Enterprise Interoperability
Research Roadmap

Update
(Version 5.0)

FINAL

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1. INTRODUCTION

1.1 Background

Today an enterprise's competitiveness is to a large extent determined by its ability to seamlessly interoperate with others. The advantage of one enterprise over another stems from the way it manages its process of innovation. Enterprise Interoperability (EI) has therefore become an important area of research to ensure the competitiveness and growth of European enterprises.

The Enterprise Interoperability Research Roadmap (EIRR), first published in 2006 under version 4.0, has proven to be an important document in describing the state-of-the-art of the Enterprise Interoperability sector, and also in guiding future directions of research in the field. While the document is still valid to a large extent, it is important that some key aspects of it are addressed in this update.

2008 will be an important year for EI research: The transition of FP6 to FP7 is taking place, with a number of FP7 projects beginning their research this year. Similarly, the second work programme (2009-2010) of FP7 will be drafted; significantly setting the direction of EC funded research in ICT. The EIRR will serve as a major input to that document, therefore it is important that it can accurately capture the current state-of-the-art and furthermore, set out refined and updated directions for EI research, so that these can be reflected by EC funded research over the next few years.

1.2 Objectives

Research has significantly advanced the field of EI in a number of areas over the past few years. This document's purpose is to account for these developments, and to interpret their impact in order to realign or fine-tune our long-term research goals in EI.

At the same time, this roadmap update can be used as a means to help maintain our past approach of integrating results from neighbouring domains, such as content and knowledge, software and services architectures and infrastructures or social sciences, and giving them meaning for our sector, to avoid duplication of work and research activities.

1.3 A Brief History of the Roadmap

Version	Description	Date
1.0	First public version by six research projects (ATHENA, CrossWork, ECOLEAD INTEROP, NO-REST and TrustCoM	21-12-2005
2.0	Second public version by interested stakeholders, focussing on the Vision and Grand Challenges	15-03-2006
3.0	Third public version by interested stakeholders; complete draft final version	05-06-2006

4.0	First public version	31-07-2006
4.1	First draft version of the status update and progress report, focussing on the Problem Space and Grand Challenges, edited by GENESIS project and EC staff	07-02-2007
5.0	First public version of the status update and progress report, focussing on the Problem Space and Grand Challenges	05-03-08

1.4 Methodology and Structure of the Update

This update to the EIRR is based on contributions from interested stakeholders, and especially input by the members of the EI cluster. The initial call for contributions was announced at the EI cluster meeting in The Hague on October 26, 2007, and over 25 contributions from stakeholders were received by November 31, 2007. A subsequent stakeholder meeting and discussions via an online forum cumulated in a first draft, released on February 05, 2008. A final round of comments and contributions based on the draft were then used to finalise the document, released on March 5, 2008.

Rather than replacing the core text, this document should be considered a preface to version 4.0, namely a progress report 18 months after the publication of 4.0. Additionally, Annex 1 of version 4.0 has been updated to reflect the completion of some research challenges and the creation of new ones.

The GENESIS project took responsibility for compiling all contributions into the updates on the grand challenges, while the supervision of the process and the update on the other sections remained with the EC in order to maintain a maximum of transparency.

2. THE STATE OF THE ART – 2008

2.1 Key Developments since v4.0

This section refers directly to the state of the art section in version 4.0 of the EIRR as we believe it still offers a reliable overview of the state of the art in EI research. However, the past two years have witnessed significant advances in the domain, so it is important to especially highlight the impact of FP6 projects in creating those changes and describe some of its consequences for future orientations.

Since the publication of the EIRR in June 2006, the ICT for the Networked Enterprise & Radio Frequency Identification unit managed over 8 projects in the EI domain, with a responsibility for approximately 36 Million Euro. The portfolio included 3 large projects (ATHENA, INTEROP and TRUSTCOM) which gives an indication of the importance of the shift from small projects in FP5 (mainly technology take-up measures) to larger RTD projects with ambitious and clearly defined objectives for the domain, capable of mobilising a 'critical mass of resources'. Additionally, the trend towards these larger Integrated Projects (IP) was confirmed by the mobilisation and cohesion of the community and hence, the potential structuring of the research area.

Over the last two years, the ICT for the Networked Enterprise & Radio Frequency Identification unit was involved in two calls. The first – and largest – was FP6 Call 5 through the Strategic Objective 'ICT for Networked Businesses', which concluded with the adoption of three new projects in EI. The second was the first call of FP7, from which five projects were selected and negotiated. The strategic positioning of these new projects along the Grand Challenges defined in the first EIRR clearly confirms their adherence to the vision defined in the document, with a specific focus on the first Grand Challenge called Interoperability Service Utility. It is worth mentioning that two formerly separated domains, i.e. Enterprise Interoperability and Enterprise Collaboration are now collectively taken as a system perspective for fostering convergence between these two research streams, as well as research issues in digital business ecosystem and semantic technologies.

This section gives a concise overview of the core elements addressed by the above research projects in the EI domain. Clearly most of these projects address more than one single target outcome of our Enterprise Networking Objective 1.3 under FP7 Call 1. Furthermore, large projects such as ATHENA (IP) and INTEROP (Network of Excellence) have delivered new knowledge and competitive advantage to the European industry by serving both research and community building objectives.

In 2006, the EIRR was targeting break-through research for stimulating and catalysing business innovation. It became a major reference document for European research in our domain by establishing EI as a *capability* for the purpose of business and not only as an ability of entities to work together. The definition of EI was not anymore restricted to the 'integration' problem encountered by enterprises, but would significantly offer a new, radical approach to the EI as a vehicle for innovation requiring new services, new approaches and new frameworks to be developed.

