
# Enterprise Interoperability

## Research Roadmap

Final Version
(Version 4.0)

31 July 2006

**Acknowledgements**

The editors would like to thank the European Commission services for their support for the planning and preparation of this document.
The proposals and opinions expressed in this document are those of the editors and contributors and do not necessarily represent those of the European Commission. The views expressed herein do not commit the European Commission in any way. The responsibility for any remaining errors remains with the editors.

**Editors**
Man-Sze Li, IC Focus
Ricardo Cabral, University of Madeira
Guy Doumeingts, Adelior France
Keith Popplewell, Coventry University

**The editors would like to pass on their acknowledgments and thanks to the following colleagues, who have submitted written comments on draft versions of the Roadmap**
Hans Akkermans, AKMC
Garry Barclay, Codescent
Guenter Boeckle, Siemens
Stuart Campbell, TIE Holding
Piero De Sabbata, ENEA
Asuman Dogac, METU
Idoia Echave, Tekniker
Pim van der Eijk, OASIS
Barbara Gatti, CEN - European Committee for Standardization
Jan Goossenaerts, TUE
Sergio Gusmeroli, TXT
Kim Jansson, VTT
Norbert Jastroch, MET Communications GmbH
Roland Jochem, University of Kassel
Al Jones, NIST
John Ketchell, CEN Pre-Standards
Kurt Kosanke, CIMOSA Association
Jean-Pierre Lorré, EBM WebSourcing
Robert Meersman, Vrije Universiteit Brussel
Freek Posthumus, UEAPME
Peter Potgieser, Interpay (eBIF)
Tapio Rissanen, EuroConseils sprl
Rainer Ruggaber, SAP Research
Henry Ryan, Lios Geal Consultants
Ville Saarikoski, TIEKE
David Shorter, IT Focus
Aurelian Stanescu, University Politehnica Bucharest
Eugene Sweeney, Iambic Innovation Ltd
Dirk Werth, DFKI
Wolfgang Wilkes, University of Hagen
Michael Wilson, CCLRC

**Presenters at the International Consultation Workshop on Enterprise Interoperability research, Bordeaux (France), 21 March 2006**
Macedonio Alanis, ITESM (Mexico)
Abhijit Deshmukh, NSF (United States)
Michael Johnson, Macquarie University (Australia)
Henry Ryan, Lios Geal Consultants (Ireland) representing eBusinessW@tch
Ville Saarikoski, TIEKE (Finland)
Xu Xiaofei, Harbin Institute of Technology (China)

**Contributors to V1.0**
ATHENA, http://www.athena-ip.org/, in particular Man-Sze Li, and Rainer Ruggaber
INTEROP, http://www.interop-noe.org/, in particular David Chen, Guy Doumeingts, Frank-Walter Jaekel, Colin Piddington, and Martin Zelm
NO-REST, http://www.no-rest.org/, in particular Kai Jakobs
TrustCoM, http://www.eu-trustcom.com/, in particular Michael Wilson
CrossWork, http://www.crosswork.info/, in particular Nikolay Mehandjiev
ECOLEAD, http://www.ecolead.org/, in particular Servane Crave

**Reviewers (self-nominated)**
Stuart Campbell, TIE
Dirk Werth, DFKI

**European Commission contact point**
Arian Zwegers, European Commission, arian.zwegers@ec.europa.eu

**Versioning and contribution history**

| 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 | Final public version | 31-07-2006 |

All public versions of this Roadmap are available at
**http://cordis.europa.eu/ist/ict-ent-net/ei-roadmap_en.htm**

# Table of contents

## 1. Executive Summary

Today, escalating economic and societal demands, together with the continued mainstreaming of ICT and the need to push further the technology limits, set a growing agenda for research. To bring technology closer to people and organisational needs means: hiding technology complexity and revealing functionality on demand; making technology very simple to use, available and affordable; providing new ICT-based applications, solutions and services that are trusted, reliable, and adaptable to the users' context and preferences.

To meet their business objectives, enterprises need to collaborate with other enterprises. Small and medium sized enterprises (SMEs), who need to specialise in niche activities in order to raise their own added value, particularly have to combine forces to compete jointly in the market. Today, an enterprise's competitiveness is to a large extent determined by its ability to seamlessly interoperate with others. As ICT-enabled collaboration becomes a decisive tool in the struggle for competitive advantage, Enterprise Interoperability has become a strategic necessity in all industries. It has also increasingly become a key feature of the business fabric of all innovation ecosystems. The i2010 Strategy Framework has explicitly identified interoperability as a key bottleneck that should be tackled.

The past decade has seen significant advances to Enterprise Interoperability. Numerous architectural frameworks and sector specific specifications have arisen from the standardisation arena. More recently, the Service Oriented Computing paradigm and Service Oriented Architectures (SOA) have emerged as a major evolutionary step, with Web Services, Grid Services and peer-to-peer (P2P) services comprising the major trends. This has been joined by developments in Semantic Web Services, Enterprise Modelling, as well as other modelling and process languages to describe business processes and their executions. Today, the market is saturated with technology-based solutions that claim to support interoperability for enterprises, with several commercial middleware solutions among the most prominent.

However, questions remain about the impact and significance of these vendor-based solutions. Specifically, a single, monolithic solution for Enterprise Interoperability rested on proprietary protocols and captive markets is untenable in a climate of change, unworkable in real businesses, and strategically undesirable for promoting innovation and growth. Market failures are possible. More than a decade after Enterprise Interoperability issues have been raised and discussed within a large number of communities, interoperability is still a problem for enterprises. Islands of interoperability persist. Integration projects remain complex and expensive. Full alignment between technical capability and business need is still largely missing. The business case for interoperability is often not apparent to potential adopters of Enterprise Interoperability solutions, particularly for SMEs. Various Enterprise Interoperability technologies and tools resulting from research lack follow-up beyond (further) research. Large question marks remain as regards the "value" and "impact" of the myriad of initiatives undertaken within the research lab, promoted by technology providers, or organised around groupings of companies.

At the same time, enterprises are, more than ever, challenged by the accelerating pace of change and innovation. Globalisation is putting increasing pressure on pricing and operational efficiency in most industries. Enterprises are also confronted with rising integration and interoperability costs, difficulties in decision making, lack of a demonstrable business case for Enterprise Interoperability, and changing models of collaboration towards open innovation.

Enterprises are spurred to innovate by pressures and challenges. The only comparative advantage an enterprise will enjoy will increasingly be its process of innovation**.** That process will combine the knowledge of markets and technology with the knowledge and talents of creative workers to create new products and services that add value to its customers, its employees, and its shareholders. To achieve that, enterprises must collaborate, in order to compete. Successful enterprises of the future will be characterised by their ability to collaborate, their ability to adapt, and their ability to interoperate.

In this Roadmap, we envision a future in which the business environment will comprise a diversity of continuously evolving "ecosystems" of enterprises, within and across which enterprises will collaborate as well as compete with one another. Enterprises, both big and small, will be able to do business seamlessly, adapt to changes in the environment dynamically, and exploit new opportunities rapidly by harnessing the full potential of software and related IT services. Interoperability of enterprises will be a

key feature within each ecosystem, and across the ecosystems. From an IT perspective, interoperability will be a utility-like capability that enterprises can invoke on the fly in support of their business activities. Specific IT functions will be delivered as services that are cheap, fast, reliable, and without major integration efforts. IT will become a routine, and not a problem. It will be a transparent and invisible part of the business operation.

To achieve this Vision, we propose four Grand Challenges that collectively constitute a long-term strategic direction for research in Enterprise Interoperability.

First, interoperability as a utility-like capability needs to be supported by an enabling system of services for delivering basic interoperability to enterprises, independent of particular IT deployment. We use the term **Interoperability Service Utility (ISU)** to denote this overall system. The ISU is envisaged to provide interoperability as a technical, commoditised functionality, delivered as services. Value-added functionalities, for which customers would be willing to pay a premium, would flow above the ISU. Conceptually, the ISU constitutes the next "layer" of open cyberspace, sitting atop the Internet and the Web. The implicit proposition is that interoperability as a technical functionality is a public good – the ISU is available for all to use, exploit and build upon. Accordingly, the ISU would be particularly useful and attractive for SMEs and start-up companies The ISU Grand Challenge is concerned with exploring the ISU design principles, potential services, business case and ownership issues, and potential regulatory implications.

