
CHALLENGERS

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Support Action on CHALLENGEs in gRidS

# CHALLENGERS Publishable Final Activity Report

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Advanced Grid Technologies, Systems and Services

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# CHALLENGERS SSA Project:

# Publishable Final Activity Report

**www.challengers-org.eu**

## 1. Introduction

CHALLENGERS SSA Project aims to develop a vision for Grid-enabled Service Infrastructures that Europe will gainfully work towards in the coming decade and beyond. The project functions as an international forum of Grid and ICT experts, building on the ideas of NGG Group as a starting point but greatly expanding its scope.

Primarily hosting a sequence of workshops, Challengers will “think outside the box”, in an effort to deconstruct the present vision, revise it by demolishing any illusions and freshen it up with a constructive set of long-term priorities.

The project uses the motto “Against Mainstream Research” which does not only apply for the outcome of the assessment performed within CHALLENGERS but also for:

- The general methodological framework adopted in order to perform an efficient holistic approach on complex systems like Grids
- The organization of the exploratory assessment process during the project’s events by the participating experts

## 2. Scope and Objectives

Senior executives in industry today need to foresee the medium to long term future of the ICT marketplace in order to make the right decisions for their company’s needs. However, executive level decision-makers in industry face considerable challenges in following the constant and often complex changes of the technology landscape, especially in terms of powerful but still evolving technologies such as Grids and service oriented architectures.

Grids have already evolved from specialised supercomputing systems to much more general computer platforms: research now aims to develop further towards ‘service-oriented knowledge utilities’. This vision, first articulated by the 'Next Generation Grid — NGG' expert group, demonstrates Grids’ natural position at the forefront of the clear trend of ICT convergence. But achieving this vision requires fragmented and often incompatible technologies serving a narrow spectrum of needs to be replaced by a unified, holistic technology. In essence, ICT itself must become knowledge-oriented at the technological level, and service-oriented at the user level. Challengers explore the landscape of these challenges taking into account the needs of real-world business environments, but also of the individual users (including home users).

CHALLENGERS Project is set to provide foundational and pragmatic insight for decision-makers into such technologies and the shifting landscape that surrounds them. The project will also address relevant socio-economic and business drivers, providing an analysis of a holistic, multidimensional nature.

Such an approach considers in depth multiple facets of the technical, social and business aspects, with central elements the constant integration, consolidation and cross-fertilisation of these analyses. Within CHALLENGERS the business foresight is tempered with technological reality, technology foresight is guided by socio-economic needs, while social foresight is informed by the practical realities that influence society.

## 3. Summary of Activities

Challengers performed their assessment and consultation study by considering in depth multiple facets of the technical, social and business aspects (Fig. 1).

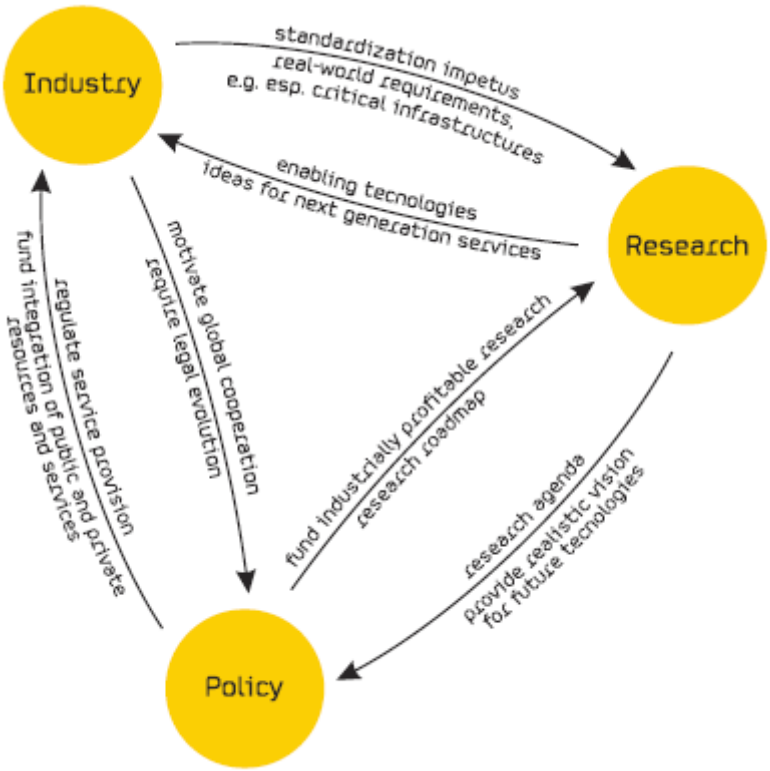


**Figure 1.** Visualization of the CHALLENGERS approach.

The constant integration, consolidation and cross-fertilisation of these analyses was of primary importance to the project's approach in an attempt to temper business foresight with technological reality. Technological foresight was guided by socio-economic needs, while social foresight was informed by the practical realities that influence society.

CHALLENGERS Project has recognised at its very beginning the necessity to widen its scope of assessment beyond Grids, due to the recognition of the fact that the framework of converging ICTs is the cornerstone of the trends and vision of future applications and services. This is the main reason why CHALLENGERS has chosen to adopt a demanding, deep and holistic approach for the description of the technology vision and the associated research challenges for the coming decade. In fact this strategic choice is the one of the main components of the "Against the mainstream" motto characterising the CHALLENGERS' effort and it importance as a choice becomes even more obvious and useful under the present conditions of economic recession, which is an additional barrier to the smooth development of all the forward looking technologies. Under those circumstances the need for identifying visionary but also efficient and feasible means to leverage the limited human and financial resources of the Community becomes even more imperative.

Since technology roadmapping is a continuous and iterative process that fits within the broader European strategic technology planning and business development context, CHALLENGERS have completed two iterations of their assessment work performed within their lifetime.

During the first iteration the project has achieved to:

- Identify the primary dimensions of the visionary applications and services that will drive technology selection and development decisions in the ICT domain.
- Determine the critical technology components that make up the research challenges which highly contribute the realisation of the identified visionary applications and satisfy their most essential needs.
- Define the scope and boundaries for the technology roadmap

During the second iteration the project has refined the roadmapping process through the following steps:

- Review, update, extend and consolidate the primary dimensions of the vision described during the first iteration in order to ensure that it exists and moreover it incorporates any new emerging trends.
- Focus on the forecasting of the finally resulted vision through the provision of a roadmap for its evolution, combined with the simultaneous forecasting on the development of emerging and forward looking technologies. The roadmap is based on timelines showing where the identified technology drivers reach their targets through the elaboration of specific technology components or aspects of these components within the time window of the coming decade.

All the project's outcomes are documented in publicly available reports that can be accessed and downloaded from the project's web-site (www.challengers-org.eu)

The project has already entered in the second and final iteration aiming to refine its Research Agenda and Roadmap that will be finally released by CHALLENGERS at the end of their lifetime.

## 4. Areas of CHALLENGERS Assessment Work

The focus of the consultation work performed by the Core Group of CHALLENGERS experts applies to the following areas:

1. **The Technology Area**

   During their assessment work CHALLENGERS has evaluated the Forward Looking Technologies (FLT) related to Grids and SOKU, as well as to their association and dependency with the advances with other well established or emerging ICT (Information and Communication Technologies). During this assessment the project adopted a holistic approach in order to investigate enabling technologies focusing on complementary or converging disciplines. The main outcome of the assessment at the technology level is the consolidation and description of the technology vision for the Grids-related technologies of the coming decade. Thus the ultimate goals of this work are the following:

   - **The introduction of a Research Agenda and a roadmap of key technology challenges**, with prioritized topics, which will be considered as the advisory tools for paving the way towards the realization of the next decade Grid vision.
   - **Increase awareness of the next decade vision for Grids** among researchers of different but complementary or converging disciplines.