The Informal Study Group report on Value Proposition for Enterprise Interoperability (VPEI)[1] advocates that “disruptive innovation at the enterprise level needs to be matched by disruptive innovation for enterprise systems of the future”. Moreover, “value is delivered at the level of the system, not components or elements of such a system”. This report gives a description of the properties of “openness” for enterprise systems and makes a distinction between universal interoperability and conditional interoperability. It further suggests that “the systemic view of ICT for enterprises is a central characteristic of EI, and distinguishes EI from other fields of ICT research which have a predominantly technology-driven approach”. It is highly likely that the Future Internet will give rise to "new opportunities of creativity and innovation, enable new forms of participation, and further catalyse the formation of networked enterprises and communities that span the world, thereby ushering in a new generation of enterprise systems requiring a reappraisal of interoperability between those systems”.

In the past, we used to say that EI was not achieved until the interaction could take place at the three layers of interoperability (technical, semantic and organisational); today, we can

1 "Unleashing the Potential of the European Knowledge Economy", Informal Study Group on Value Proposition for Enterprise Interoperability Report, An Enterprise Interoperability community document, 69 pg. Edited by Man-Sze Li, IC Focus, Servane Crave, Orange / France Telecom, Antonio Grilo, Universidade Nova de Lisboa, Roelof van den Berg, Erasmus Research Institute of Management. Work coordinated by the Enterprise Interoperability Cluster of the Information Society and Media Directorate-General, European Commission, 2008

declare that EI will not be fully achieved until we reap the benefits brought by the new technology paradigms, including the paradigms for the Future Internet.

In the last two years, and from a technical view point only, our research projects addressed many different areas of the EI domain like: Service Oriented Architectures for interoperability (both industry and SME-driven), collaboration methods and tools, business and industrial strategies for EI, design and execution of interoperable services, interoperability in product design and manufacturing engineering, architectures and frameworks for Systems (intra- and inter-enterprise) Interoperability, approaches and solutions for model-driven interoperability, Enterprise Application Interoperability Modelling tools and approaches, Semantic Services and Ontology Frameworks, etc. An updated list of the Indicative Research Challenges is available in Annex 1.

As well as technological research, new business models and innovation scenarios were also targeted, some of them based on the underlying principles and design patterns of the Web 2.0 trend (the more noticeable model currently developed being the new 'Software as a Service' approach combined with the concept of interoperability as a utility-like capability, like in the new FP7 COIN IP project).

Looking at the structuring of the research domain, our community has achieved knowledge integration through the merging of three disciplinary components to found EI as a new research domain. The original three areas of IDEAS were Enterprise Modelling, Ontology, and Architectures and Platforms (which formed the S&T basis of ATHENA and INTEROP). ATHENA then refined this in the course of the project into the so-called “ATHENA Railroad”. Discussions related to creating the EIRR led to establishing those main areas as reflected in the Chapter titles of Chapter 4 – 8 of Annex I (V4). Furthermore, a number of initiatives were established to complement and support market-driven interoperability adoption such as the Interop-VLAB which will furthermore stimulate the scientific activity on the European level and beyond. The iVLAB moreover acts as a reference in the EI domain, and is consulted by international bodies (e.g. IMS organisation, IFIP.) This will be further enhanced through the creation of the IEKR (Interoperability Explicit Knowledge Repository), soon hosting all the deliverables of EI Cluster projects. Another initiative worth mentioning is the Enterprise Interoperability Center, a major deliverable of the ATHENA project, and a platform to define and apply integration methodology and tools leveraging existing standards where possible to define common public business processes for achieving interoperability of networked organisations across multiple industries. Last but not least, a European Master Programme in EI has been set-up by the INTEROP partners.

It goes without saying that the domain also benefits from the important achievements obtained by neighbouring domains such as: future networks, content and knowledge, interaction and interfaces, software and services architectures and infrastructures, etc. Some of the work listed above is still ongoing, but we can already say that the results obtained by the community of projects under FP6, mostly based on the directions developed in the EIRR, are the cornerstones of the future EU funded Research in the area of Enterprise Interoperability.

2.2 Updated Problem Space

The progress of FP6 and FP7 projects has been – and still is – constantly updating the definition of problems in the Enterprise Interoperability domain.

As we stressed the importance of value innovation for enterprises, and the fact that the mechanism and the nature of innovation are changing, it becomes critical to strive for innovation of IT systems that enable, support, and catalyse the innovation process of enterprises in times of profound and accelerating change. Disruptive innovation at the enterprise level needs to be matched by disruptive innovation for enterprise systems of the future. This is because value is delivered at the level of the system, and not by components or elements of such an (enterprise) system. The updated four Grand Challenges of the EIRR underline this systemic view of ICT for enterprises, which is intrinsically different from the technology-driven approach of other areas of ICT research. The question therefore becomes: what innovation is needed for EI research to support future enterprise systems?

The ISU challenge is very relevant; it must be studied with attention and in particular the distinction between the “base/generic” services and the “value added” services should be addressed, also with the implications in terms of value creation model for enterprises of any size.

A number of researchers commented, based on the experience and outcome of previous and current projects, that further analysis of the implications of blending Enterprise Interoperability with Enterprise Collaboration is needed. This is indeed an important issue, which will be studied by the FP7 COIN project, and which is targeted by the Knowledge Oriented Collaboration Grand Challenge, with a special focus towards the business initiation and formation process steps.

3. VISION

A vision describes long-term strategy and targets. By its very nature, our vision for EI – as presented in version 4.0 of this research roadmap – still captures our view of the field two years later today. Nevertheless, in light of this cluster's achievements over the time elapsed, parts of the vision can be fine-tuned to reflect recent developments.

When discussing our vision for the future of interoperability research, it is vital that we bear our core *clientele* in mind. As stated in the i2010 communication, a key goal of our research is to support new patterns of business that enhance innovation in enterprises and adaptation to new skill needs.[2] European enterprises will have to remain the principal benefactors from our research.