There is no doubt that the Web will in time become a basic building block of future enterprises. The second Grand Challenge is about **Web Technologies for Enterprise Interoperability**, and proposes four key research areas for leveraging Web technologies in future Enterprise Interoperability solutions. The focus is on value creation through the delivery of novel and improved services by these next-generation solutions. The proposed research areas are Enterprise Interoperability Operating System (OS) for enabling client-side application delivery, "Mash-up" technology solutions for building derived services based on combined distributed content databases of third parties, Web Service Logic Execution Environment (SLEE) solutions for minimising system integration costs of heterogeneous elements in different enterprises, and Web community solutions that ensure that benefits are accrued to the appropriate transacting parties.

The next phase enabled by Enterprise Interoperability is the sharing of knowledge within a Virtual Organisation (VO) to the mutual benefit of the VO partners. The third Grand Challenge is about **Knowledge-Oriented Collaboration**. It addresses two primary needs identified by enterprises in successfully forming and exploiting VOs, namely rapid and reliable formation of collaborative consortia to exploit product opportunities, and the application of enterprise and VO knowledge in operational and strategic decision making in VOs, leading to enhanced competitiveness and profitability. To this end, nine research areas are identified. These research areas focus on knowledge to set up and operate VOs, and on sharing knowledge within a VO.

The potential value of Enterprise Interoperability goes beyond the technical domain to much broader developments in business, the economy, and the society. Therefore, Enterprise Interoperability must leverage those developments in order to maximise the value. To do so, Enterprise Interoperability critically needs to be established on a more solid and rigorous base of science and, specifically, scientific principles. The fourth and final Grand Challenge is about creating that **Science Base for Enterprise Interoperability**, by combining and extending the findings from other established and emerging sciences. These include, subject to further investigations, Systems/Complexity science, Network science, Information science, Web science, Services science, Economic science, and Social sciences. The science base is expected to comprise a new set of concepts, theories, and principles derived from established and emerging sciences; and associated methods, techniques, and practices for solving Enterprise Interoperability problems. The Grand Challenge is a challenge for the Enterprise Interoperability research field as a whole.

More than 70 indicative Research Challenges for supporting one or more of the above Grand Challenges, contributed by stakeholders through a bottom-up open process, are provided in Annex I to the Roadmap. They are categorised according to the three main dimensions to Enterprise Interoperability – policy, business-economic and technical. These Research Challenges are examples of specific research activity that may be performed; they are neither definitive nor prescriptive.

The Roadmap targets break-through research for stimulating and catalysing business innovation. Research is by its nature speculative and open-ended. It is not the purpose of a research roadmap to pick business, technology or other winners. Intrinsic to the concept of Enterprise Interoperability is that interoperability is a need; it takes place within the context and from the perspective of enterprises. Enterprises are the primary beneficiaries of Enterprise Interoperability solutions. The research work must lead to results that add value to enterprises, and help enable open, competitive markets in both supply and demand of solutions.

The present document is the result of extensive, open consultation on the future of Enterprise Interoperability research coordinated by the European Commission, over a period of almost one year. In anticipation of FP7, many stakeholders believe that Enterprise Interoperability is an area where research can lead to outstanding results in terms of innovation, leading to economic growth and employment. The Roadmap is a contribution in that direction. Accordingly, it seeks to be ambitious, focussed, problem solving and forward-looking. As a consolidated result of the contributions of the large numbers of stakeholders involved in its development, the Roadmap is a commitment of those stakeholders to the future of Enterprise Interoperability, and specifically long-term research activity in Enterprise Interoperability. It is hoped that the Roadmap will serve as a useful input to the work programming of FP7 in the coming months and years. It is also hoped that it will be used extensively and widely by all.

## 2. Introduction

Enterprise Interoperability is a relatively recent term that describes a field of activity with the aim to improve the manner in which enterprises, by means of Information and Communications Technologies (ICT), interoperate with other enterprises, organisations, or with other business units of the same enterprise, in order to conduct their business. This enables enterprises to, for instance, build partnerships, deliver new products and services, and/or become more cost efficient.

In contrast, "enterprise interoperability" (without capitals) is – analogous to the IEEE definition of interoperability[1] – the ability of an enterprise to interact with other organisations, to exchange information and to use the information that has been exchanged. It should be noted that interoperability is not only a property of ICT systems, but also concerns the business processes and the business context of an enterprise.

This Roadmap is about Enterprise Interoperability, and the term used within the document is generally within that meaning, unless otherwise indicated (by using the term without capitals).

The present document is the result of open consultation on the future of Enterprise Interoperability research coordinated by the European Commission, over a period of almost one year[2]. It is intended to represent the shared view of interested stakeholders in the Enterprise Interoperability research field who contributed to its development. The Roadmap remains a public document now and in future. It is edited by four voluntary experts in the field.

### 2.1. Background

To meet their business objectives, enterprises need to collaborate with other enterprises. For some enterprises, doing business globally has become critical to their survival, while others discover new opportunities by focusing their business in a local setting. Enterprises, both big and small, need to establish cooperation agreements with other enterprises. Small and medium sized enterprises (SMEs), who need to specialise in niche activities in order to raise their own added value, particularly have to combine forces to compete jointly in the market. Today, an enterprise's competitiveness is to a large extent determined by its ability to seamlessly interoperate with others.

In this process of change, ICT plays a significant role both enabling and triggering the re-organisation of business activities. ICT has become ubiquitous in the business domain, and has had a profound impact as the major enabler of the move towards the knowledge society. In particular, the Internet has considerably accelerated the diffusion of inter-organisational networking and has intensified the collaboration between organisations. Regardless of size and type of business, virtually all organisations' ICT systems are interconnected through the Internet. As ICT-enabled collaboration becomes a decisive tool in the struggle for competitive advantage, interoperability within and between organisations has become a strategic necessity in all industries. However, seamless communication and integration of data and information as well as synchronised inter-organisational business processes are complex. Legacy enterprise applications, for example, often hinder cooperation endeavours, since they require complex system integration efforts. For example, some estimates claim that around 40% of system implementation budgets are spent on system integration with other (legacy) systems within an enterprise. Recent developments suggest that the ICT industry is slowly moving from proprietary solutions towards Web-based technologies and standards. But there is still substantial potential for improvement in ICT technologies for Enterprise Interoperability.

Current research, technology development, and standardisation activities concerning Enterprise Interoperability remain largely fragmentary, and there is a lack of practical solutions in the broader market. At the same time, businesses witness a proliferation of "standards" and "standards"-producing organisations. Likewise, many well-known technology providers have established links with standards-producing organisations and switch links and emphasis depending on area, commercial interest, and

[1] "The ability of two or more systems or components to exchange information and to use the information that has been exchanged." Institute of Electrical and Electronics Engineers. *IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries*. New York, NY: 1990.
[2] http://cordis.europa.eu/ist/ict-ent-net/ei-roadmap_en.htm

convenience. Isolated initiatives lead to islands of interoperability, lacking in critical mass and wider application, potentially further compounding problems.

From a policy point of view, the i2010 Strategic Framework[3] recognises the importance of Enterprise Interoperability. This Framework is the logical link between the high-level goals of the Lisbon Strategy and more operational ICT-related actions. The Lisbon Strategy reflects the most fundamental insight of economic science that a well-functioning market will lead to high productivity, which is the key prerequisite to economic growth and social welfare. The i2010 Framework recognises that "businesses are getting productivity gains from ICT but still face a lack of interoperability, reliability and security, difficulties to reorganise and integrate ICT into the workplace and high cost of support". Interoperability is explicitly identified as one of the key bottlenecks that should be tackled by i2010 in order to make the European Union more competitive. The Strategic Framework also mentions that "the co-ordination of the Commission's research and deployment instruments will be enhanced by focusing them on key bottlenecks such as interoperability, security and reliability, identity management, rights management and ease of use."

The Seventh Framework Programme for research, technological development and demonstration activities (FP7, 2007-2013)[4] recognises that ICT is critical to Europe's future and underpins the realisation of the Lisbon agenda. Half of the productivity gains in Europe's economies are explained by the impact of ICT on products, services and business processes. ICT is the leading factor in boosting innovation and creativity and in mastering change in value chains across industry and service sectors.