2. **The Industry/Business/Critical Infrastructures Area**

   CHALLENGERS will assess the business, economic and societal impact contributed by tomorrow's Grid technology, in conjunction and convergence with other key ICT. The project will pave the roadmap to sustainable economic models – not just for the trading of Grid

resources, but also to understand how and on what basis these Grids will be financed in the first place. Part of this work will come from a consideration of how the needs of researchers may align (or not) with those of business and industry, and how far the research community can benefit from technologies developed for other purposes. The adoption of appropriate economic models is essential to promote investment in grid infrastructure across the whole community at a level that will provide significant impact for research.

At the societal level, CHALLENGERS will provide ideas of how research should go beyond purely IT-centric capabilities and include international open standards, business modelling and social research in order to address the complete end-to-end process from researcher to end user and enhance the acceptability of new services.

Within the same framework, CHALLENGERS will address the needs of critical infrastructures**,** public safety and security applications as well as life improvement practices.

**3. Interactions between Communities and Standardisation issues**

Part of CHALLENGERS' activity is devoted on identifying actions and measures that need to be taken in order to interact with the international policy-making / standards-defining groups, to understand their thinking, to offer (strongly) proposed changes for the benefit of Europe and to promote trans-national cooperation between the various initiatives and research Groups. The specific activity is based on interaction with major standardization bodies, initiatives in national and worldwide level as well as commercial developers and development groups. Through this interaction the project aims:

- to shape a way of thinking that allows to make the move to standardization more acceptable and more rapid
- to propose and support the wide adoption of the Grid technologies
- to assess the socio-economic impact for the next decade

# 5. Consolidated CHALLENGERS Vision and Identified Challenges

## *5.1. The CHALLENGERS Vision: From Grids and Service Oriented Architectures (SOA) to Service Oriented Knowledge Utility (SOKU) Architectures*

The work performed by CHALLENGERS and the resulted European vision for Grids, as described by CHALLENGERS is radical, in the following sense:

- It provides a breakthrough for the future sustainability of Grids, highly based on a social visionary dimension
- The proliferation of Grids is envisioned within a "utility-based" context for masses of users
- Shows up all the capacity and capabilities of Grids without focusing on targeted sectors or communities, but keeps the vision live for all of them
- The vision is fully justified through structured and prioritised technology challenges
- The idea of assessment based on a "Killer applications" seeking approach is suppressed: CHALLENGERS suggest a vision putting in the forefront the need to improve the characteristics that render a Grid-based infrastructure useful for specific families of applications, rather than the characteristics that make an application useful for users

A graphical representation of the vision and the associated research challenges, as described by the CHALLENGERS Project is summarised in the Figure 2.

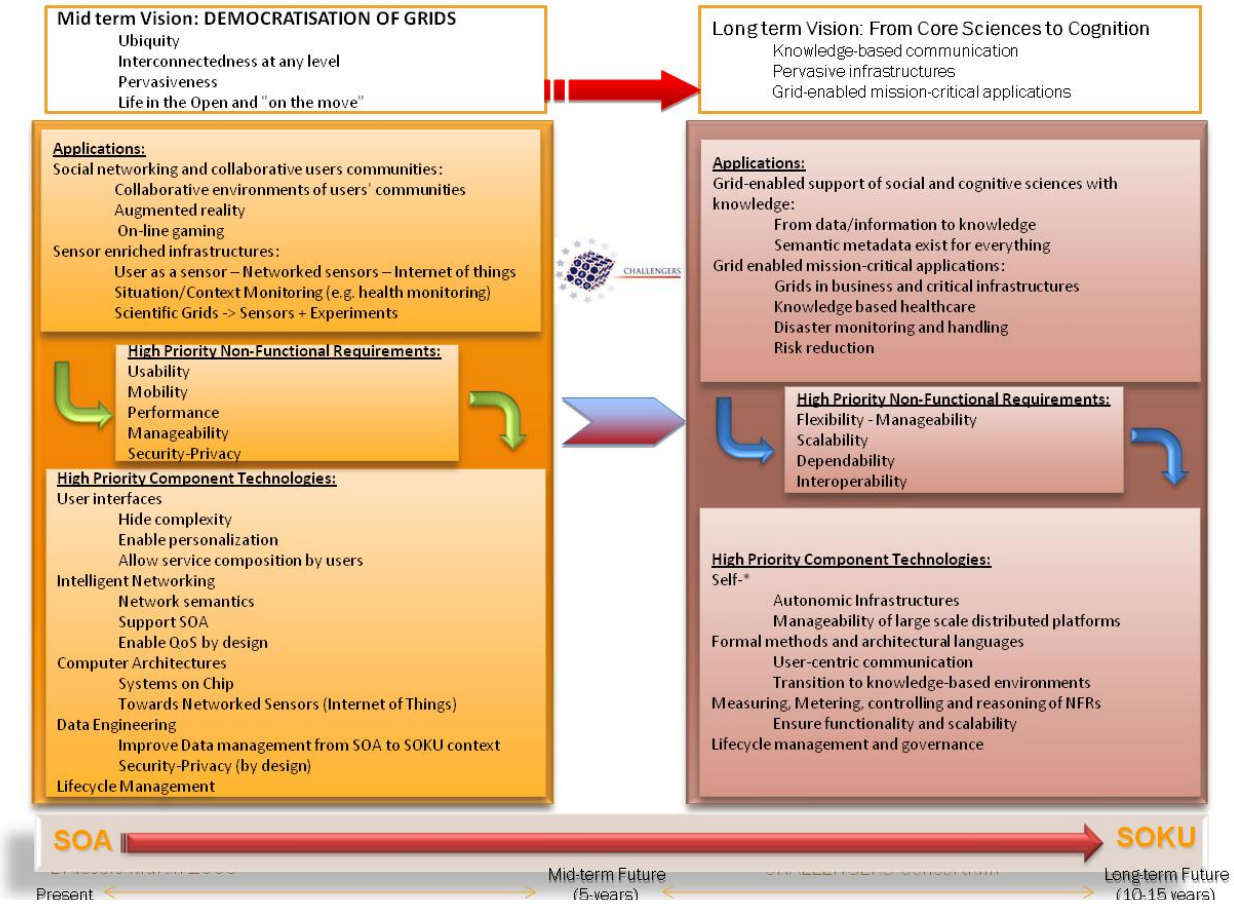


**Figure 2.** Summarisation of the CHALLENGERS vision and associated research challenges.

During the first cycle of their assessment work, CHALLENGERS has identified specific weaknesses, in the development of Grid architectures and have recommended a user-centric vision, based on the future evolution of infrastructures that will take advantage of the inherent advantages of Grids and will lead to the improvement and maturation of attributes that can render Grids as one of the cornerstone technological instruments for the future evolution of ICT.

The core of the user-centric vision, as described by CHALLENGERS is based on the development of infrastructures that will allow their end-users to have a broad, easy and multi-purpose interaction with services enabling autonomous and transparent synergies between them, under well defined and controlled relationships. The path of the realisation of the user-centric approach adopted CHALLENGERS comprises three major highlights:

1. Ubiquity and “Interconnectedness at any level”
2. Life in the Open and “on the move”
3. Moving from core sciences to cognition and from information and data based communication to knowledge-driven and knowledge-oriented communication

while the pillars of the strategy for the implementation of the visionary approach are:

- The democratisation of Grid-based and Grid-enabled infrastructures and services to wide communities of users, including citizens and individual users, within a mid-term horizon
- The development of large scale architectures and platforms, with enhanced autonomic properties, in order to serve mission critical applications, especially as far as decision making and control is concerned. This is a long term strategic target applicable within the next 10-15 years
- Enable the transition from communication based on data and/or information to knowledge-based communication and interaction through the enhancement of numerous aspects of life improvement, business and science, including the development of knowledge-assisted processes for cognition-based decision on behalf of user (within a 10-15 years horizon)

The vision and the corresponding strategic framework, described in the paragraph that follows, lies on the fulfilment of certain research challenges and advancements of Grids middleware and ICT components, prioritised under certain criteria related with the need to resolve present weaknesses and to pursue future targets.