The rapidity of managing innovation and creating ecosystems to cater for short-term, short-notice collaboration has become increasingly important, thus changing the requirements of interoperable solutions. Enterprises of the future will be nodes in innovation ecosystems, thereby requiring 'interoperability to become interoperable', to allow the creation of large-scale ecosystems and to avoid forming islands of ontologies in different business domains and application scenarios. The increasing complexity that comes with flexible collaboration

[2] i2010 Communication COM(2005) 229

requires mechanisms to be established, capable of supporting spontaneous collaboration activities. The ability to apply existing core enterprise knowledge in new products or projects by combining the knowledge bases of many enterprises is another path to success but requires further research and take-up measures. Enterprises in Europe should build on their strong position in this area and take a lead in these developments.

The vision statement articulated in the EIRR describes interoperability as a "utility-like capability that enterprises can invoke on the fly in support of their business activities", with specific IT functions being delivered as services that are cheap, fast, reliable, and without major integration efforts. The overall aim is to make IT become "a transparent and invisible part of the business operation". An infrastructure is required to make this happen, which is labelled the Interoperability Service Utility (ISU), constituting the first Grand Challenge of the Roadmap.

From the point of view of future EI offerings, an infrastructure of EI utility services must be in place, in order to support next-generation EI value added services that meet the characteristics of future enterprise systems. Using the idiom of Enterprise 2.0, a utility infrastructure for EI is needed to facilitate two major outcomes: participatory input based on co-creation and innovative output based on the unique nature of individual enterprises.

These developments will also influence our way of thinking about interoperability: In order to meet the needs of future enterprise systems, traditionally proprietary offerings might usefully be re-categorised as utility offerings, commoditised and affordable to all. Interoperability should become a utility-like capability that enterprises can invoke on the fly in support of their business activities.

Finally, creating a science base for interoperability remains a key issue to be addressed by research over the following years. We see the scientific approach to be a significant step to help us focus on technology independent research, and thus make real progress rather than spend time and resources on legacy integration and unnecessary duplication of work. The systemic view of ICT for enterprises is a central characteristic of EI, and distinguishes EI from other fields of ICT research which have an over-riding technology-driven approach. In fact, various projects in FP5 and FP6 successfully addressed the question of legacy integration. Our research now has to move beyond this and focus on new issues, both to justify public funding of that research and to ensure that we maintain the edge of forward-looking research.

4. GRAND CHALLENGES REVISITED

In the present version, the notions of Grand Challenges and Research Challenges, introduced in the previous versions of the roadmap, have been sustained. The same has happened with the number of identified Grand Challenges, as representing four global domains of research for reaching the overall vision. However, both the progress of the state of the art, and the evolution of new ideas have been used as drivers for change. Thus, the scope of some Grand Challenges had to include those new developments or even include new research ideas, resulting in the following:

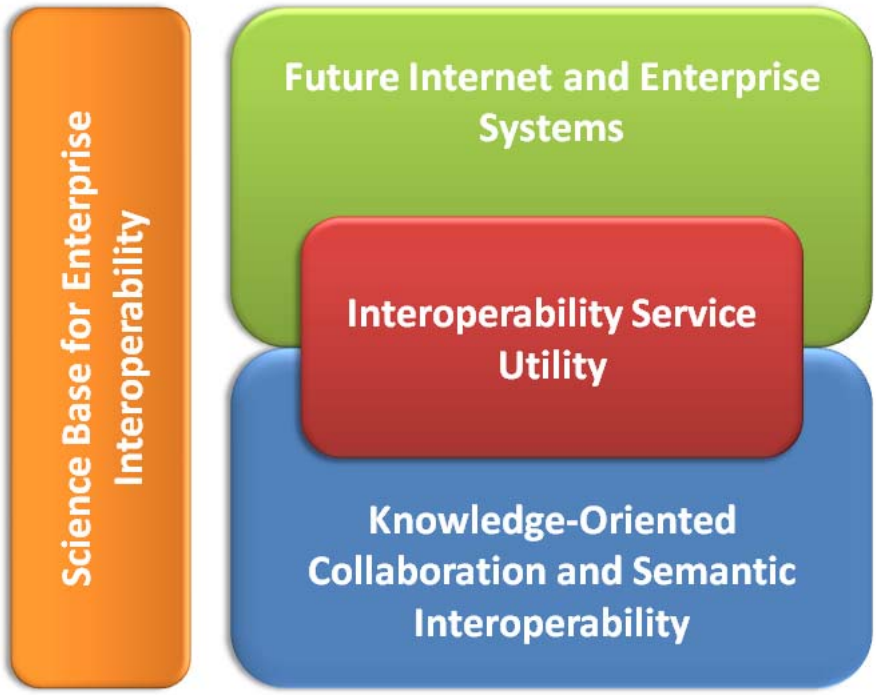
GC1: Interoperability Service Utility. This Grand Challenge further extends the previous version, in the direction of focusing on the key services needed by the industry, including SME-specific needs and preconditions.

GC2: Future Internet and Enterprise Systems. Extending the previous GC2 (Web Technologies for Enterprise Interoperability), this Grand Challenge sets the additional target of utilising and extending the new generation of enterprise systems, i.e. Enterprise Systems which are fully open, adaptive and integrated with innovation processes.

GC3: Knowledge-Oriented Collaboration and Semantic Interoperability. This Grand Challenge carries forward all the key topics from the previous version, further focusing on the needed semantics for organising, managing and exchanging knowledge and information – of both incoming and outgoing nature in the modern SME.

GC4: Enterprise Interoperability Science Base. Keeping the main target of GC4, that is the empowerment of the scientific foundation of Enterprise Interoperability, new challenges are put forward as a result of the last 2 years of discussions among the EI community members in the area.

Although specific attempts for answering key challenges should be encouraged, the above Grand Challenges are expected to be interrelated, when trying to provide complete, sustainable and adaptive solutions to the enterprise of tomorrow. As illustrated in the Figure below, attempts towards the Interoperability Service Utility are bound to drive and utilize developments in Future Internet and Enterprise Systems, while adopting and fertilizing evolutions in the Knowledge and Semantic Interoperability domain. A Scientific Base for Enterprise Interoperability should, in the meantime, act both as a repository of generated knowledge but also as an incubator of new ideas and future challenges to target.