Today, escalating economic and societal demands, together with the continued mainstreaming of ICT and the need to push further the technology limits, set a growing agenda for research. To bring technology closer to people and organisational needs means: hiding technology complexity and revealing functionality on demand; making technology very simple to use, available and affordable; providing new ICT-based applications, solutions and services that are trusted, reliable, and adaptable to the users' context and preferences.

In anticipation of FP7, many stakeholders believe that Enterprise Interoperability is an area where research can lead to outstanding results in terms of innovation, leading to economic growth and employment. This Roadmap is a contribution in that direction.

### 2.2. Objectives

The primary objective of the Roadmap is to define and characterise the areas of research in Enterprise Interoperability. The Roadmap is an input to FP7. Accordingly, it has a long-term perspective (7 year plus).

The Roadmap also aims at presenting a convincing and comprehensive case for Enterprise Interoperability, and at motivating stakeholders towards the research in Enterprise Interoperability.

### 2.3. Scope

The overall scope of the Roadmap covers those areas which relate to the interoperability of enterprises. These areas therefore include: why enterprises need to interoperate, how enterprises interoperate, as well as what constitutes interoperability as a capability. Intrinsic to the field of Enterprise Interoperability is that interoperability is a need; it takes place within the context and from the perspective of enterprises. Enterprises are the primary beneficiaries of Enterprise Interoperability solutions. Issues within the field of Enterprise Interoperability therefore cannot be abstracted from issues faced by enterprises.

[3] i2010 – a European Information Society for growth and employment, COM(2005) 229
http://ec.europa.eu/information_society/eeurope/i2010/i2010/index_en.htm
[4] "Building the Europe of Knowledge", proposal for a decision of the European Parliament and of the Council concerning the seventh framework programme of the European Community for research, technological development and demonstration activities (2007 to 2013), COM(2005) 119 final, 6 April 2005
http://cordis.europa.eu/fetch?ACTION=D&SESSION=&DOC=1&TBL=EN_DOCS&RCN=6797&CALLER=FP7_LIB

The present Roadmap is a research roadmap. Research is by its nature speculative and open-ended. It is carried out for the purpose of solving certain problems, within the context as described in the previous paragraph. Specifically, in conformance with its objectives, **this Roadmap targets break-through research for stimulating and catalysing business innovation.** This has several consequences.

First, the focus is on setting a strategic direction for the research in Enterprise Interoperability, with reference to the ambition of FP7 and within the overall policy context of i2010. This strategic direction is established, collectively, by the four Grand Challenges in this document. The research areas described by the Grand Challenges are not prescriptive, in respect of methods, techniques, solutions, the implementation of those solutions, the way in which those solutions are provided, and who are to provide those solutions. Therefore, indicated areas of research in this Roadmap are not put in time as in other roadmaps. Importantly, the scope of the research field as a whole is defined by the problems to be solved, and is not pre-determined by specific solutions to the problems – such solutions are the outcome of the research. **It is not the purpose of a research roadmap to pick business, technology or other winners**.

Second, the actual research work arising from the Roadmap must take into account the state-of-the-art, the state-of-play, and the state-of-practice, as a baseline of the research work. For Enterprise Interoperability, this includes, critically, available and emerging standards and publicly available specifications, as well as open source development (see further below). It is also vitally important that the research work is not decoupled from considerations of 1) the specific target users of the research results; 2) deployment issues, implementation aspects and take-up measures; and 3) the impact of the research and measurement of the impact. These are essential and complementary measures to the research, and should be duly reflected in the specific research plans that may be linked to this Roadmap.

Third, Enterprise Interoperability research cannot take place in isolation of research in neighbouring fields, many of which have also developed documents on strategic research direction. These neighbouring research fields include those within ICT for Enterprise Networking[5], to which Enterprise Interoperability belongs under the present Sixth Framework Programme (FP6), as well as those within Software Technologies[6], Grid Technologies[7], and New Working Environments[8]. In addition, the European Technology Platform "Networked European Software and Services Initiative (NESSI)"[9] has developed a strategic research agenda which identifies interoperability as a "cross-domain aspect" of its technology domains. Dialogue with these activities has already started in the course of developing this Roadmap, with a view to collaboration and synergy in the follow-up effort to the respective research areas identified in the Roadmap and other relevant publications.

Fourth, a research roadmap is one of several kinds of roadmap in the field of Enterprise Interoperability. Therefore, the present Roadmap could in principle be complemented by a technology roadmap, a standards roadmap, and one or more product roadmaps (for private companies). The objectives of these other roadmaps would be different, as for their focus and target audiences.

It is however fully recognised that there need to be close links between research and standards activities. Within the field of Enterprise Interoperability, standards are often a prerequisite to the initial adoption of particular products or services. It has been argued that, for research results to have a meaningful impact on standards, research and standardisation work would need to go hand-in-hand. Specifically, contribution to standardisation should be an integral part of research projects[10].

Equally, it is fully recognised that open source development is a key issue for interoperability. It has been suggested that open source reference implementation of standards has a positive impact on the validation and adoption of the standards, as well as the robustness of the standards-based software. Moreover, open source development creates entirely new business opportunities for SMEs in the

[5] http://cordis.europa.eu/ist/ict-ent-net/index.html
[6] http://cordis.europa.eu/ist/st/index.html
[7] http://cordis.europa.eu/ist/grids/index.html
[8] http://cordis.europa.eu/ist/ework/index.html
[9] http://www.nessi-europe.com/
[10] See the submission of Pim van der Eijk, OASIS, to this Roadmap, in Chapter 46 of Annex II (Disposition of Comments).

Enterprise Interoperability markets. On this view, open source development presents unique challenges for research[11].

In summary, the scope of this Roadmap has been carefully defined to support and stimulate the further development of research in the field of Enterprise Interoperability, without seeking to prescribe the details of the research, whilst attempting to reinforce the collaborative nature of research. The scope is positioned such that the Roadmap is ambitious, focussed, problem solving, and forward-looking. Enterprise Interoperability research must produce results that add value to enterprises.

### 2.4. Structure of this Document

This Roadmap comprises a main document divided into nine chapters and two annexes.

The main document includes an Executive Summary (Chapter 1), Introduction (Chapter 2) and a description of the Current Situation and Problem Space (Chapter 3). It then presents a Vision (Chapter 4) and four separate but inter-related Grand Challenges (Chapters 5 to 8), closing with Concluding Remarks (Chapter 9).

Annex I contains the description of a considerable number of Indicative Research Challenges. They are proposals of specific research that may be performed within the scope of one or more of the Grand Challenges. For ease of reference within the Grand Challenges chapters of the Roadmap, each Research Challenge is assigned and identified – see Section 4.5.

Annex II is a Disposition of Comments. These comments arose from open consultation on successive public draft versions of this Roadmap. They are broken down into 440 issues. A response is given to each issue. Both the comments and the responses provide further insight into the substance of the Roadmap, including additional information on the Grand Challenges. For ease of use, Annex II is available in two formats. The first is divided into chapters reflecting individual sets of submissions. The second is sorted by categories of issues.

### 2.5. History of this Document

The Roadmap document originates from the work of four research projects in the European Commission's Cluster on Enterprise Interoperability[12] and two additional research projects contributing to the cluster's work. These six projects (ATHENA, INTEROP, NO-REST and TrustCoM plus CrossWork and ECOLEAD) drafted the first public version of this document (Roadmap V1.0), which was published by the European Commission on 21 December 2005[13].

The European Commission held a public consultation workshop[14] on Enterprise Interoperability research on 10 January 2006, with Roadmap V1.0 as the input document. The report of this workshop is available[15].

Subsequent to the consultation workshop, the development of the Roadmap was broadened from an activity of the Cluster projects to an activity of all interested stakeholders in Enterprise Interoperability research. Further documents were prepared by four editors as voluntary experts in the field.

By agreement of the editors in consultation with the European Commission, the second public version of this document (Roadmap V2.0) focuses on the Vision and Grand Challenges for Enterprise Interoperability research. It is a partial draft of the full coverage envisaged for the Roadmap. Roadmap V2.0 was published by the European Commission on 15 March 2006[16].