The impact of Grid-based architectures and infrastructures within the visionary context, as described by CHALLENGERS, can be considered either through the role they play as service oriented platforms (SOAs) or through the prism of a broader service oriented knowledge utility architecture (SOKU). This transition from SOAs to SOKUs, and the involvement of additional ICT disciplines is the primary motivation of the revision and update of the initial vision preformed by CHALLENGERS during the second iteration of their assessment work.

## *5.2. The context of the strategic framework for the realisation of the CHALLENGERS Vision for Grids: from democratization to social collaborative ecosystems*

The vision for Grids, as perceived and described by CHALLENGERS, as well as the associated Research Agenda and Roadmap are the result of the assessment based on a methodology comprising a simultaneous "top-down" and "bottom-up" approach, where the common ground in both direction were the non-functional requirements (NFRs) of Grid-based platforms. Each of these two approaches has provided different but complementary insights to the fulfilment of these requirements in the future Grid-based environments, allowing the description of the vision and the posed challenges in a holistic manner. Even though it is evident that this assessment on a completely new and more extended basis and methodology, in comparison with the previous work of the NGG Group, many conclusions presented by CHALLENGERS are really close to the NGG vision.

The strategic framework for the realisation of the vision, as described by CHALLENGERS is distinguished in mid term (5-years) and long term (10-15 years).

### 5.3.1. Mid-term (5 years) strategy

1. Sustainability of Grids is feasible only by following a user-centric approach that will allow the benefits of the specific technology to reach wide communities of individual users, with emphasis to "consumers" and home users.
2. The prerequisite for the successful accomplishment of this process of democratisation of Grids is feasible only if the research and industrial community involve masses of users in their research endeavours to tackle the associated technology challenges.
3. Future research efforts should be planned taking into account the user trends and needs for communication and information exchange and recommend solutions or frameworks that these trends can be leveraged or further promoted through the use of Grid-enabled infrastructures, applications or services.
4. Visionary dimensions like ubiquity, pervasiveness, interconnectedness at any live, "life in the open" and "on the move" for every-day users and wide communities should be challenged through the development of large scale distributed grid enabled platforms, enriched with multidisciplinary technologies (e.g. sensors, mobile devices etc) in order to deliver novel services and promote the networking of people with common interests or need for communication.
5. Users should be involved in those efforts not only to consume services. They should be provided with technological tools and means to set-up simple but custom applications or services that from one hand serve their needs and interests within the new environments or digital communities while on the other hand they prove the added value of the new technologies. Similar previous and present experience, regarding introduction of new technological products and services to the "consumers", highly supports the anticipation that if active involvement of users under this perspective becomes feasible will lead to "explosion" of democratisation, with extremely positive impact to any future evolution.

6. The deployment of any new platforms, and the provision of services directly to the interested communities, under real-life conditions will have multiple impact to the effort for the realisation of the Grids vision, by the following means:
   - Will encourage close collaboration of the research, business and industrial communities to develop testbeds for testing novel approaches or services and multidisciplinary technologies under real-life conditions since the actual testers will be the involved users.
   - Deployment of such testbeds is essential for researchers and industry to test novel practices, services or devices within environments that are not mission-critical, serving nevertheless the needs of real users.
7. In connection with the research efforts, the research and business community should recommend frameworks for information of the communities of users about ongoing endeavours and their direct involvement towards democratisation at the earliest possible stages of any effort.
8. Effort for the democratisation of Grids should be supported through the exploitation of any up to date achievements, existing infrastructures or ongoing standardisation results.

### 5.3.2. Long-term (10-15 years) strategy

Under the assumption that democratisation of Grids will have been achieved to satisfactory levels, through well coordinated and intense efforts the new picture, regarding the position of Gris in the "computing cloud" can be envisioned as follows:

- The critical mass of Grid enabled platforms that serve and support the needs of wide communities of user will be reached and tangible results of democratisation will be reflected on numerous "best practices" and paradigms.
- The democratisation will result in growing ecosystems of social collaborative environments, the scale of which will reflect both the degree of democratisation as well as the achievements of addressing the technology challenges as specified for the mid-term time window.

The above situation will allow challenging the long term vision for Grids through the following strategic scenario:

1. Technological advancements validated by the users' communities will take up actions, from the side of the business sector, for deepening the adoption and incorporation of Grid technologies in business activities and inter or intra enterprise activities.
2. Standardisation effort will be significantly leveraged, while the industry will more actively involved towards the production of products and the provision of services that will support the existing ecosystems or will allow the creation of new ones.
3. Democratisation of Grids and maturation of key technologies will allow for supporting of mission critical applications or critical infrastructures with Grid-enabled practices and solutions, with proven usability, reliability and, efficiency.
4. Research efforts will be oriented to encounter the technological challenges related with:
   - Manageability of large scale infrastructures or ecosystems, through the enhancement of technologies that enable autonomic behaviour, self-awareness, governance of service etc.
   - Mechanisms on knowledge gathering, transformation and presentation towards communication based on knowledge
   - Improvement of intelligence of infrastructures and provided services towards cognitive and context aware environments.

The strategic framework as proposed by CHALLENGERS and presented above is based on clearly described and systematic efforts that will allow the research and business communities to tame the

Grid technologies in order to develop and establish novel grid-enabled practices in citizens' every day activities and facilitate the adoption of similar practices from business and enterprises.

## *5.3. Prioritisation of the research challenges*

### 5.3.3. The methodoly

CHALLENGERS introduced the concept of the *Priority Matrix* and Priority Chart as the main tools for prioritizing the research items and key actions for a successful roadmap. This is a simple and effective approach, acting moreover as an immediate visualization tool for most "urgent" and important research topics that need to be tackled by the European research community in the years to come.

The construction of the priority matrix requires the assessment of the momentum and of the evolution potential of the non-functional requirements underlying any Grid-based system.

Figure 3 describes schematically the main analysis path followed by CHALLENGERS experts in order to assess individually the various Non-Functional-Requirements (NFRs) and assign them the appropriate position in the prioritization matrix.

The idea behind it is to assess the "momentum" of the NFRs, where the term momentum is used to signify:

- the compliance of a specific NFR with the state-of-the-art of the set of the technology components it is associated with
- the scope of influence or potential impact on these technology components

Today there is not an official index that can provide information on the "momentum" of these NFRs. For this reason the Challengers consortium had to make this assessment by surveying the status of the NFRs in the various technologies and by estimating their future development. This assessment has been based on the experts' opinion which has been processed and elaborated in a "semi-structured" way. This way required answers to questions like:

- "how many technology components are influenced by a specific NFR?"
- "To what scope this influence occurs?"
- "What quality advancements will any improvements cause?"
- "Is this advancement feasible and reasonable within a future time window?"

These questions made visible the future qualitative advancement in the relative technology, and the feasibility and cost limitations that are associated.
So, the answers to these questions helped to identify the "momentum" of the NFRs, and classify their importance accordingly.