4.1. Interoperability Service Utility

In the version 4.0 of the Roadmap, interoperability is envisioned as a utility-like capability that can be invoked on-the-fly by enterprises in support of their business activities. The

properties of such a utility-like infrastructure should be that it is simple and easily attainable by enterprises and especially by SMEs, regardless of their capabilities or existing infrastructures, by being:

- All-inclusive for all kinds of enterprises in principle (universal or near-universal access), regardless of their size, business sector or geographical location.
- Available at an affordable initial cost and requiring low maintenance and subsequent investment
- Of guaranteed quality, relevant to a service level agreement, and following a set of common rules.
- Not necessarily controlled, owned or directed by a single private entity (supply-side flexibility).

The version 4.0 of the roadmap proposed the term Interoperability Service Utility to denote an overall system that would constitute the realisation of this strategic view. Towards the instantiation of this prototype ISU, a series of research directions were proposed for further consideration in order to elaborate on issues such as the ISU design principles, the set of basic and value-added interoperability services, the potential business model and ownership status and finally the regulatory framework for its operation.

Over the time elapsed since the last version of the Roadmap several issues along the abovementioned research dimensions have been examined, mainly in the scope of FP6 projects, whose objectives related to the ISU concept. In particular, existing interoperability frameworks and architectures have been reviewed and new approaches have been promoted, leveraging features like end-to-end interconnection, process alignment, data integration, service orchestration, knowledge exchange against scalability, setup cost, and operational efficiency. Additionally, technologies and technical solutions such as SOA, MDI, BPMN, BPEL, CCTS and UBL[3] have been put to the test, elevating even more the need for standardised approaches in areas such as cross-organisational business processes, business document exchange, service integration and web-service orchestration. Finally, legal framework and regulatory issues were also examined, putting forward the need for incorporating legal issues and legal rules into the design and implementation of interoperability software.

Research efforts hitherto have mainly engaged the framework and technological aspects of interoperability enactment through the ISU. However, the need to move away from monolithic, centralised architectures and software paradigms that focus only within the enterprise and not on business partners and customers, and to engage newer architectural models that put us on a track in achieving the loosely coupled enterprise, with an increasing capability for collaboration among all kinds of applications, to foster virtual alliances and respond effectively and swiftly to competitive challenges, still remains eminent. In such a dynamic framework several research issues attaining to the architectural design of the ISU as a “system of systems”, its semantic capabilities and its linking to business context, and finally service provision model and mechanisms still remain to be addressed. Specifically, this entails:

3 SOA (Service Oriented Architectures, MDI (Multiple Document Interface), BPMN (Business Process Modeling Notation), BPEL (Business Process Execution language), CCTS (Core Components technical Specification) and UBL (Universal Business Language)

- Architectural design of the ISU as a “system of systems” that will enable interoperability among peer systems without intervening in vital information exchange or exchange of collaboration knowledge, but sustaining interoperability through a mediation centre that will provide for coordination, negotiation and delegation functions.

- Semantic solutions for enabling the ISU operation and linking the ISU to the enterprises business context. New methods, ontologies (industry specific or generic) and tools for semantic mediation, service repositories, service matching, service retrieval and provisioning.

- Basic ISU services allowing end-to-end interoperability and Value Added ISU services supporting co-creation of services and enabling innovation and value creation.

- Software as a Service (SaaS) and Interoperability as a Service (IaaS) as service provision models of the ISU.

- ISU standardisation and standards-based operations.

- ISU business models and value assessment of ISU-related business models.

- Methods to link enterprise modelling to ISU engineering and tools to enable the transformation of enterprise models to executable logic descriptions.

- Accommodating cultural differences and multilingualism when needed

4.2. Future Internet and Enterprise Systems

The present Grand Challenge aims at utilising the concepts, technologies and solutions orienting from novel approaches in internet which alter the way in which EI serves business needs. The recent vision developed for EI as a enabler for innovation stated that we will need to support new, flexible, temporary partnerships with changing members of the ecosystem, within and across ecosystems which are themselves changing. Extending the new generation of federated enterprise architectures requires addressing the following characteristics: system openness, system adaptability and system integration within a new perspective of the enterprise.[4] But the openness of enterprises and of enterprise systems requires reappraisal. Specifically, this is not only a matter of being open in the conventional sense of “plug and play”, but also of being very “closed” in accordance with dynamically changing and unique business needs, such as allowing (new) business partners to quickly and effectively share strategic and proprietary information in a protected environment. It has to be stressed that this interaction should lead to more productive, more easily deployed and eventually more penetrative business systems for the typical SME.

The drivers for change in the domain of internet and enterprise systems have been, over the last years:

[4] See section 5.3.1 of the report "Unleashing the Potential of the European Knowledge Economy", Informal Study Group on Value Proposition for Enterprise Interoperability Report, An Enterprise Interoperability community document, 69 pg. Edited by Man-Sze Li, IC Focus, Servane Crave, Orange / France Telecom, Antonio Grilo, Universidade Nova de Lisboa, Roelof van den Berg, Erasmus Research Institute of Management. Work coordinated by the Enterprise Interoperability Cluster of the Information Society and Media Directorate-General, European Commission, 2008 page

- The successful implementation of numerous European and international research projects, targeting architectures and systems for achieving interoperability, which resulted in relevant prototypes (e.g. ebXML servers, ERP/SCM connectors and middleware for electronic services, P2P implementations for businesses, etc).

- The empowerment and initial deployment of Web 2.0 technologies in the enterprise domain, which certainly pose new requirements for ubiquity, autonomic behaviour and syndication of business systems, possibly leading to a new generation of enterprise applications.[5]

- The gradual maturing of model-based, rule-driven, executable workflow technologies, which begin to appear in the commercial offerings of software and service vendors, and should be re-integrated in further research initiatives.