[11] See the submission of Jean-Pierre Lorré, EBM WebSourcing, to this Roadmap, in Chapter 30 and Chapter 47 of Annex II (Disposition of Comments).
[12] http://cordis.europa.eu/ist/ict-ent-net/ei.htm
[13] ftp://ftp.cordis.europa.eu/pub/ist/docs/directorate_d/ebusiness/20051221_roadmap_v10.pdf
[14] http://cordis.europa.eu/ist/ict-ent-net/ws20060110.htm
[15] ftp://ftp.cordis.europa.eu/pub/ist/docs/directorate_d/ebusiness/20060110_report.pdf
[16] ftp://ftp.cordis.europa.eu/pub/ist/docs/directorate_d/ebusiness/20060315_roadmap_v20.pdf

An international consultation workshop[17] on Enterprise Interoperability research was organised by the European Commission during the I-ESA conference on 21 March 2006, with Roadmap V2.0 as the input document. The report of this workshop is available[18].

A complete draft of the Roadmap (Roadmap V3.0) was then developed. It combines the Grand Challenges of V2.0 with the indicative Research Challenges of V1.0. It also takes into account the results from the 10 January and 21 March 2006 consultation workshops, as well as the written comments and contributions received up to 31 May 2006. The Grand Challenges are described in the main document, the consolidated indicative Research Challenges in Annex I, and the written comments, further contributions, and their responses in Annex II, Disposition of Comments. Roadmap V3.0 was published by the European Commission on 6 June 2006[19]. Annex I, Indicative Research Challenges, was published on the same date[20]. Annex II, Disposition of Comments, was published on 28 June 2006[21].

The European Commission held the final public consultation workshop[22] on Enterprise Interoperability research on 16 June 2006, with Roadmap V3.0 as the input document. The report of this Workshop is available[23].

The output of the final workshop and further written comments and contributions that arrived after 31 May 2006 were extensively discussed and analysed by the editors. Following intensive activity, the Roadmap was finalised at the end of July 2006, in accordance with the original schedule. The present final version of the Roadmap (V4.0)[24] is published together with the final version of Annex I, Indicative Research Challenges[25], and Annex II, Disposition of Comments[26], by the European Commission.

The Roadmap, suitably adjusted, will be published in book form by the European Commission as a DG INFSO Directorate D[27] publication in the autumn of 2006.

[17] http://cordis.europa.eu/ist/ict-ent-net/ws20060321.htm
[18] ftp://ftp.cordis.europa.eu/pub/ist/docs/directorate_d/ebusiness/ws20060321_report_en.pdf
[19] ftp://ftp.cordis.europa.eu/pub/ist/docs/directorate_d/ebusiness/20060606_roadmap_v30_en.pdf
[20] ftp://ftp.cordis.europa.eu/pub/ist/docs/directorate_d/ebusiness/20060606_roadmap_v30_annex_1_rcs_en.pdf
[21] ftp://ftp.cordis.europa.eu/pub/ist/docs/directorate_d/ebusiness/20060606_roadmap_v30_annex_2_doc_en.pdf
[22] http://cordis.europa.eu/ist/ict-ent-net/ws20060616.htm
[23] ftp://ftp.cordis.europa.eu/pub/ist/docs/directorate_d/ebusiness/ws20060616-report_en.pdf
[24] ftp://ftp.cordis.europa.eu/pub/ist/docs/directorate_d/ebusiness/ei-roadmap-final_en.pdf
[25] ftp://ftp.cordis.europa.eu/pub/ist/docs/directorate_d/ebusiness/ei-roadmap-final-annex1_en.pdf
[26] ftp://ftp.cordis.europa.eu/pub/ist/docs/directorate_d/ebusiness/ei-roadmap-final-annex2_en.pdf,
and sorted by category: ftp://ftp.cordis.europa.eu/pub/ist/docs/directorate_d/ebusiness/ei-roadmap-final-annex2-cat_en.pdf
[27] European Commission Information Society and Media Directorate-General, Directorate D Network and Communication Technologies

# 3. Current Situation and Problem Space

## 3.1. State of the art

This section presents a general overview of the state-of-the-art in Enterprise Interoperability. One may argue that Enterprise Interoperability covers a number of areas, each of which has its own state-of-the-art. This section does not aim to list all these areas, or to give a complete overview of the state-of-the-art in each area[28]. Certain standards, specifications and organisations are mentioned, as examples only. Their inclusion or otherwise implies no judgement.

Nowadays, enterprises are accustomed to establish business relations and cooperate with other enterprises. One of today's trends is the increasing cooperation among enterprises during the entire product life cycle. This is related to business drivers, such as the need for cost reduction, flexibility, product innovation, focus on core competencies, and so on. The result is anything from a rather stable alliance between partners as in a supply chain to a more transitory cooperation as in a virtual enterprise[29]. Business ecosystems emerge in which organisations cooperate and compete within an inclusive framework that adapts, evolves and sustains.

Some frameworks provide architectural guidelines that support the interoperability of inter-enterprise systems, such as the RosettaNet Framework, the OAG Integration Specification, and FIPA's architecture and associated set of specifications for distributed, communicating software agents. Among the most well-known is ebXML, a set of specifications supported by OASIS and UN/CEFACT, and proposed by a large group of businesses, government standards committees and academics to enable a well structured electronic business framework. The vision of ebXML is to enable a global electronic marketplace where enterprises of any size and in any geographical location can meet and conduct business with each other through the exchange of XML-based messages.

Almost every established industry sector has set up organisations that have developed sector specific specifications for business-to-business (B2B) transactions within the industry. Examples of such organisations are ODETTE in automotive, CIDX in chemical, GS1/UCC in retail, EURATEX in textile, HL7 in healthcare, IAI in construction, OTA in travel, and PIDX in petroleum.

On the technical side, the Service Oriented Computing paradigm and Service Oriented Architectures (SOA) have emerged as an evolutionary step from Object and Component based approaches, with the promise to overcome the deficiencies of past solutions, real or perceived. Service Oriented Architecture is a paradigm for organising and utilising distributed capabilities that may be under the control of different ownership domains. The perceived value of SOA is that it provides a framework for matching needs and capabilities and for combining capabilities to address those needs. While both needs and capabilities exist independently of SOA, in SOA, services are the mechanism by which needs and capabilities are brought together[30].

Three major trends in Service Oriented Computing can be discerned, namely Web Services, Grid Services and peer-to-peer (P2P) services. Web Services build upon XML standards to provide a coherent platform for building loosely coupled distributed applications. The key theme to Web services is on-the-fly service creation through the use of loosely coupled, reusable software components. Today, a large number of standardisation and standards-related initiatives in the Web Services area can be reported[31]. Grid Services on the other hand originate from the requirement of Grid Computing

[28] For state-of-the-art descriptions of various areas within Enterprise Interoperability, the reader is referred to e.g. "Second Version of State of the Art in Enterprise Modelling Techniques and Technologies to Support Enterprise Interoperability", February 2005, available for download at http://www.athena-ip.org/; "State of the art and state of the practice including initial possible research orientations", November 2004, available for download at http://www.interop-noe.org; "State-of-the art for Interoperability architecture approaches", December 2005, available for download at http://www.interop-noe.org; "State of the Art Evaluation", June 2004 and updated in December 2005, available for download at http://www.eu-trustcom.com/.

[29] For an overview of Network and Virtual Organisation topologies, see "Challenges in Virtual Organisations Management", available for download at http://www.ecolead.org.

[30] Source: OASIS SOA Reference Model, http://www.oasis-open.org/committees/download.php/18486/pr-2changes.pdf

[31] See for instance "State of the Art Evaluation" (available for download at http://www.eu-trustcom.com/); W3C http://www.w3.org/; OASIS http://www.oasis-open.org/; and an overview of OASIS Technical Committees relevant to this document in Chapter 15 of Annex II (Disposition of Comments).

to standardise the interface mechanism for accessing distributed computational (grid) resources. Those resources have moved away from solely computing power – as in the original Grid definition – to include software, data, knowledge and capabilities. Although P2P computing has had many successes till now, it still lacks consensus on how applications should be built and what semantics should be supported, thus rendering the notion of P2P services the vaguest of the three.