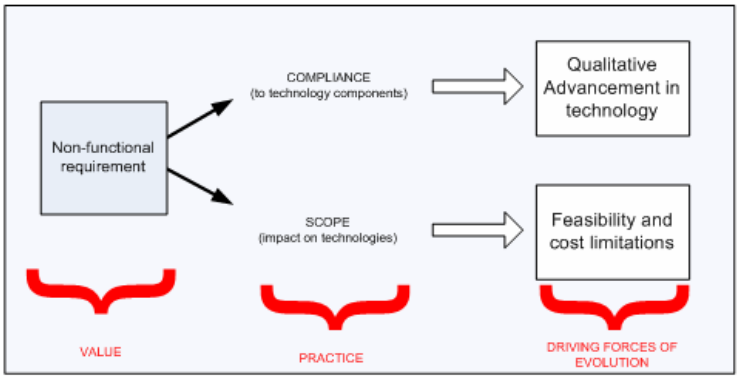


**Figure 3.** Momentum and evolutionary assessment of Non-Functional Requirements of Grid-based systems.

The result of this assessment has as subsequence the derivation of the Priority Matrix and the associated two-dimensional Priority Chart as shown in Figures 4 and 5 respectively, which are outcomes of a well established procedure.

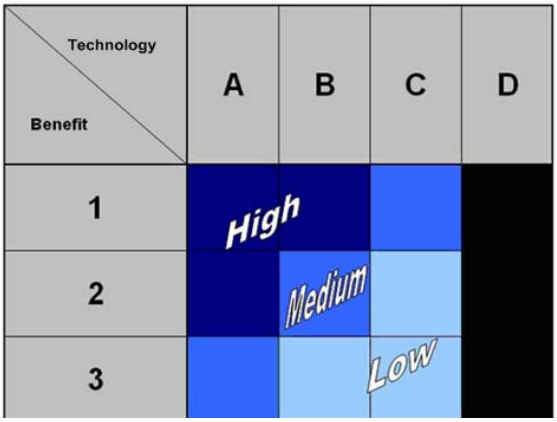


**Figure 4.** The Priority Matrix template.

The "Benefits" corresponding to the rows of the Priority Matrix are the pursued Non-Functional Requirements (NFRs) prioritized in terms of importance, during the assessment procedure described above.

The "Technology" columns of the matrix correspond to the technology components, contributing to the development of improvement of a "Benefit" (NFRs). These columns are also prioritized with regard to their importance in terms future research.

Thus the 'hot' research challenges, as combination of technology components and NFRs, are located in the upper left area of the Priority Matrix leading diagonally to less challenging combinations ending up to the lower right area of the matrix.

Accordingly, the Priority Chart, derived during the same assessment process, depicts the technology components on the following 2-axes system:

- The *horizontal axis* corresponds to the *degree of importance* of the technology components, as identified by the experts, during the assessment.
- The *vertical axis* corresponds to the general performance of a specific technology component at its present status (state-of-the-art). Low performance of an individual component at present is interpreted to high research effort in the future and vice versa. In that case, it is noted that the term 'performance' should not be confused with the non-functional requirement of a system as a whole.

Putting the technology components in the priority chart we arrive to distribute them around the 'priority axis' that runs the chart diagonally, starting from low priority items (or issues) in the lower left area of the chart towards the high priority items, located at the upper right area of the chart.

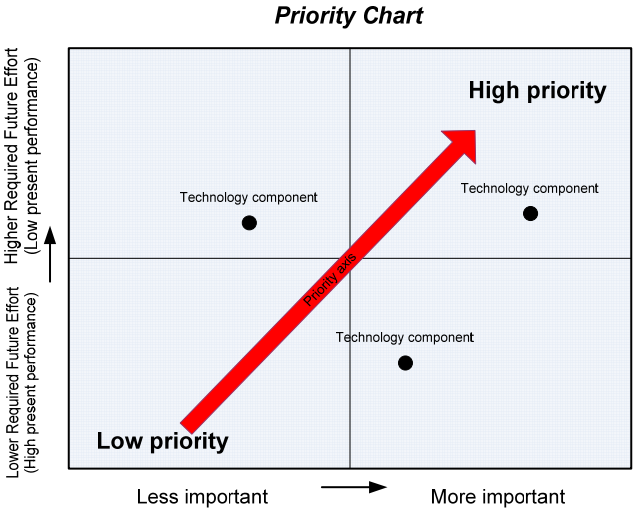


**Figure 5.** The Priority Chart template.

### 5.3.4. The mid-term (5-Years) prioritised challenges

According to the methodology above, the Priority Chart of the 5-year vision for Grids, as described by CHALLENGERS is shown in Figure 6.

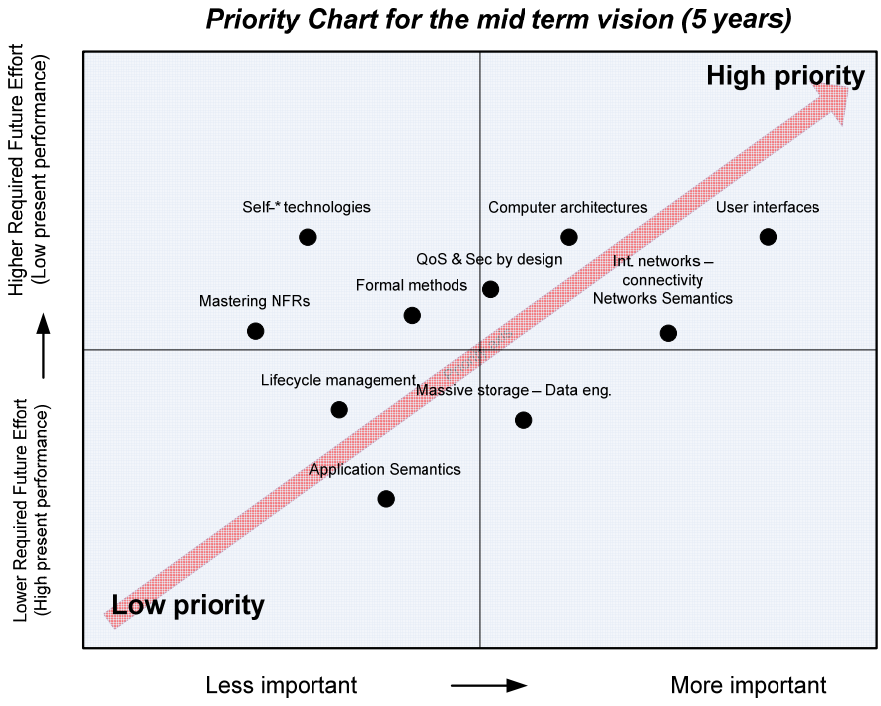


**Figure 6.** The Priority Chart of Technology Components towards the 5-year Grids Vision.

The most prominent issue of the roadmap towards the realization of the vision of the future Grid-based systems is the advancement of **research for usability of services through multi-purpose and multi-modal, intelligent interfaces, so as to "democratize" the usage of these infrastructures and promote them among a wide spectrum of end-user, with emphasis to "customers" and home users**.

The second very important step, is **the improvement of performance and manageability of the core building blocks of ICT (computers /HW and networks) that will definitely form the backbone of the future Grid-based infrastructures**, namely:

- efficient computer architectures
- parallel and distributed computing principles
- intelligent and seamless connectivity

What is needed to be done in the sequel is the ability to allow various features to be tailored to such infrastructures "by design". Especially, **QoS and security features will form the cornerstone for this advancement** since these will distinguish the future ICT infrastructures to current best – effort or best practice ones. Particularly beneficial to that are **Formal methods and Programming models**, especially within the context of **IT Service Management, Delivery and Support**, which will accelerate and enforce the commercial adoption of any visionary Grid-based infrastructure.

### 5.3.5. The long-term (10-15 Years) prioritised challenges

Accordingly the Priority Chart of the 10- 15 year vision for Grids is shown in the following Figure 7.

