e-IRG also recommends that organisational structures and incentives are put in place that ensure that all the actors in the commodity computing domain will have an interest in – when technically appropriate – bringing new users and user communities into contact with other components of the e-Infrastructure.

## *3.3 Standards and interoperability*

e-IRG recommends continuing[23] interoperability benchmarking through global standardisation. In addition to making it easy to benchmark in terms of suitability, dependability and cost-effectiveness in different application domains, this will ensure long-term interoperability of different implementation technologies used for providing e-Infrastructure services and create a marketplace for commercial offerings.

## *3.4 High Performance Computing*

e-IRG recommends establishing organisational structures and processes that ensure that European know-how related to exascale computing can be rapidly accessed. This requires design of optimal support structures that ensure all European expert communities can freely and efficiently share information, about both specific solutions and general best practices. International efforts, such as IESP, should be followed.

## *3.5 Sustainable data management infrastructure*

e-IRG recommends that sufficient EU and national resources are reserved for preparatory work to create a blueprint for enabling data-intensive research. e-IRG also recommends that established e-Infrastructure initiatives appoint a representative to liaise with this new

23 As stated, for example, in the 2006 report of the e-IRG Task Force on Sustainable e-Infrastructures.

initiative. e-IRG will commit its expertise, contacts to policy makers, and data management experts to support this initiative.

## 3.6 Networking

e-IRG supports Pan-European efforts focusing on the impact of new research networking technologies and policies on the innovation potential of e-Infrastructure, and the impact of cost and policy differences in the member states on commercial deployment. More efforts should be targeted towards ensuring that new networking technologies are taken into use as rapidly and broadly as possible.

## 3.7 Commercial uptake

e-IRG recommends gathering information about successful commercial uptake of e-Infrastructure–related innovations to identify policy, funding and other mechanisms that would support seamless transition of proven e-Infrastructure collaboration models into broader use in society.

## 3.8 New user communities

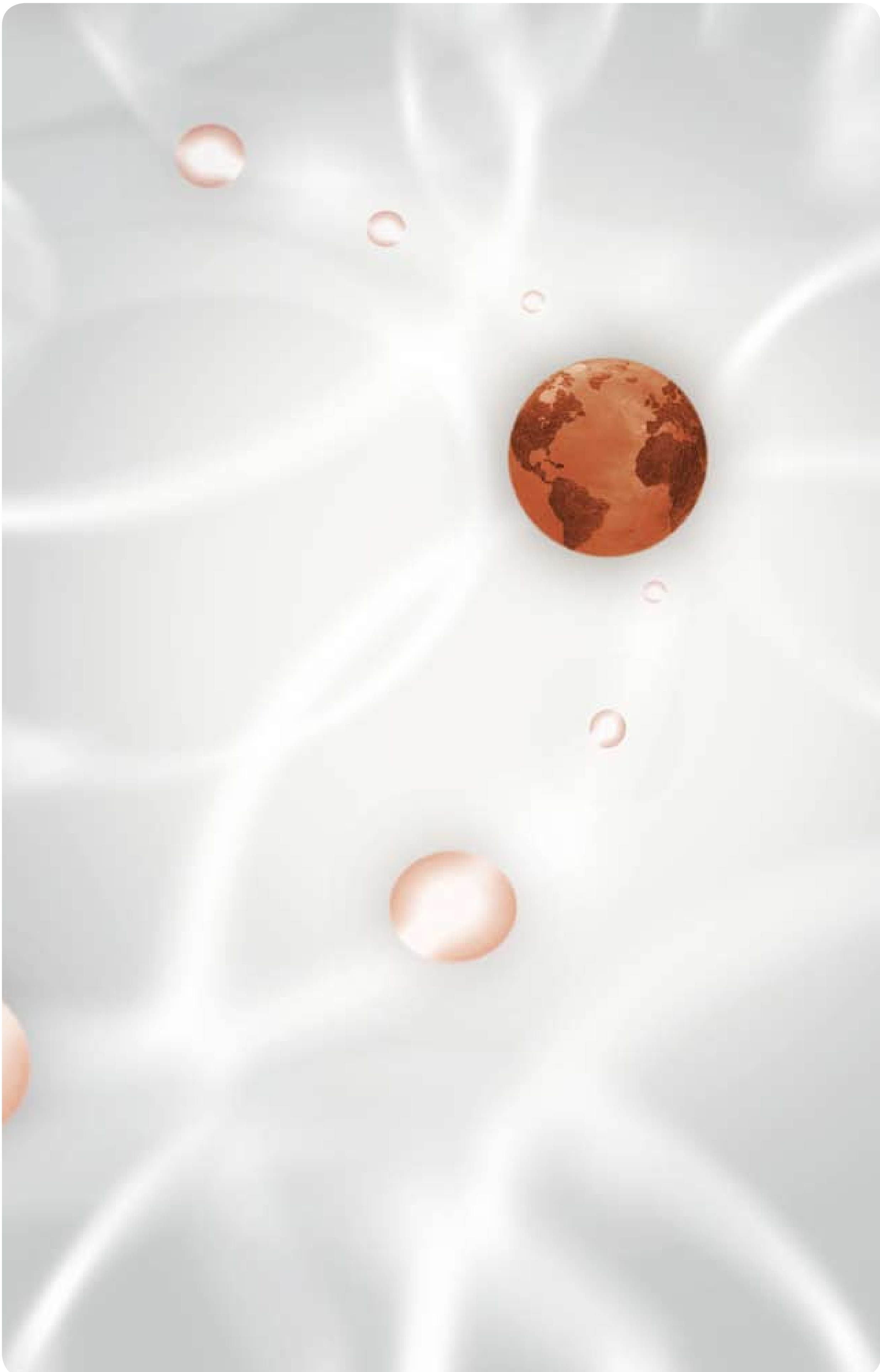
e-IRG recommends that the member states, European Commission and the sustainable e-Infrastructure initiatives propose and provide resources for mechanisms that will:

- Accelerate the adoption of sustainable e-Infrastructure services by new user communities
- Complement the competitive "call for projects" approach with a faster mechanism to target resources to popular e-Infrastructure services
- Identify partners and collaborative processes to support the organisational development of new user communities.

## 3.9 International collaboration

e-IRG recommends that funding agencies and host organisations ensure that policies related to funding and human resources are flexible enough that – when such opportunities present themselves – European e-Infrastructure experts will be able to accept visible leadership roles in global groups without sacrificing their career development within the European Research Area. This will maximise the positive, global impact of European e-Infrastructure investments in the global arena.

This empowering of individual European experts should be matched with policy-level actions to align procedures, to maximise information exchange, and strengthen cooperation on international matters.



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