Based on the above observations and results, all the solution-oriented ideas of the roadmap version 4.0 still apply (Enterprise Interoperability Operating System, Mashup Technology Solutions for Enterprise Interoperability, Web SLEE Solutions for Enterprise Interoperability, Web Community Solutions for Enterprise Interoperability), put in the context of significantly advancing the state of the art. Furthermore, new ideas that appear relate to:

- Model-based technological frameworks for achieving interoperability by design or through retrofit, during enterprise systems development and deployment, covering also widely-spread legacy applications, in an inter-enterprise or intra-enterprise environment.

- New examples of business-pervasive service platforms, specifically designed for SMEs or for vertical industrial sectors when needed, reaching new levels of adaptability, dynamic behaviour, and integration with the innovation process of the enterprise.

- New end-to-end examples of executable interoperability, in the form of coordinated intra- and inter-enterprise workflow management, including technologies for automating semantic reconciliation and process flow management among diverse systems and services.

- New requirements for services and new service paradigms for the Future Internet, leading to new characteristics and properties for system openness, system adaptability and system integration in dynamic, programmable environments forming part of the Future Internet infrastructures.[6]

4.3. Knowledge-Oriented Collaboration and Semantic Interoperability

The term “virtual organisation” (VO) signifies a grouping of legally distinct or related enterprises coming together to exploit a particular product or service opportunity. The last version of the roadmap determines as the next phase of Enterprise Interoperability the sharing of knowledge within a VO to the mutual benefit of the VO partners. This especially includes knowledge about how to create, operate and integrate successful VOs.

Specifically, the roadmap addressed two primary needs identified by enterprises in successfully forming and exploiting VOs.

[5] See also Forrester Report “Top Enterprise Web 2.0 Predictions For 2008”, 1/2008

[6] Idem, see section 5.3.1 of the report "Unleashing the Potential of the European Knowledge Economy".

- Rapid and reliable formation of collaborative consortia to exploit product opportunities.

- Application of enterprise and VO knowledge in operational and strategic decision making in VOs, leading to enhanced competitiveness and profitability.

The proposed grand challenge comprised a series of research aspects elaborating on key determinants of VOs, such as necessary knowledge categories to enable collaboration, tools for knowledge representation, management, acquisition and generation, repositories of collaboration knowledge and best practices, assessment of knowledge-based collaborations and business intelligence.

A further aspect of this Grand Challenge is the definition, acquisition and application of knowledge collaboration (including EI) capabilities and services, and the matching of these specific end-user needs. Human actor collaborations rely on a common knowledge base that is, most of the times, implicitly understood. On the contrary computer actor collaborations require that this implicit knowledge is made explicit to all parties, therefore the corresponding knowledge base to support the collaborations needs to be far more complex, inclusive and expressed in a machine processable format or notation. Ongoing research proves that emerging technologies such as ontologies, semantics, the semantic web (Web 2.0) and even further, the anticipated social semantic web trend provide the means to create and share such diverse knowledge bases.

This roadmap puts forth the need for research in such advanced technologies as key enablers of semantic interoperability and knowledge-based collaborations,[7] specifically:

- Ontology development and management. Ontologies that will furnish the semantics for the Semantic Web and which should be developed, managed, and endorsed by committed practice communities, regardless of subject.

- New methodologies, techniques and tools for the discovery, capture and re-use of knowledge collaborative capabilities and services: *Folksonomies* and other similar web-scale tagging structures for describing information by human and/or machine actors within the scope of an organisation, including approaches for collaborative ontology engineering

- Next generation knowledge management system providing advanced knowledge services (identification, collection, representation, processing and exploitation) in support of knowledge-based collaborations.

4.4. Science Base for Enterprise Interoperability

This Grand Challenge aims at assisting the establishment of EI as a scientific discipline by extending, assimilating, and integrating developments from both established and emerging sciences. Version 4.0 of the roadmap has already identified such neighbouring sciences, as following:

- Systems/Complexity science

- Network science

[7] See also, Nigel Shadbolt, Wendy Hall, Tim Berners-Lee, The Semantic Web Revisited, IEEE Intelligent Systems, 2006.

- Information science
- Web science
- Services science
- Economic science
- Natural sciences (biology, etc.)
- Social sciences[8]

Bringing this approach further, and integrating results from Networks of Excellence and Integrated Projects from FP6 on the subject,[9] it has been proposed that the research work could be organised along the following axes:[10]

- Basic research (Investigation of basic ideas and concepts, initial formal methods to describe problems and solutions, critical research questions)
- Concept formulation (Circulation of solution ideas, development of a research community, convergence on a compatible set of ideas, solutions on specific sub-problems, refinement of problem's structure)
- Development and extension (Exploration of preliminary applications of the technology, populations of formal description, generalisation of approaches).
- Internal enhancement and exploration (Extension of the approach to vertical domains, application of the technology in real problems, stabilisation of technological means, development of training material, and initial assessment of impact).
- External enhancement and exploration (Communication towards a broader community, substantiation of value and applicability, detailing towards complete system solutions)
- Popularisation (Standardisation and methodologies for production-quality, versioning of the technology, systematic assistance in commercialisation and marketing of technology offerings).

By applying the proposed method suggested above, EI could become an engineering activity that optimizes the approach towards developing solutions for all Enterprise Systems.

8 The EIRR also mentions Social networks, Community, Business network governance, Business content, Decision, Change management sciences

9 See also INTEROP NoE and ATHENA-IP FP6 Projects.

10 See also S. Redwine and W. Riddle, "Software Technology Maturation," Proc. 8th Int'l Conf. Software Eng., IEEE CS Press, 1985, and M. Shaw, P. Clements, "The Golden Age of Software Architecture", IEEE Software, 2006.