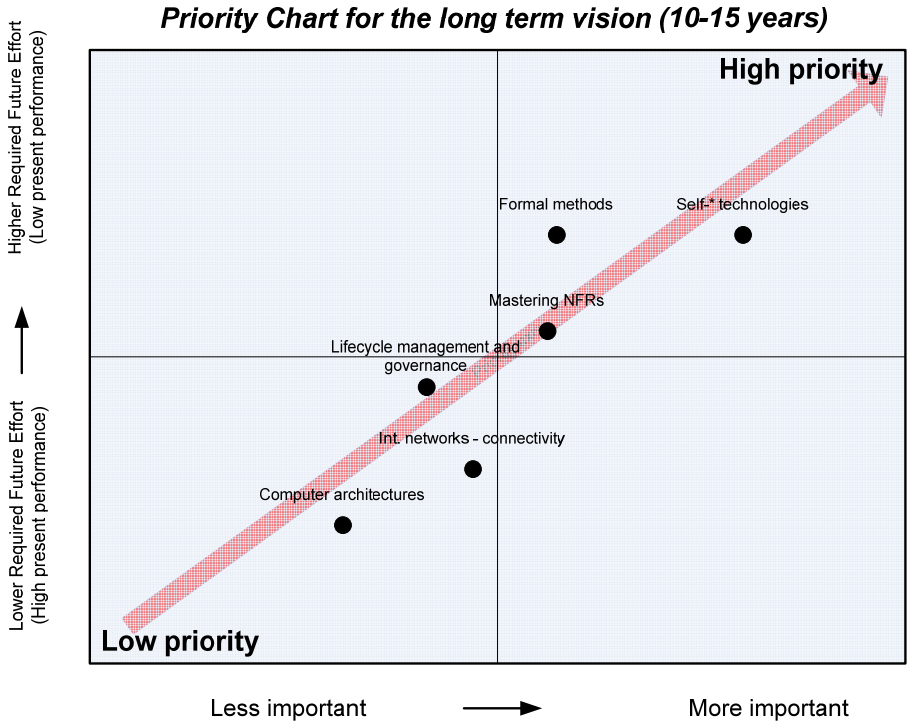


**Figure 7.** The Priority Chart of Technology Components towards the 10-15 years Grids Vision.

The long term vision of the roadmap relies on the fact that the 5–years Grids Vision will be achieved and can provide valuable results. Having this as a starting point it is assessed that the **manageability of large scale** (especially for Consumer or Enterprise) Grids need to **tackle** the managerial **overhead** that these large infrastructures are going to imply. It is going to be beneficial if this is going to be **delegated to automated mechanisms** that are going to enhance the **autonomy of systems** in decision making and adaptation through self-* technologies.

In order to allow **a human oriented communication** in the whole development chain of future infrastructures, **formal methods of modelling and programming** would be required that abstract the design, development and operation of such infrastructures in simple human language and through a small set of intermediate steps so as to avoid any complexity. This will assist the research progress towards the mastering of NFRs in real-time and their convergence despite the heterogeneity in Virtual Organizations and the Service Governance which will be inline with policies, strategies and market trends. Last but not least, are the two basic building blocks of IS namely the computers and the networks who connect them. Research on these technologies is then envisaged to provide at a "stratospheric" level computational capacity, accessibility and all this with 100% reliability.

### *5.4. Consolidating the Vision: architectures for the integration of the physical and digital worlds in every day future life's human activities*

The follow-up task of the roadmapping process of the project, in reference to the revision and consolidation of the described vision, was to investigate the converging ICTs (including Grid-related technologies) as underlying to another, multidisciplinary, convergence process: that of **the integration of the physical and digital worlds in every day life's human activities in the future.**

The revision and update of the CHALLENGERS visionary framework was an attempt to combine the new findings and interdisciplinary trends with the already described context and consider Grids together with additional emerging and forward looking technology trends, as integral parts of a generalised future architecture with the following attributes:

- Will allow participation of composed services as first class objects;

- Will allow participation of data, software, devices and persons either as components within services or as first-class objects;
- Is effective, efficient, resilient, self-*

During the second (and final) iteration of the assessment process it became evident that the *demand for the democratisation*, as the backbone of the **CHALLENGERS vision for Grids *is absolutely valid and applicable* for a number of novel emerging and forward looking ICT that go beyond Grids and that materialise current users' demands and evolving trends**. Specifically, those changing trends where examined in terms of the present status of the demand for services, communication interaction as well as for participation of users into collaborative and social networking communities. There are specific facts indicating the increase of the aforementioned tendencies:

- the dramatic growth in connected devices, in the use of internet-based interaction and of real-time data streams
- the wide adoption of service oriented architectures (SOA) and Web 2.0 technologies (e.g. Blogs, Mashups etc) in social networking and open collaboration activities
- the spectacular increase and use of mobile devices
- the establishment of "everything as a service" (*aaS) concepts

On the other hand the advancements in broadband communication, the convergence between telecommunications and web technologies, including any emerging hardware innovations has led to a corresponding dramatic growth of service usage, observable through the increasing plethora of new services with an analogous explosion in the number of clients, in combination with an explosion in the size of produced or consumed data. CHALLENGERS have observed that explosion in service development and consumption has posed requirements, similar to the requirements pursued for other promising technologies, including the Grids:

- Virtualisation of resources in terms of computational and storage resources as well as bandwidth
- Accessibility anytime, from anywhere preserving required QoS
- Preservation of response to burst loads
- Enhanced mobility and flexibility based on the provision or transferability of service whenever or wherever this is necessary
- Federation and negotiation of services through decentralised management mechanisms

Taking into account the above observations the main drivers of the CHALLENGERS consolidated vision are the following:

i. The visionary context as described by CHALLENGERS, highly reflects technology and application trends not solely related with the future sustainability of Grid technologies, go beyond them tackling motivations and expectations, both in terms of research challenges and in terms of users needs, that drive the evolution of a significant number of currently emerging and forward looking ICT

ii. A holistic examination of the current tendencies in the domain of ICT (including Grids) provides indications that a considerable portion of the evolution today stems from the need to support a user-centric vision, where novel technologies are advancing on paths or seeks breakthroughs to reach wide communities of users. This evolutionary trend takes into account the increasingly growing need of users to form communities of participation, in the form of collaborative or social networks. To this end, today's users take full advantage of any novel technology capabilities of the present digital environments, with this being also an indication that new breakthroughs that will lead to the further improvement, enrichment or sophistication of such digital environments are highly anticipated by the users.

iii. The above mentioned remarks fully support CHALLENGERS' central visionary pillar based on democratisation of novel and emerging ICT: **The process of democratisation not only is visible within a short term future, but it is already put on and happening, pursuing means to:**
   - ✓ **enable and organize mass participation in the future**

- ✓ **allow the management of mixed, large-scale and ad-hoc participation of humans and machines**

***Virtual digital worlds and environments are foreseen as the primary vehicle of this process of democratisation of novel and emerging technologies, while the major research challenges associated with the realisation of this visionary aspect are growing around the "architectures or platforms of participation".***

iv. Within this holistic reassessment and revision of the vision, CHALLENGERS foresee that Grid technologies maintain a position among the future ICT, in the sense that their future advancements can contribute efficient solutions or improved functionalities that satisfy the needs and the expectations related with a user-centric vision.

v. CHALLENGERS adopted an approach to their assessment on Gird technologies that has led to findings, in terms of open issues and future challenges, the majority of which was proven to be existing and valid in any architecture and platform that realises large-scale distributed systems oriented to support the described user-centric vision. Considering this, the future vision and related challenges brings Grids together with a whole spectrum of uprising technologies, such as:
   - the Internet of Things and of Services
   - Cloud infrastructures
   - Technologies of sensors, actuators and displays towards a 3D WEB

vi. The concept of democratisation of technologies, besides from serving the rapid maturation of novel technologies, in a user-centric manner, still supports the long-term vision of CHALLENGERS that leads to:
   - the establishment and growth of large scale distributed platforms, enriched with sensors and actuators suitable to serve the development of mission critical applications
   - new breakthroughs in the various domains of scientific research through the fusion of experiments, measurements and simulations within novel digital collaborative environments
   - the transition to a communication based on 'knowledge and experience'

### *5.5. Consolidating the Roadmap towards the Vision: drawing the critical timeline*

The final step of the process of revision and consolidation of the vision on the evolution of Grids and other forward looking ICT, as described by CHALLENGERS, was the preparation of the timeline in the place of a visualised summarisation for the forecasting of the realisation of the vision within time over a horizon of a decade.