There are several middleware solutions on the market that embody parts of integration brokering, business process management, and application development platform functionality. Examples of commercial solutions are IBM WebSphere, Microsoft BizTalk, Oracle Fusion, and SAP NetWeaver. Examples of open-source software solutions are JOnAS by the ObjectWeb consortium, Tomcat and Geronimo by the Apache Software Foundation, and Eclipse by the Eclipse Foundation. These solutions offer (partial) support in Enterprise Application Integration and business process integration.

The state-of-play in deploying services is usually (somewhat roughly) bundled under the term "Web 2.0". Web 2.0 is characterised by the development of "lightweight" software from standard technology building blocks that can be released quickly over the Web, then learn from the experience of early users to refine the service. For Web 2.0 advocates, just a couple of engineers are needed to build something interesting and compelling. In addition, "mashup" technologies use public APIs of firms with given infrastructures or databases to provide new services. Web 2.0 has been closely linked to the increasing availability and falling prices of broadband communications. The broadband era is giving rise to new opportunities for collaborative development of software, leading to rapid prototyping, wide experimentation, faster time-to-market, and entirely new business models. These developments can dramatically lower the entry barrier for SMEs/micro-enterprises/individuals to enter into new businesses and create new markets.

The Semantic Web intends to create a universal medium for information exchange by putting documents with computer-processable meaning (semantics) on the World Wide Web. The Semantic Web comprises the standards and tools of XML, XML Schema, Resource Description Framework (RDF), RDF Schema, and Web Ontology Language (OWL)[32].

Semantic Web Services aim to combine concepts of the Semantic Web with Web Services technologies. The Web Service Modelling Ontology (WSMO) is a formal ontology for describing various aspects related to Semantic Web Services. The objective of WSMO is to define a coherent technology for Semantic Web Services by providing the means for semi-automated discovery, composition and execution of Web Services based on logical inference mechanisms[33]. Furthermore, enlarging the notion of SOA by applying Semantic Web Service technology and using ontologies and Semantic Web markup languages to describe data structures and messages passed through Web service interfaces, lead to the development of Semantically-enriched Service-Oriented Business Applications[34].

The semantics of real-world objects are described via a (domain) ontology, which Gruber defines as "a formal, explicit specification of a shared conceptualisation"[35]. The elements that compose an ontology can be seen distributed over three layers: upper level ontology, which incorporates the most general domain concepts[36]; an application ontology layer, which incorporates the specific concepts of the application domain[37]; and a lower level ontology, which incorporates attributes and other elementary concepts that are used to compose higher level concepts. In addition, ebXML Core Components are sets of semantic building blocks that represent the general types of business data in use today and provide for the creation of new business vocabularies and restructuring of existing business vocabularies[38].

[32] Source: http://en.wikipedia.org/wiki/Semantic_web
[33] See ESSI WSMO Working Group, http://www.wsmo.org/
[34] See FUSION, FP6-027385, http://www.fusionweb.org/
[35] T.R. Gruber. (1993). Towards Principles for the Design of Ontologies used for Knowledge Sharing. In: Proceedings of the International Workshop on Formal Ontology (N. Guarino (ed.)), Padova, Italy.
[36] See for example SUMO (Suggested Upper Merged Ontology) by the IEEE Standard Upper Ontology effort, http://suo.ieee.org/ and http://www.ontologyportal.org/; and the ontology of Sowa http://www.jfsowa.com/ontology.
[37] See for example the TOVE ontologies for enterprise modelling, http://www.eil.utoronto.ca/tove/ontoTOC.html; the AIAI Enterprise Ontology, http://www.aiai.ed.ac.uk/project/enterprise/enterprise/ontology.html; and the DIP Business Data Ontology, http://dip.semanticweb.org.
[38] See http://www.unece.org/cefact/ebxml/CCTS_V2-01_Final.pdf

Several modelling and notation, and process languages are available to describe business processes and their execution. WS-BPEL, the Business Process Execution Language for Web Services, currently drafted in an OASIS Technical Committee, is generally considered one of the most promising. WS-BPEL provides a language to specify business processes that are composed of and exposed as Web Services. It specifies business process behaviour based on Web Services, i.e. it can be seen as a (business) extension to the Web Services paradigm.

Over 300 Enterprise Modelling languages and tools are available to support Enterprise Modelling with partially overlapping approaches[39]. Enterprise Modelling can be defined as the art of "externalising" enterprise knowledge, i.e. representing the enterprise in terms of its organisation and operations (e.g. processes, behaviour, activities, information, object and material flows, resources and organisational units, and system infrastructure and architectures). The goal is to make explicit knowledge that adds value to the enterprise or can be shared by business applications and users for improving the performance of the enterprise. Today, the first attempts to combine languages are recognisable[40].

Enterprises wishing to cooperate and interoperate with each other will inevitably run into trust and contract management issues. Regarding contracts and Service Level Agreements to formalise inter-enterprise cooperation, two basic types of activities can be discerned. Firstly, there is work that aims to provide support for managing legal contracts between organisations and automate part of the process associated with their definition and enforcement (e.g., Business Contracts Architecture). Secondly, there is work that originates from the network and systems management community relating to customer-provider relationships and the Quality of Service promise associated with a (Web) service (e.g. WSLA, GRASP SLA framework, HP's Web Service Modelling Framework, WS-Agreement). In addition to the above, one could mention SLAng and ebXML's Trading Party Agreement and Collaboration Protocol Agreement[41].

### 3.2. Problem Space

The past decade has seen significant advances to Enterprise Interoperability, particularly those related to ICT infrastructure aspects. For example, the Internet (and browser technology) has facilitated the search for information, and the exchange of information among enterprises. It has also contributed to the creation of new business models of Enterprise Interoperability. In addition, a number of software suppliers (e.g. IBM, Microsoft, Oracle and SAP) have gained a de facto ascendancy in the enterprise software market, contributing to the integration and efficiency gains of enterprise functions. However, questions remain about the impact and significance of these vendor-based solutions to Enterprise Interoperability. More than a decade after Enterprise Interoperability issues have been raised and discussed within various communities, interoperability is still a problem for enterprises. Islands of interoperability persist. Integration projects remain complex and expensive. The business case for interoperability is often not apparent to potential adopters of Enterprise Interoperability solutions, particularly for SMEs. Various technologies and tools resulting from research lack follow-up beyond (further) research. Large question marks remain as regards the "value" and "impact" of the myriad of initiatives undertaken within the research lab, promoted by technology providers, or organised around groupings of companies.

In seeking to characterise the current problem space for Enterprise Interoperability, we have identified the following relevant dimensions:

- Managing more rapid change/innovation
- Adapting to globalisation
- Large integration/interoperability costs
- Difficulties in decision making (e.g. when to interoperate with other enterprises)
- Lack of business case for Enterprise Interoperability
- A change in the model of collaboration towards open innovation.

[39] See "Second Version of State of the Art in Enterprise Modelling Techniques and Technologies to Support Enterprise Interoperability", February 2005, available for download at http://www.athena-ip.org/.
[40] See for example the Unified Enterprise Modelling Language initiative (UEML, IST-2001-34229, and INTEROP, FP6-508011), which proposes a more integrated approach for exchange of enterprise models among Enterprise Modelling tools.
[41] See "State of the Art Evaluation", June 2004 and updated in December 2005, available for download at http://www.eu-trustcom.com/.

These dimensions are described in the paragraphs below and help justify the Vision (see Chapter 4) and Grand Challenges (see Chapters 5 – 8) in this Roadmap.

Perhaps the most important issue facing enterprises today is that the **pace of change and innovation** has accelerated. This represents a challenge and an opportunity to enterprises. Indeed, managing the process of innovation belongs to the core of our Vision. The acceleration of the process of creative destruction means that tastes and market demand change more rapidly. In these conditions, the recognition of threats and opportunities to the existing business model, a high degree of flexibility by firms, and a greater readiness to adapt the enterprise strategy have become critical. However, such process of change has proven difficult to be mastered. Large hierarchical-type enterprises have had difficulties in recognising changes in their market, and in flexibly managing this change process within the firm. On the other hand SMEs, while typically more flexible, have often insufficient resources to monitor market changes and to invest to adapt their businesses to these changes. Furthermore, the process of managing change in the context of Enterprise Interoperability has not been based on scientific concepts and principles, and has often been carried out in an ad hoc manner. It is costly and difficult to create novel enterprise relations to address new business opportunities in a timely manner. In particular SMEs, given their overall lack of sufficient "interoperability", have a great need for "adaptable interoperable solutions" to better cope with this changing business environment.