5. CONCLUSION

This roadmap update (v5.0) is to be considered, and read as, a supplement to version 4.0 of the roadmap. Incremental changes in the state of the art and evolutions in the problem definition or solution elicitation have been the drivers of change for this update. Following this process, the four revised Grand Challenges are:

GC1: Interoperability Service Utility.

GC2: Future Internet and Enterprise Systems.

GC3: Knowledge-oriented Collaboration and Semantic Interoperability.

GC4: Enterprise Interoperability Science Base.

Further to the redefinition of Grand Challenges, a full update of the research challenges is contained in Annex I – Indicative Research Challenges. This update includes a small number of new challenges, and furthermore, provides a mapping of the individual research challenges to the corresponding Grand Challenges.

The new basis of the state of the art has been described, underlining the new standards for screening new proposals and research initiatives in the enterprise interoperability domain.

Finally, this roadmap update is a collective effort of all interested stakeholders, available to all interested stakeholders. Specifically, it is submitted to the European Commission as an input to the FP7 programming. For the Roadmap to remain relevant, it must be subject to regular review and updates in the lifespan of FP7.

The final proposal of its editors is that this open, inclusive initiative in developing the roadmap should be maintained within the framework of FP7.

ANNEX 1 (V5.0): INDICATIVE RESEARCH CHALLENGES

Annex I: Indicative Research Challenges

1. Introduction

The present document is Annex I to the 2008 Progress Report of the Enterprise Interoperability Research Roadmap. It attempts to map the list of indicative research challenges of Annex I of version 4.0 of the Enterprise Interoperability Research Roadmap to the Grand Challenges as specified in the current version of that roadmap. The aim of this mapping is to help produce a better overview over the various Grand Challenges and to give a better insight into the specific research activities related to each of those challenges.

The purpose of the indicative research challenges is to list explicit research ideas as specific research issues within the Grand Challenges established in the Roadmap. They are not meant to be prescriptive or comprehensive. The structure of the table below follows the structure of the Annex I of version 4.0 of the Enterprise Interoperability Research Roadmap, and the section numbers and research challenges numbers are directly referring back to the respective sections and challenges in that document.

2. Research Challenge / Grand Challenge Mapping

Section in Annex I (4.0)	**Name of the Research Challenge**	**Number**	**Applicable Grand Challenges**
2.	**Policy Challenges**	(P)	
2.1.	Dissemination of Information About Existing Legislation and Regulation	(P1)	Not applicable

2.2.	Harmonisation of National Implementation of EU Directives Supporting E-Commerce	(P2)	Not applicable
2.3.	Encouraging Adoption of IPv6	(P3)	Not applicable
2.4.	Software Licenses for Distributed and Movable Applications	(P4)	Not applicable
2.5.	Regulation of Trusted Certification Authorities	(P5)	Not applicable
2.6.	Exchange of Data Across National Borders	(P6)	Not applicable
2.7.	Trans-European Limited Liability Incorporation	(P7)	Not applicable
NEW	Global Harmonisation of Product, Process and Business Model Data Standards (de facto, ISO, CEN, Etc.)	(P8)	Not applicable
NEW	Availability of Master Data Localisers	(P9)	Not applicable
3.	**Business – Economic Research Challenges**	(B)	
3.1.	Business Interoperability Framework	(B1)	Currently not covered
3.2.	Business Interoperability Framework – Long Term	(B2)	Currently not covered
3.3.	Business Interoperability and Society	(B3)	Science Base
3.4.	Business Models for Interoperability	(B4)	Science Base
3.5.	Enterprise Grid-Based Economics	(B5)	Outside the scope of the Grand Challenges
3.6.	Interoperability Impact Analysis	(B6)	Currently not covered
3.7.	Interoperability Impact Analysis - Long Term	(B7)	Currently not covered
3.8.	Contribution of Interoperability to Productivity	(B8)	Science Base

3.9.	Decentralised Governance of Business Processes	(B9)	Knowledge-Oriented Collaboration and Semantic Interoperability
3.10.	SME-Related Economic and Deployment Considerations	(B10)	Interoperability Service Utility
3.11.	Technology Trajectory of Interoperability	(B11)	Science Base
3.12.	Interoperability and Digital Ecosystems	(B12)	Knowledge-Oriented Collaboration and Semantic Interoperability
3.13.	Decentralized Quality Management of Business Processes	(B13)	Knowledge-Oriented Collaboration and Semantic Interoperability, Future Internet and Enterprise Systems
4.	**Enterprise (Business/Knowledge) Research Challenges**	(T1)	
4.1.	Interoperability of Enterprise Models	(T1.1)	
4.1.1	Process Model/Tool Interoperability	(T1.1.1)	Knowledge-Oriented Collaboration and Semantic Interoperability, Science Base
4.1.2	Generic Rules & Services for Model Derived Service Environments	(T1.1.2)	Science Base, Knowledge-Oriented Collaboration and Semantic Interoperability, Future Internet and Enterprise Systems
4.1.3	Enterprise Model Interoperability (Distributed) – Def. of Problem / Domain / Prototype	(T1.1.3)	Currently not covered
4.1.4	Enterprise Model Interoperability (Distributed)	(T1.1.4)	Currently not covered
4.2.	Usability of Enterprise Models	(T1.2)	
4.2.1	Model Generated Solutions and Work Places	(T1.2.1)	Future Internet and Enterprise Systems
4.2.2	Enterprise Model Visualization and Usability	(T1.2.2)	Future Internet and Enterprise Systems