This forecasting timeline was drawn during the second iteration of the assessment process and was an attempt to describe the envisioned evolution within that 10-years time window, in manner that reflects a continuous flow of the maturation of technologies and map all the important interactions between disciplines and applications as they are developed and grow in time.

During the first cycle of the assessment process of the project the envisioned evolution was examined and outlined within two distinct time horizons. Even though these findings were proven extremely useful for the analysis of the associated research challenges, the improvement of the perception of the described foresight that would allow its presentation over time on a continuous basis could not be feasible and complete, before the validation, update and enrichment of the initial findings.

Figure 8 shows the 10-years forecasting timeline of the vision for the advancement of Grids and other emerging ICT, expressed in terms of anticipated progress and the development of specific services and applications. Three main streams of evolution are envisioned according to the description of the previous paragraph:

i. The democratisation process of Grids and novel ICT

ii. The evolution of scientific experimentation and simulation as a result of the development of sensor networks, linked and managed with large scale distributed Grid-based platforms and of the Internet of Things
iii. The development of large scale infrastructures to support mission critical applications in significant business or administrative domains (e.g. health sector, critical infrastructures, disaster handling etc)

In forecasting diagram of Figure 8, the Non-Functional Requirements were selected as the drivers of the technology vision and their push within time becomes significant in specific moments within the forecasting.

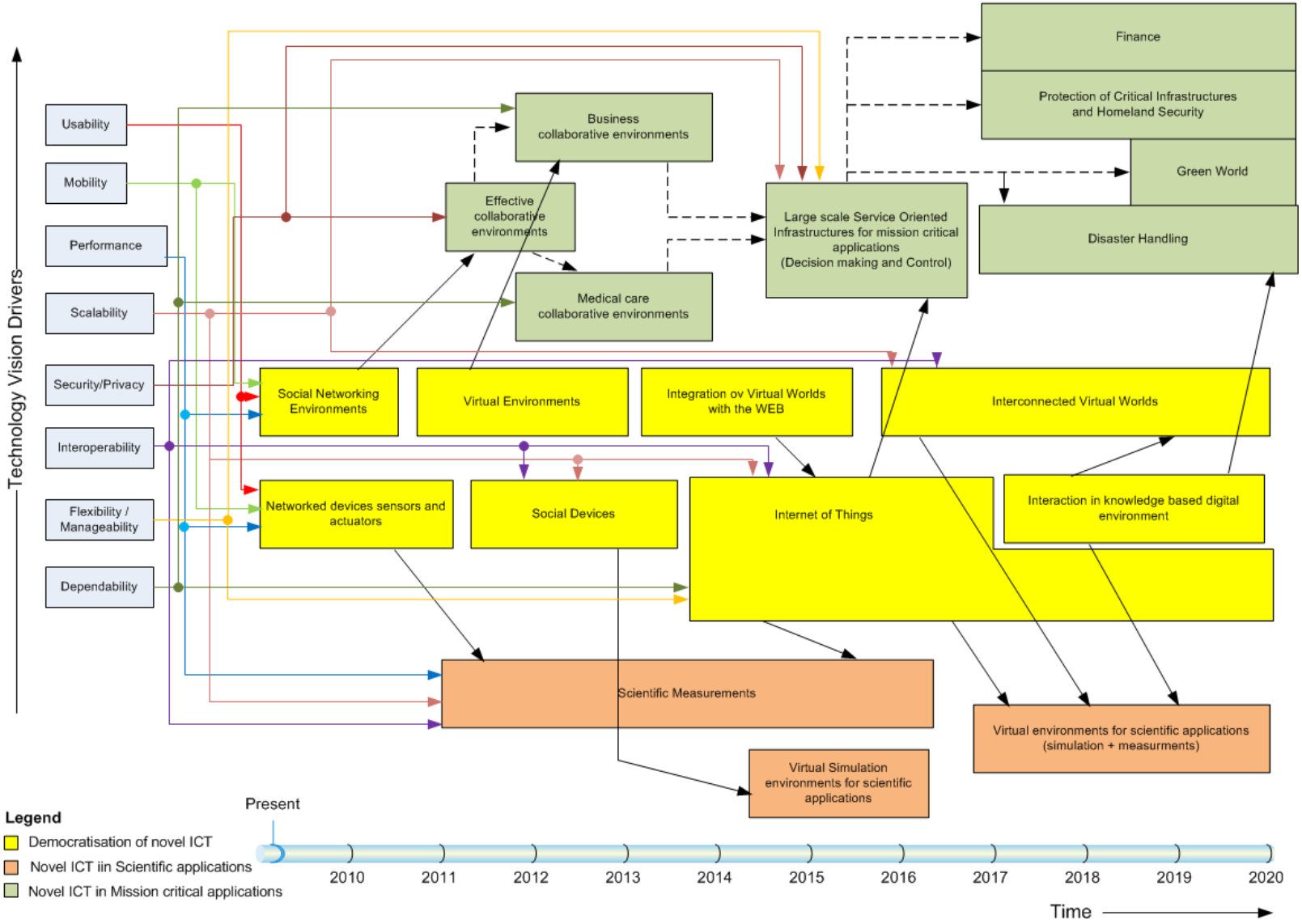


**Figure 8.** The Forecasting Timeline for the CHALLENGERS' consolidated evolution of Grids and other emerging ICT.

## 6. Additional Information

The major consolidated results at the end of the CHALLENGERS project and the assessment process are presented in three key-documents, namely:

- **The Final CHALLENGERS Research Agenda and Roadmap on the technology challenges towards the European Vision for Grids and Forward Looking ICT in the coming decade.** This public document is related with the assessment performed by CHALLENGERS at the technology level and is considered as Annex I of the present Public Activity Report.
- **The Final Assessment on the socioeconomic impact of Grids in Business and Life Improvement Foresight.** This public document is related with the assessment performed by CHALLENGERS at the level of business and life improvement foresight and is considered as Annex II of the present Public Activity Report.
- **The consolidated CHALLENGERS report on standardisation issues.** This public document is related with the assessment performed by CHALLENGERS at the level of standardization issues and is considered as Annex III of the present Public Activity Report.

All the three above mentioned key-documents are publicly available, accessed and downloaded from the project's web-site (www.challengers-org.eu), along with the series of all the public reports of the CHALLENGERS following assessment workshops:

[1]. Public Report of the 1st CHALLENGERS Workshop on Interactions of the European with International Grid Communities, Pisa, Italy, 11-12 October 2006.

[2]. Public Report of the 1st CHALLENGERS Workshop on Core and Forward Looking Technologies, Paris, France, 10-11 January 2007.

[3]. Public Report of the 1st CHALLENGERS Workshop on Grids in Business and Life Improvement Foresight, Barcelona, Spain, 24-25 May 2007

[4]. Public Report of the 1st CHALLENGERS Workshop on Research Challenges and Visions, Athens, Greece, 11-12 October 2007.