This process of managing change and innovation is essential for wealth creation in advanced economies. Only Enterprises that are able to successfully innovate will be able to survive in the long run. An indication of the capacity of an economy to renew and change (improve) itself are the revenues derived from new products and services. This is a measure of technological prowess and economic dynamism and performance in advanced economies. The measure offers a number of advantages relative to other performance indicators such as the ratio of R&D spending to sales[42]. In addition, revenues from new products and services measure output of the production process rather than input to the production process, and are thus more results oriented. New products were in the past the areas where firms in advanced countries were able to achieve revenue and profit growth.

The second issue is **globalisation**. The growing integration of economies has contributed to raising competition worldwide in a number of industries and services, and has resulted in increasing pricing pressure and efficiency requirements in most industries. Increasingly, thanks to ICT, SMEs (including some very small high-tech enterprises) are able to have international operations or conduct business transactions with other international businesses. While the media focus has been on the dangers of outsourcing or of delocalisation to lower wage countries, little attention is given to regional delocalisation. The wage disparities between regions of countries, and the availability of qualified knowledge workers in non-urban regions of high wage countries, suggest there are growing opportunities for enterprises of advanced countries of the EU to better leverage their resources and benefit from regional based cost differences. Unfortunately, this process of globalisation has often required the development and use of proprietary, complex, expensive project specific solutions, which are out of reach for many SMEs. So what methodologies and tools are needed to support Enterprise Interoperability in the context of globalisation, in particular solutions that allow enterprises to build and concentrate resources on value enhancing areas of activity, while interoperating with other firms in areas of activity where it is not the most cost efficient?

Thus, the enterprise challenge of managing change and innovation and the challenge of managing the increase in competitiveness brought about by globalisation is likely to grow in importance in the near future, particularly for SMEs, which do not have the large R&D budgets available to the largest corporations and have more limited capability to interoperate with other enterprises (if at all). In that sense, an aim of the research agenda proposed in this Roadmap is to develop solutions that facilitate the tasks of enterprises in managing change and innovation, and that increase enterprise competitiveness. With improved Enterprise Interoperability solutions based on Web Technologies, it is expected that it will become easier and less costly for SMEs to transform new product ideas into new products and services generating new revenues, and it will be possible for enterprises to more confidently adopt Enterprise Interoperability solutions with the goal of increasing their global competitiveness.

[42] A recent Booz, Allen and Hamilton study argues that R&D spending is a poor predictor of future (sales and margin growth) performance (Jaruzelski, Dehoff, and Bordia, Winter 2005, "The Booz Allen Hamilton Global Innovation 1000: Money Isn't Everything", *strategy+business*, Issue 41).

The third issue is the **large costs** associated with integration of ICT systems and the costs of (electronic) interoperability with other firms, and in addition the long lead time and technical risk associated with such projects. ICT projects that require a high degree of system integration are often the most complex and risky type of projects, as evidenced by the cost overruns in some high visibility projects (e.g. Toll Collect project in Germany for highways, and the US Federal Aviation Administration (FAA) Air Traffic Control modernization project, a project expected to be completed $39 Billion over budget and 20 years late[43]). Thus, to minimize risks, enterprises have tended to adopt solutions of leading software providers, to choose established system integrators, or to avoid risky system integration projects altogether. In summary, integration costs, delays, and risks represent an important obstacle to the implementation of Enterprise Interoperability solutions. Recent years have seen an increasing number of Enterprise processes migrate to solutions based on Web technologies, which offer standardised interfaces, flexibility, while minimising integration costs. But despite the availability of numerous proprietary solutions, integration costs remain high and Enterprise Interoperability is lacking adequate technical solutions.

The fourth issue concerns **decision making**. Managers also face difficulties in making decisions related to Enterprise Interoperability. The setup of transactions between enterprises has traditionally been accomplished only after face-to-face negotiations between agents representing both enterprises. It continues to be so to a large extent. Most decisions related to transactions between enterprises require the intervention of human managers who, given their experience, knowledge, and intuition, are better able to form informed decisions in the context of new business interactions, and are better able to recognise the value and the business case in the transaction with another enterprise. For example, most transactions between enterprises build on personal knowledge and trust between the managers of the different firms.

It has been far more difficult to codify such transactions in the context of ICT systems. Particularly, manager intervention has typically been necessary for transactions that require tacit knowledge, i.e. knowledge that has not been described, and for business problems that are novel or different from the norm of past problems and require the development of novel solutions. ICT systems have also been unable to deal with new or changed environments and complex communications, such as understanding ideas, evaluating their social significance, and negotiating and persuading[44]. The time dimension is also important in that enterprises have changing needs to interoperate over time. Thus far, in most fields (with the notable exception of financial markets), the difficulties in enhancing decision making with support of ICT for Enterprise Interoperability have proven insurmountable. Yet this need not be so. Better tools, information and methodologies/guidelines can be developed to aid managers in Enterprise Interoperability decision making.

It is a well known fact that there is substantial enterprise value in information, particularly in the case of privileged access to information. Throughout history business success has often hinged on having access to restricted valuable information or knowledge. However, the volume of information that is being generated is overwhelming. Currently, every year mankind is generating novel unique information that in quantity surpasses all written information generated in 40 thousand years of civilised history[45]. The hypothesis that business success often depends on decision makers (managers) having timely (i.e. "real-time") access to the right information and knowledge, that today's information (and by inherence knowledge) is accessible to any enterprise worldwide, and that unprecedented information quantities are being created yearly, have stark implications for Enterprise Interoperability. Current ICT systems are not prepared to deal with this much information. Likewise, while enterprises have been substantially more agile in managing new information, they are also unprepared for environments where so much information is being generated every year.

The fifth issue is the perception that Enterprise Interoperability is a fuzzy concept without a clear **business case**. Organisations lack examples of successful cases, best practices, and guidelines about where most value is created through Enterprise Interoperability. The complexity of Enterprise Interoperability operations from a legal and logistical perspective has been overwhelming, particularly

[43] United States General Accounting Office, October 30, 2003, "Testimony Before the Subcommittee on Aviation, Committee on Transportation and Infrastructure, House of Representatives: AIR TRAFFIC CONTROL FAA's Modernization Efforts—Past, Present, and Future".
[44] Shiller, May 2006, "Career Counseling for the 21st Century", Project Syndicate
[45] Deshmukh, 2006, "Enterprise Systems Research at the National Science Foundation: Information Big Bang", National Science Foundation, presented at Enterprise Interoperability workshop, Bordeaux, 21 March 2006, available for download at ftp://ftp.cordis.europa.eu/pub/ist/docs/directorate_d/ebusiness/ws20060321_deshmukh_en.pdf

in an international context. For enterprise decision makers, with competing priorities, scarce resources and limited time, venturing into solutions for Enterprise Interoperability has not been a realistic option.

Finally, **Open Innovation** is a terminology coined by Henry Chesbrough in his 2003 book with the same title[46]. Chesbrough argues that companies today are no longer restricted to their own pool of ideas but are able to pick and choose the best ideas from a more diverse source, be it outside suppliers and consultants, other firms' products (e.g. Google and mashup technology), joint R&D projects with other firms, or embracing the open-source movement (e.g. IBM and Lunix), in effect enhancing their process of innovation. So the fundamental concept here is one of openness, to enable a richer set of competing ideas on which to base innovation projects, enhancing the potential value of the projects, while sharing risk and costs. This concept is related to community aspects such as grass root development and social networks, and has a strong SME dimension.

In summary, there are numerous challenges to adopting Enterprise Interoperability solutions. There is a lack of functioning solutions, and there is a lack of evidence of the value of Enterprise Interoperability. The Grand Challenges in this Roadmap aim to address and overcome these deficiencies.

[46] Chesbrough, 2003, "Open Innovation: The New Imperative for Creating and Profiting from Technologies", Harvard Business School Press

# 4. Vision

## 4.1. Vision Statement

We envision a future in which the business environment will comprise a diversity of continuously evolving "ecosystems" of enterprises, within and across which enterprises will collaborate as well as compete with one another. Enterprises, both big and small, will be able to do business seamlessly, adapt to changes in the environment dynamically, and exploit new opportunities rapidly by harnessing the full potential of software and related IT services. Interoperability of enterprises will be a key feature within each ecosystem, and across the ecosystems. From an IT perspective, interoperability will be a utility-like capability that enterprises can invoke on the fly in support of their business activities. Specific IT functions will be delivered as services that are cheap, fast, reliable, and without major integration efforts. IT will become a routine, and not a problem. It will be a transparent and invisible part of the business operation.