4.3.	Cross-Organisational Business Processes	(T1.3)	
4.3.1	Organisational Roles and Policies	(T1.3.1)	Future Internet and Enterprise Systems
4.3.2	Modelling Cross-Organizational Business Processes	(T1.3.2)	Currently not covered
4.3.3	Monitoring of Business Processes	(T1.3.3)	Currently not covered
4.3.4	Aligning Business Strategy and ICT Strategy	(T1.3.4)	Currently not covered
4.4.	Agreements and Contracting	(T1.4)	
4.4.1	Service Level Agreements	(T1.4.1)	Knowledge-Oriented Collaboration and Semantic Interoperability, Future Internet and Enterprise Systems
4.4.2	Contracting	(T1.4.2)	Knowledge-Oriented Collaboration and Semantic Interoperability
4.5.	SME Situation Challenges	(T1.5)	
4.5.1	Data Mapping and Conversion	(T1.5.1)	Knowledge-Oriented Collaboration and Semantic Interoperability
4.5.2	Services Access to Intermediaries	(T1.5.2)	Knowledge-Oriented Collaboration and Semantic Interoperability
4.5.3	Beyond Local Services	(T1.5.3)	Knowledge-Oriented Collaboration and Semantic Interoperability
4.5.4	SME Related Economics and Deployment	(T1.5.4)	Knowledge-Oriented Collaboration and Semantic Interoperability, Future Internet and Enterprise Systems
4.5.5	SME Digital Ecosystems	(T1.5.5)	Future Internet and Enterprise Systems

NEW	Model Mapping and Conversion	(T1.5.6)	Knowledge-Oriented Collaboration and Semantic Interoperability
4.6.	Interoperability Aspects of Intercultural Cooperation	(T1.6)	Science Base, Knowledge-Oriented Collaboration and Semantic Interoperability, Future Internet and Enterprise Systems
5.	**ICT Systems and Architecture & Platform Research Challenges**	(T2)	
5.1.	Run Time Aspects of Business Processes	(T2.1)	
5.1.1	Cross-Organizational Business Process Execution	(T2.1.1)	Currently not covered
5.1.2	Monitoring and Redesign of Business Processes	(T2.1.2)	Future Internet and Enterprise Systems
5.1.3	Decentralized Governance of Business Processes	(T2.1.3)	Future Internet and Enterprise Systems
5.2.	Service Discovery, Brokering, Negotiation & Mediation	(T2.2)	
5.2.1	Service Description	(T2.2.1)	Knowledge-Oriented Collaboration and Semantic Interoperability
5.2.2	Models and Meta-Models for Service-Oriented Architectures	(T2.2.2)	Future Internet and Enterprise Systems
5.2.3	Service Composition	(T2.2.3)	Future Internet and Enterprise Systems
5.2.4	Observation & Validation of Collaborations Between Business Processes and Services	(T2.2.4)	Future Internet and Enterprise Systems, Knowledge-Oriented Collaboration and Semantic Interoperability
5.2.5	Service Discovery	(T2.2.5)	Future Internet and Enterprise Systems, Knowledge-Oriented Collaboration and Semantic Interoperability
5.2.6	Automatic Service Composition	(T2.2.6)	Knowledge-Oriented Collaboration and Semantic Interoperability

5.3.	Non-Functional Aspects	(T2.3)	
5.3.1	Non-Functional Aspects in Interoperability	(T2.3.1)	Science Base
5.3.2	Usability of the EI Solutions	(T2.3.2)	Science Base
NEW	Acceptability of the EI Solutions	(T2.3.3)	Science Base
5.4.	Infrastructures & Services	(T2.4)	
5.4.1	Autonomous Architectures (Agents, P2p)	(T2.4.1)	Interoperability Service Utility
5.4.2	Repositories and Persistence Services	(T2.4.2)	Interoperability Service Utility
5.4.3	Terminal Interoperability	(T2.4.3)	Interoperability Service Utility
5.4.4	Grid-Based Enterprise Interoperability	(T2.4.4)	Interoperability Service Utility
5.4.5	Adaptive & Self-Adaptive Systems	(T2.4.5)	Interoperability Service Utility
5.4.6	Interoperability to Support Ambient Intelligent Applications	(T2.4.6)	Interoperability Service Utility
5.4.7	Networked Business Support Through Information Exchange and Sharing	(T2.4.7)	Interoperability Service Utility, Knowledge-Oriented Collaboration and Semantic Interoperability, Future Internet and Enterprise Systems
5.5.	Supplementary Research Challenges	(T2.5)	
5.5.1	Providing Role and Context Based Privacy in E-Business	(T2.5.1)	Future Internet and Enterprise Systems, Knowledge-Oriented Collaboration and Semantic Interoperability
5.5.2	Intelligent Collaborative Planning on the Supply Chain Based on Smart Products	(T2.5.2)	Knowledge-Oriented Collaboration and Semantic Interoperability

6.	**Methodology Research Challenges**	(T3)	
6.1.	Interoperability Frameworks and Architectures	(T3.1)	
6.1.1	Integrated Paradigm for Interoperability	(T3.1.1)	Science Base, Future Internet and Enterprise Systems
6.1.2	Unified Paradigm for Interoperability	(T3.1.2)	Currently not covered
6.1.3	Federated Paradigm for Interoperability	(T3.1.3)	Future Internet and Enterprise Systems, Interoperability Service Utility
6.1.4	Interoperability Methodologies	(T3.1.4)	Currently not covered
6.2.	Networked Enterprises Operations Support	(T3.2)	Currently not covered
6.3.	Interoperability Domain Establishment	(T3.3)	Science Base
6.4.	MDI – Model Driven Interoperability	(T3.4)	Currently not covered
6.5.	Model Design Solutions and Interoperability Design Patterns	(T3.5)	Science Base, Future Internet and Enterprise Systems
7.	**Semantics and Ontology Research Challenges**	(T4)	
7.1.	Business Process Ontology	(T4.1)	Knowledge-Oriented Collaboration and Semantic Interoperability
7.1.1	Business Process Description Ontology	(T4.1.1)	Currently not covered
7.1.2	Business Process Classification Ontology	(T4.1.2)	Currently not covered
7.1.3	Process Mediation	(T4.1.3)	Knowledge-Oriented Collaboration and Semantic Interoperability
7.2.	Ontology Infrastructure	(T4.2)	