[5]. Public Report of the CHALLENGERS International Workshop on the standards roadmap to international grid interoperability by 2020, Oxford, UK, 13-14 December 2008.

[6]. of the 2nd CHALLENGERS Workshop on Core and Forward Looking Technologies, Stuttgart, 21-22 February 2008.

[7]. Public Report of the 2nd CHALLENGERS Workshop on Business and Life Improvement Foresight, Barcelona, 11-12 June 2008.

[8]. Public Report of the 2nd CHALLENGERS Workshop on Research Challenges and Visions, Barcelona, 13 June 2008.

## 7. Involvement of Experts, Promotion and Awareness

CHALLENGERS comprise a Core Group of experts who collectively act as a think tank providing, through the assessment performed within the project's activities, consultation services to the ERA and the Business Communities as well as the EC policy instruments, in order contribute towards Europe's addressing major technological, economic and societal challenges and to stimulate more effective and efficient RTD.

The group aims to increase awareness of the next decade vision for Grids among researchers of different but complementary or converging disciplines. The ultimate goal is to "inspire" the stakeholders, organizations, researchers, SME and users in general for working towards the direction of developing interoperable and less complex Grid systems and architectures. The interacting components in such Grid based environments will be proposed in a way that will empower cost-effectiveness for the future business aspects and allowing for the emerging concept of "anywhere, anytime and by anything" mode.

The fact that the majority of the CHALLENGERS Core Group have been members of the Next Generation Grids (NGG) Group in the past, as well as the prior or present close collaboration between them within the framework of research activities and projects ensure the maximum

coherency of the think tank. Moreover the extension of the Core Group with the participation of additional high profile experts with complementary and interdisciplinary expertise in the assessment process ensures that the project outcomes reflect a widely shared vision among the European Grid academic and industrial community.

From the organisational point of view, CHALLENGERS SSA comprises the following contractors:

1. Institute of Communication and Computer Systems (ICCS/NTUA)- Coordinator (GREECE)
2. ATOS Origin (SPAIN)
3. Science and Technology Facilities Council (STFC – UK)

Apart from the main contractors, the main work of the project is highly based on the Core Group of experts, comprising 10 persons, coming from research and academic institutions as well as from business enterprises form the ICT domain. The members of the CHALLENGERS core group are high-level experts with long experience and deep expertise in the domain of Grids and ICT and are listed in the following table.

The Members of the CHALLENGERS Core Group of experts.

| Expert's Name | Organization | Country of Origin |
|---|---|---|
| Dora Varvarigou | ICCS/NTUA | Greece |
| Santi Ristol | ATOS Origin | Spain |
| Keith Jeffery | STFC (ex CCLRC) | UK |
| Colin Upstill | IT Innovation | UK |
| Stefan Wesner | HLRS | Germany |
| Michel Riguidel | ENST | France |
| Domenico Laforenza | ISTI/CNR | Italy |
| Jarek Nabrzyski | PSNC | Poland |
| John Barr | Group451 | UK |
| Theo Dimitrakos | BT | UK |

In order to increase the visibility and dissemination of its results, soon after reaching the milestone of the release of the initial Research Agenda and Roadmap, CHALLENGERS have broaden and intensified their collaboration and dissemination activity through their participation in a number of events. This collaboration activity is relative with:

- Contribution to the consultation work performed through workshops of similar projects (e.g. 3S project)
- Presentation of the project's visionary positions and recommendations in events of the European Commission (e.g. EC Info Days etc)
- Close collaboration with similar Roadmapping projects, such as the 3S, for taking up coordinated and concrete actions on better dissemination
- Dissemination of the CHALLENGERS up to date results in other projects' events (e.g. EchoGrid, Fassbinder etc)

## 8. Intentions for use and impact

CHALLENGERS is a Specific Support Action Project with a primary mission to describe a clear and justified vision as well as an associated Research Agenda and Roadmap on the future of Grid technologies for the coming decade. CHALLENGERS' outcome is offered as consultation service mainly to the policy making European institutions, with the European Commission in the centre, but moreover to the European Research and Business Communities activated in the domain of ICT.

The application and progress monitoring of the results of the project's assessment goes beyond the scope of CHALLENGERS work and the project's lifetime. CHALLENGERS are absolutely responsible to deploy their methodology in order to clearly describe their position and support this position with a

concrete technical justification, and will seek ways to disseminate and spread the outcome of this consultation endeavour in order to contribute to the acceptance and realisation of the described visionary evolution. Nevertheless, this realisation is a possibility, which might be the result of a complicated process with numerous not foreseen and interacting factors and trends, outside CHALLENGERS, in relation with:

- Advancements in the ICT domain
- Market, business and commercial trends and choices
- Users' habits and trends on the use of ICT artefacts
- Policy issues
- Consensus of the communities involved into the realisation of the future vision and evolution

The technology evolution process is highly dynamic and thus hard to predict up to a point. However, CHALLENGERS share the responsibility of the realisation of the Grids vision both with the European research and business communities as well as with the policy making institutions (e.g. the EC) as far as two of the above aspects are concerned. CHALLENGERS Project focused on:

- Describing in a clear and fully justified manner its position taking into account all the known technology, business and socioeconomic parameters involved
- Pursuing the contribution and the consent of as many experts as possible on the outcome of its assessment work. The formulation of a visionary position based on the wide approval of the research and the business communities will be the first and very decisive step of ensuring the validity and the value of this position.
- Disseminating, spreading and defending its findings across Europe and across communities. This will result in an additional boost towards the formulation of a common understanding and consensus among the key players and stakeholders of Grids technology.
- Seeking ways to continue the iterations of its assessment process in order to update the finding according to dynamic changes in the technological landscape and the new business or users' trends.

The last point of action presumes a minimum level of acceptance of CHALLENGERS positions both from the side of the research and business communities, as well as from the side of the policy makers. Besides that the project's consortium and the members of the Core Group have already invested significant effort on the three other actions, and will continue doing so until the end of the project, aiming to maximise the soundness and the impact of the CHALLENGERS results.

## 9. Dissemination and use

Within the present section is provided the title and a short description of the major consolidated public reports of the CHALLENGERS SSA that are worthy to worthy accessed and studied by any interested party or member of the European Research and Business Community, but also members of policy making organisations on technology issues as well as policy makers.

The consolidated public reports briefly presented and described here are distinguished between:

- The consolidated public reports, as result of the assessment workshops of the project in the areas of technology, business and standardisation
- The major extended consultation documents on the three abovementioned areas produced during the project as a result of an exhausting processing of the outcomes of the assessment events

All the documents and reports mentioned in this section are available and downloadable in .pdf format through the project's public site (www.challengers-org.eu) from the menu "Reports and Documents" (http://challengers-org.eu/index.php/ Reports-and-Documents/)

## *9.1. Consolidated Reports and Key Documents in the Technology Area*

### 9.1.1. 1st Public Report on Core and Forward Looking Technologies

The specific report is the outcome of the 1st CHALLENGERS Workshop on Core and Forward Looking Technologies that took place in Paris, France in January 2007. A chart of the current landscape of enabling technologies for Service Oriented Knowledge Utility (SOKU), Grid-enabled Service Infrastructures, Service Oriented Architectures (SOA) and Next Generation Grids is provided. The report contains a revised and broadly agreed hierarchy of these enabling technologies, an assessment of their current maturity and their prospects for further improvement, an enhanced understanding of their interdependencies, and a deeper view of their intrinsic value and of any extrinsic motivations and barriers influencing their evolution. Emphasis is placed entirely on the level of how these enabling technologies support the Grid and what the Grid requires of them, of their interrelations, and of the value they offer to their environment and how this environment may motivate or impede them – and our work will *not* concentrate on technical details of each individual technology.