## 4.2. Vision Description

Enterprises are spurred to innovate by pressures and challenges, notably competition and the desire to create new market space. With the increased access to information worldwide, cheaper telecommunications, and the global markets for labour and capital, knowledge and information can be transported instantaneously around the world. Consequently, any advantage gained by one enterprise can be rapidly eliminated by competitive improvements elsewhere. The only comparative advantage an enterprise will enjoy will be its **process of innovation.** That process will combine the knowledge of markets and technology with the knowledge and talents of creative workers to create new products and services that add value to its customers, its employees, and its shareholders.

By focussing on the core innovation and information-centred activities, enterprises will have an even greater need to develop knowledge and links with other companies in order to provide the products and services that the market demands, or to create a new market space. **Enterprises need to collaborate in order to compete.** They also need to maximise their flexibility and speed in order to transform business ideas and propositions into offerings that generate new revenues or new revenue streams.

Successful enterprises in the future will likely be nimble, but highly productive. They will be focussed on innovation and information exploitation. They will establish numerous knowledge links to other enterprises with which they can combine rapidly and flexibly to respond to market changes or to create new markets. The size of an enterprise will matter far less than its **ability to collaborate**, its **ability to adapt**, and its **ability to interoperate**. Moreover, there will be many different forms of collaboration. For example, enterprises will link closely where there are opportunities to create value by leveraging shared capabilities, and loosely where the greater value lies in differentiated focus.

In this future, enterprises constituting an ecosystem are continuously evolving and adapting to respond to market changes on the basis of rich descriptions of their past operations, their presently available services, and their potential business performance and legal constraints. New enterprises are dynamically created to take advantage of new business opportunities. The interoperability of these enterprises is mediated by ICT.

In this future, where enterprises exist as nodes in innovation ecosystems, the issue of interoperability will no longer be limited to the silos within single enterprises. Instead, it will become an issue that spans all enterprises throughout and across the entire innovation ecosystems. Hence, **enterprise interoperability** will be a key feature of the **business fabric** of all ecosystems. Furthermore, the technology solutions that support Enterprise Interoperability must operate within a legal and regulatory framework underpinned by **policy**. Specifically, these solutions must (1) be readily available and at a cost affordable by all enterprises, (2) produce tangible business and economic value and impact on all users, and (3) act as an essential enabler for enterprises to innovate and to grow. A sustained policy effort is needed to ensure that optimal conditions are available to achieve an open, transparent and equitable market for the supply and provisioning of these technology solutions.

Successfully addressing the research challenges needed to realise this vision will produce the following benefits, which are in principle subject to measurement and verification:

- An increase in enterprise flexibility
- A decrease in the barriers to enterprise collaboration
- An increase in an enterprise's ability to exploit new business opportunities
- A decrease in the cost of interoperability
- A decrease in time to market for new innovations
- Increased access to new markets (geographic and product/service space)
- Increased access to technologies, knowledge, skills and information
- Improved quality of ICT solutions, and ICT-enabled products and services
- Improved performance measurement
- A decrease in the barriers to geographically distributed team work
- Increased access to innovation ecosystems, particularly for SMEs.

### 4.3. The Research Context

The ICT industry is changing rapidly. Offerings are moving from products to services. Pricing is moving from licensing to pay per use. Traditional sectors and application domains are maturing and commoditising; they are not areas of growth for Europe. Functions are moving from the enterprise to the Internet and to the Web, which is undergoing a dramatic change of its own.

Developments characterised by the term "Web 2.0", for example, could potentially open up entirely new business areas and new markets by leveraging the capability of software and IT-enabled services. "Web 2.0" itself is also a prime example of an innovation-centric ecosystem. The message from the market is clear: **a single, monolithic solution for Enterprise Interoperability rested on proprietary protocols and captive markets is untenable in a climate of change, unworkable in real businesses, and strategically undesirable for promoting innovation and growth**. Open, competitive and transparent markets are essential. The stage for the next generation of Enterprise Interoperability research is set.

Enterprises must innovate in order to survive. Innovation is by its very nature disruptive. The 2nd Pillar of the i2010 Strategic Framework[47] explicitly links innovation with investment in ICT research. An over-riding focus is the management of innovation and creation of value in the full cycle of ICT research – from the initial generation of ideas to the final shipment of R&D results to the market. In respect of the present Roadmap, therefore, the answers to four questions become strategically important: (1) What does innovation mean for enterprises? (2) What support does Enterprise Interoperability provide for innovation? (3) What value does Enterprise Interoperability bring to businesses, the economy, and society? (4) What research should be funded to enable the next generation of ICT solutions that support and catalyse enterprise innovation?

There is an increasing opinion from both public and private sectors that research for research sake is an insufficient justification for financing. Research needs to be relevant for industry. ICT research needs to show that it has impact and especially benefits beyond the ICT community itself ("mainstreaming of ICT research"). Both impact and the value created for enterprises must be tangible, measurable and verifiable. The large volume of research and statistics correlating ICT deployment with productivity growth is an example of responding to such issues.

Based on the preceding remarks, we conclude that Enterprise Interoperability research:

- Should be decoupled from the business models of existing supply side incumbents
- Should not replicate what already exists or is in the pipeline
- Should not reinvent what is in principle already achievable on the market
- Should focus on problem-solving, rather than pure theoretical pursuits, so that Enterprise Interoperability solutions result that are directly beneficial, applicable, and easy to use
- Should focus on the public interest aspects of Enterprise Interoperability, in particular the infrastructural aspects that all stakeholders could exploit (but which private organisations would be reluctant to finance or to build individually)

[47] See footnote 3.

### 4.4. The Research Framework

In order to encompass the full problem space for the enterprises, we have adopted a broad framework in positioning the individual Research Challenges, as shown in Figure 1.

The framework identifies the dimensions within which we define and position the Research Challenges.

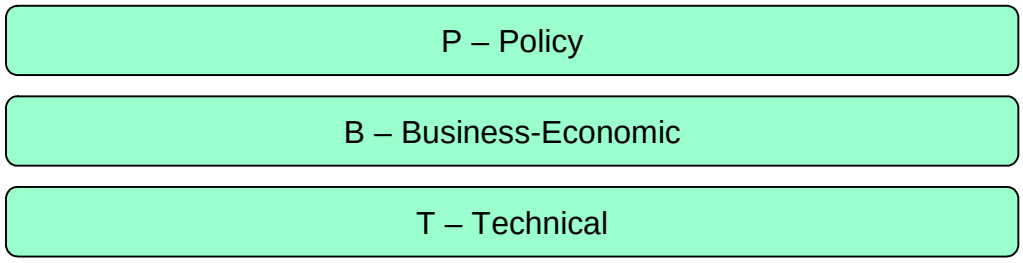


**Figure 1 Framework for Research Challenges**

It needs to be emphasised that the three dimensions are mutually interdependent and reinforcing. Starting from the Vision, it is possible to depict the relationships between these dimensions in different sequences, as shown in Figure 2.

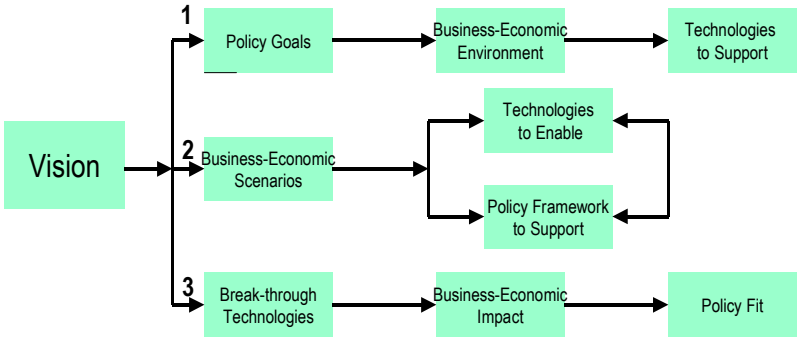


**Figure 2 Relationships between the Dimensions**

The use of each the three sequences can yield different formulation of research challenges. For the purpose of this document, we can summarise the sequence as follows:

Sequence 1: Start from the stated policy goals, review developments in the business-economic environment. Set targets in this environment. Consider the technologies needed to support businesses to reach the business-economic targets. Derive research challenges in the sequence of policy – business-economic – technical.