7.2.1	Business Ontology Authoring and Management System	(T4.2.1)	Knowledge-Oriented Collaboration and Semantic Interoperability
7.2.2	Semantic Data Mapping & Mediation	(T4.2.2)	Knowledge-Oriented Collaboration and Semantic Interoperability
7.2.3	Semantic Annotation	(T4.2.3)	Knowledge-Oriented Collaboration and Semantic Interoperability
7.2.4	Business Ontology Evolution and Versioning	(T4.2.4)	Knowledge-Oriented Collaboration and Semantic Interoperability
7.2.5	Business Ontology Validation	(T4.2.5)	Knowledge-Oriented Collaboration and Semantic Interoperability
7.2.6	Enterprise Ontology Based Query/Retrieval, Discovery, Search	(T4.2.6)	Knowledge-Oriented Collaboration and Semantic Interoperability
7.3.	Ontology-Based Modelling	(T4.3)	Knowledge-Oriented Collaboration and Semantic Interoperability
7.4.	Business Product Ontology	(T4.4)	
7.4.1	Link Between Product and Process Ontologies	(T4.4.1)	Knowledge-Oriented Collaboration and Semantic Interoperability
7.4.2	Ontology Based Product Management	(T4.4.2)	Knowledge-Oriented Collaboration and Semantic Interoperability
7.4.3	Business Product Ontology Development Infrastructure	(T4.4.3)	Knowledge-Oriented Collaboration and Semantic Interoperability
7.5.	Other Supplementary Research Challenges	(T4.5)	
7.5.1	Semantic Context Based Business Document Content Interoperability	(T4.5.1)	Knowledge-Oriented Collaboration and

			Semantic Interoperability
7.5.2	Semantic Based Interoperability of Business Processes	(T4.5.2)	Knowledge-Oriented Collaboration and Semantic Interoperability
7.5.3	Enhancing Web Service Registries With Reasoning Capabilities	(T4.5.3)	Future Internet and Enterprise Systems, Knowledge-Oriented Collaboration and Semantic Interoperability
7.5.4	Semantic Based Interoperability Profiles	(T4.5.4)	Future Internet and Enterprise Systems, Knowledge-Oriented Collaboration and Semantic Interoperability
7.5.5	Application of Ontologies to Collaborative Community Processes	(T4.5.5)	Currently not covered
8.	**Generic Modelling Research Challenges**	(T5)	
8.1.	Distributed Active Models (Interoperation of Models) – for Simulation and Enactment	(T5.1)	Currently not covered
8.2.	Simulation and Enactment of Distributed Processes (Models for Interoperation Effects)	(T5.2)	Knowledge-Oriented Collaboration and Semantic Interoperability
8.3.	Usability of Models	(T5.3)	Science Base, Knowledge-Oriented Collaboration and Semantic Interoperability
8.4.	MDA/DSL Technologies	(T5.4)	Science Base
8.5.	Distributed Model Synchronisation	(T5.5)	Currently not covered
8.6.	Semantic Based Model Mappings and Transformations	(T5.6)	Currently not covered
8.7.	Knowledge Mining & ADM	(T5.7)	Knowledge-Oriented Collaboration and Semantic Interoperability
8.8.	Knowledge-Driven Support for Interoperability in Virtual Organisations	(T5.8)	Knowledge-Oriented Collaboration and

			Semantic Interoperability
8.9.	Knowledge Sharing and Protection in Virtual Organisations	(T5.9)	Knowledge-Oriented Collaboration and Semantic Interoperability
8.10.	Knowledge Capture, Creation and Application in Virtual Organisations	(T5.10)	Knowledge-Oriented Collaboration and Semantic Interoperability
9.	**Other Challenges**	(O)	
9.1.	Ensuring Seamless Research/Standardization Interfaces	(O1)	Science Base

3. Full Description of Proposed New Research Challenges added to the above list (as suggested by the EI community)

Research Challenge	**P 8: Global harmonisation of product, process and business model data standards (de facto, ISO, CEN, etc.)**
Description	Many organisations, and especially SMEs, can find it very difficult to manage the large number of available standards they have to deal with in running their business, considering the emerging opportunities of globalisation.
State of the Art	There are a significant number of standards for product, process and business model data being adopted by organisations today, however the lack of interoperability between those standards remains a significant problem for business collaboration.
Research Activity	To develop a global framework that, based on current standards, provides services and tools that will enable the immediate integration of organisations (especially SMEs), independently of the standards in adoption by the different parties.

Research Challenge	**P 9: Availability of master data localisers**
Description	Establishment of master data localisers, with services and information accessible, and which is managed independently of language and cultural preferences.
State of the Art	There is a large amount of information globally distributed and represented in different formats, and described under different specifications. When there is a need to access and manage it, several barriers exist, including those related with stakeholders' language and culture.
Research Activity	Definition of a global agile framework for the implementation of localisers, able to understand and manage linguistic aspects and cultural practices.

Research Challenge	**T 1.5.6: Model mapping and conversion**
Description	Model mapping and conversion is concerned with enterprise models in use within and between organizations, when developing collaboration activities (inter, intra), and there is a need to share information based in such heterogeneous models.
State of the Art	There are several models in use by organizations. Interoperability is achieved when organizations adopt the same model. However there is a lack of a referential framework to support a global integrated, unified or federated access to them, in heterogeneous modelling environments.
Research Activity	Research for data mapping and conversion, should be extended to support model mapping and conversion.

Research Challenge	**T 2.3.3: Acceptability of the EI solutions**
Description	The technical solutions developed for Enterprise Interoperability will meet the technical requirements, but there is no evidence that they will be accepted by the relevant individuals within an enterprise.
State of the Art	Specialised tools for tasks in EI are available. It can be seen that often these tools are provided by developers addressing a very narrow and specific context, limited both by the technical as well as the cultural or societal scope.
Research Activity	Address the need to examine from a social and legal perspective the acceptability of EI technologies and the challenges involved (from an individual, company and societal perspective: what are the variables influencing acceptance, what business and social conditions must exist to influence acceptance).