### 9.1.2. 2nd Public Report on Research Challenges and Visions

The specific report is the outcome of the 2nd CHALLENGERS Workshop on Research Challenges and Visions that took place in Barcelona, Spain in June 2008. The mission of the specific consultation workshop was to investigate the converging ICTs (including Grid-related technologies) as underlying to another, multidisciplinary, convergence process: that of the integration of the physical and digital worlds in every day life's human activities in the future. Within this context, the main goal of the Barcelona technology workshop was to identify and show up all the challenges related to the attempt of tackling disciplines beyond ICT and way into the future. Four topics were selected as the focus point of the assessment discussions in Barcelona: (i) Virtual Worlds; (ii) Sensors, actuators and displays in the Future Internet of 'Things' (thing-to-thing communication); (iii) Embedding users' human behavior into the digital environments of the future (person-to-thing and thing-to-person communication) and (iv) ICT for a Green World.

### 9.1.3. Final CHALLENGERS Research Agenda and Roadmap for the European Vision for Grids of the coming decade

CHALLENGERS Project has recognised at its very beginning the necessity to widen its scope of assessment beyond Grids, due to the recognition of the fact that the framework of converging ICTs is the cornerstone of the trends and vision of future applications and services. This is the main reason why CHALLENGERS has chosen to adopt a demanding, deep and holistic approach for the description of the technology vision and the associated research challenges for the coming decade. In fact this strategic choice is the one of the main components of the "Against the mainstream" motto characterising the CHALLENGERS' effort and it importance as a choice becomes even more obvious and useful under the present conditions of economic recession, which is an additional barrier to the smooth development of all the forward looking technologies. Under those circumstances the need for identifying visionary but also efficient and feasible means to leverage the limited human and financial resources of the Community becomes even more imperative.

Since technology roadmapping is a continuous and iterative process that fits within the broader European strategic technology planning and business development context, CHALLENGERS have completed two iterations of their assessment work performed within their lifetime. The release of the Final Research Agenda and Roadmap for the European Vision for Grids (and novel ICT) for the coming decade was the outcome of the second iteration of the project, which has refined the roadmapping process through the following steps:

- Review, update, extend and consolidate the primary dimensions of the vision described during the first iteration in order to ensure that it exists and moreover it incorporates any new emerging trends.
- Focus on the forecasting of the finally resulted vision through the provision of a roadmap for its evolution, combined with the simultaneous forecasting on the development of emerging and forward looking technologies. The roadmap is based on timelines showing where the identified technology drivers reach their targets through the elaboration of specific technology components or aspects of these components within the time window of the coming decade.

The document concludes with the graphical representations of (i) the forecasting timeline for this final consolidated vision and (ii) the timelines of the evolution of the technology challenges for each one of the three main evolutionary dimensions.

## *9.2. Consolidated Reports and Key Documents in the Business Area*

### 9.2.1. 1st Public Report on Grids in Business and Life Improvement Foresisght

The specific report is the outcome of the 1st CHALLENGERS Workshop on Business and Life Improvement Foresight that took place in Barcelona, Spain in May 2007. The report provides an up-to-date assessment on the relation of Grids and ICT in general with the business sectors and paves the wave of aspects of the specific issues that need to be studied in further in depth.

The report describes the Strengths, Opportunities, Problems and Threats towards the adoption of Grids, as recognised by the experts participated in the Workshop:

- Strengths: Focus on the inherent strengths of Grid as a platform, both today and in the future.
- Problems: Focus on the problems in the Grid computing space today, as seen from an infrastructure perspective.
- Opportunities: For both Grid as a platform as well as for the services that run on it.
- Threats: From the perspective of both the platform and the services hosted on it.

All the above mentioned observations are summarised in the corresponding SPOT matrix.

### 9.2.2. 2nd Public Report on Grids in Business and Life Improvement Foresight

The specific report is the outcome of the 2nd CHALLENGERS Workshop on Business and Life Improvement Foresight that took place in Barcelona, Spain in June 2008. The scope and objectives of the event were built on top of the existing SPOT matrix (Strengths, Problems, Opportunities and Threads) elaborated previously. The final goal, as described in this report was the elaboration and preparation of a global roadmap with recommendations on: i) opportunities to pursue ii) strengths to ensure iii) problems to solve and iv) threats to mitigate, with regard to the application of Grid-based technologies in business and life improvement foresight.

Moreover this report continues work started before the emergence of the current cloud computing era, which aimed to identify the challenges to increased adoption of Grid technologies by business. Thus, in addition to focusing on how the problems previously identified can be overcome, this report incorporates the effects of the tumultuous changes to the environment caused by the swift uptake of the cloud metaphor.

#### 9.2.3. Final Report on the Impact of Grids in Business and Life Improvement

The document presents, the impact of Grids in today's business, scientific and social activities is presented. Specifically, that section refers to the adoption of Grids in particular sectors of business and social life, while some successful business cases resulted from the adoption of Grids are also described.

The report also describes the recent emergence of cloud computing and what effect this has had on the Grid computing sector. A brief presentation of previous and current efforts follows in order to introduce Grid-based services in areas relative with life improvement, namely medicine, scientific, finance etc.

The SPOT matrix with a summarisation of the principal strengths, problems, opportunities and weaknesses, as identified by CHALLENGERS is presented and a SPOT for the Grid in light of the cloud advent is introduced

Finally, the report provides a presentation of the existing and new technology providers on Grid solutions, as well as with their market position in terms of the products they offer.

### *9.3. Consolidated Reports and Key Documents in the Standardisation Area*

#### 9.3.1. Public Report on Standards Roadmap to International Grid Interoperability by 2020

The specific report is the outcome of the CHALLENGERS International Workshop on the Standards Roadmap to International Grid Interoperability by 2020 that took place in Oxford, UK in December 2007. The report describes a roadmap for the standards required for Grid technologies to move from the current position to achieve interoperable inter-enterprise grids and comprises the distilled results of the assessment discussions with regard to the following four issues:

- the global grid vision for 2020
- the standards roadmap from present until 2012
- the roadmap from 2013 to 2016
- the roadmap from 2017 to 2020

The goal of the specific report is to provide guidance to the EU and the ICT research community in planning future work programmes, and future research proposals.

#### 9.3.2. CHALLENGERS' Report on Standardisation Effort

The CHALLENGERS project has developed a roadmap for the future of Grid computing from three perspectives: technical, business and international/standardisation. The development process has included consulting widely with experts as individuals and through workshops. This document reflects on the research agenda and roadmap produced from the perspective of the standardisation issues. Funding bodies, researchers, and product champions need to be aware of the role of standards as a tool to drive the technology lifecycle.

During 2008 the term "grid" has died as a marketing term in favour of "cloud", but the technologies which have been developed to meet the vision of collaborative inter-enterprise computing that it conveyed continue – service oriented architecture (SOA), service composition, virtualisation, policy based management using contracts and SLA, distributed authentication, authorisation and accounting systems (AAA) etc… The research challenges highlightened for grids by the Challengers research agenda and roadmap associated with the non-functional requirements of describing services for composition, managing services, security, and usability remain as challenges. Along with

the changes to technology and marketing have come both progress in standardising individual technologies, and clarity to the standardisation environment for these technologies.

The standards roadmap introduced by CHALLENGERS project lags behind the technology roadmap in addressing the identified research challenges as would be expected of a dependent activity. Standardisation is consensual activity, so it is also more conservative than technology foresight. Therefore the SOKU vision at the end of the CHALLENGERS' technology vision is understandably a little too radical to occur in the standards roadmap for global interoperability, although all the dependent technologies it requires are present, most evidently those relating to detailed semantic description of service quality, contracts, service level agreements, policy based management, authentication, authorisation, accounting, security, and usability across the whole process of composed services from end to end.

## 10. Contact and Further Information

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