Sequence 2: Start from a set of business-economic scenarios for a future timeframe, ideally based on direct inputs from individual industry sectors. Review technology developments and prioritise the technologies needed to help realise the scenarios. Review the policy framework and prioritise the policy measures needed to help realise the scenarios. Ensure that the technology developments and policy measures are mutually complementary. Use policy measures to stimulate the development of particular technologies if needed. Derive research challenges in the sequence of business-economic – technical + policy.

Sequence 3: Identify the "break-through" technologies. Assess their ("disruptive") impact on businesses. Ensure that policy measures are supportive of the development of the technologies and use policy measures to alleviate any negative business-economic impact that the break-through technologies may create. Derive research challenges in the sequence of technical – business-economic – policy.

It needs to be stressed however that, regardless of which sequence is being considered, there is no question of one dimension taking precedence of (being "more important" than) others. In modern

society, policy, business-economics and technology issues are inter-related and often intertwined, even though they do pose different questions:

- Should we? (i.e. what is the business-economic value?)
- Can we? (i.e. what is the technology?)
- May we? (i.e. what are the policy and governance measures?)

For the purposes of this Roadmap, and in order to emphasise the industry relevance of the research, we propose Sequence 2 as the main orientation. This underpins the choice and description of the Grand Challenges and the detailed Research Challenges that are presented in the present Roadmap.

### 4.5. The Grand Challenges and Research Challenges

In this Roadmap, we propose four Grand Challenges to give a strategic direction to the research work as a whole. A Grand Challenge is a global domain of research for reaching the vision.

In recognition of the state-of-the-art and the problem space (Chapter 3), and based on the Vision presented above, the development of the Grand Challenges have been guided by the following principles:

- The public interest dimension of Enterprise Interoperability as a strategic element of innovation ecosystems
- The needs of end users of technologies and related services in enterprise networking, leading to research activities that have tangible impact above and beyond research
- SMEs as the backbone of European industry and the unique contribution of SMEs to innovation
- The need to open up the field of Enterprise Interoperability research by linking with other scientific domains and communities
- The need to reinforce and strengthen international co-operation in research, from ideas generation to collaboration at project and possibly even at programme level.

The four proposed Grand Challenges are:

- Interoperability Service Utility
- Web Technologies for Enterprise Interoperability
- Knowledge-Oriented Collaboration
- A Science Base for Enterprise Interoperability

Each Grand Challenge is structured into a strategic view, a problem statement, and new ideas. Under new ideas, *example* Research Challenges are indicated[48]. A Research Challenge identifies the specific research activity that may be performed in support of the Grand Challenge.

We believe that the above Grand Challenges are complementary to one another. Therefore, the same specific Research Challenge may contribute to one or more Grand Challenges. On the other hand, the particular requirements of the Grand Challenges may lead to the Research Challenges being tackled differently, potentially yielding "competitive" results. Alternative and indeed competitive Research Challenges to those indicated are also entirely possible. It is apposite to reiterate that it is not the purpose of a research roadmap to pick business, technology or other winners – the same vision could be realised with different scenarios, using other means. The point is to explore what is possible; and then, on the basis of the research results, to consider and determine what is optimal.

The Grand Challenges are presented in Chapters 5 - 8. The indicative Research Challenges are presented in Annex I.

[48] Research Challenges are identified by the dimension in which they are positioned in the framework of Section 4.4, i.e. P(olicy), B(usiness-economic) and T(echnical), followed by a number in accordance with the numbering scheme of Annex I.

## 5. Grand Challenge: Interoperability Service Utility

### 5.1. Strategic View

This Roadmap envisions a diversity of continuously evolving ecosystems of enterprises. Interoperability of enterprises will be a key feature both within and across such ecosystems. Specifically, interoperability will be a **utility-like** capability for enterprises, a capability that is:

- Available at (very) low cost
- Accessible in principle by all enterprises (universal or near-universal access)
- "Guaranteed" to a certain extent and at a certain level in accordance with a set of common rules
- Not controlled or owned by any single private entity.

Continuous utilisation and commoditisation has been a basic feature of technology advancement. In the field of IT, this means that the basic functionality of IT should be made available to all enterprises comprehensively and non-discriminately. As IT becomes embedded into the business and economic fabric of society, that functionality should be a routine, a "given" – and not a costly luxury – for business and economic operations. Interoperability of enterprises is quickly becoming a part of this functionality, a fundamental premise that all enterprises can leverage. From the perspective of enterprises as users of IT, more and more IT capabilities will become the *context* for business, not the *core value* of business. In accordance with our Vision (see Chapter 4), interoperability as a utility-like capability is essential for enabling business innovation and value creation. The present Grand Challenge is concerned with the realisation of this proposition.

We use the term Interoperability Service Utility (ISU) to denote the overall system that provides enterprise interoperability as a utility-like capability. That system comprises a common set of services for delivering basic interoperability to enterprises, independent of particular IT solution deployment. The utility metaphor is to indicate that enterprises should be able to expect and afford basic, interoperable IT as a critical infrastructure for operation, just as water, electricity, and indeed the Internet and the Web[49].

The ISU is envisaged to be particularly useful and attractive for SMEs and start-up companies.

### 5.2. Problem Statement

Although most firms in the EU-25 are connected to the Internet (91.1% in 2005), only a minority use e-business solutions for linking internal processes (33.5% in 2005); and an even smaller minority use e-business solutions for linking with business partners (15.1% in 2005). Moreover, the gap between the use of e-business between SMEs and large enterprises remains substantial: only about 30% of the firms that use (mostly basic) e-business solutions are SMEs. Use of enterprise integration systems among all EU-15 firms is tiny – 10.2% use such systems to integrate with suppliers and 9.3% use such systems to integrate with customers[50].

These figures illustrate that the use of IT in business is far from routine for European enterprises. **The use of IT to support business relations is the exception, rather than the norm**. Moreover, while SMEs comprise the vast majority of European enterprises, **SMEs use of e-business solutions is particularly an acute problem**[51].

Open consultation with stakeholders, in the context of developing this Roadmap, strongly affirms that SMEs must collaborate in order to survive. Moreover, **Enterprise Interoperability can increase the**

[49] Another metaphor that has been used in this context is "plug and play business".

[50] Source of all figures in this paragraph: Eurostat, quoted in the Commission Staff Working Paper annexed to "i2010 – First Annual Report of the European Information Society", COM(2006) 215. The Working Paper also indicates that the corresponding figures in the US are higher.
http://ec.europa.eu/information_society/eeurope/i2010/docs/annual_report/sec_2006_604_en.pdf

[51] It should be further noted that businesses with less than 10 employees (micro enterprises) make up almost 90% of all European enterprises. In addition, the indications are that large enterprises are increasingly becoming an aggregation of specialised entities operating like SMEs.

**capability of SMEs to join new markets**[52]. However, there are huge differences between SMEs and large enterprises. These differences include: (1) the benefits of interoperability are not self-evident; (2) the entry barriers for SMEs to join collaboration networks and enter new markets remain high; (3) the fear of losing control through collaboration and interoperability is paramount, given the SMEs' lack of "clout" and negotiation power; (4) the time, effort and expenses needed to make use of IT is disproportionate to the size and scope of their operation; and finally, (5) SMEs are extremely diverse entities for whom a one-size-fits-all solution would not be appropriate.

The SME issues point to a more fundamental problem about the role and exploitation of IT in the enterprise's process of innovation. **Full alignment between technical capability and business need is still largely missing.** Considerations of business needs are secondary to those of technical capability in many IT initiatives. Collaboration between networking enterprises remains largely dependent upon specific IT solutions. This implies IT as a barrier to, rather than a facilitator for, collaboration and innovation.

### 5.3. New Ideas

The Vision of this Roadmap postulates a close relationship between Enterprise Interoperability, value creation and business innovation. Historically, as processes become mechanised, their value decreases. Enterprises reap competitive advantage by moving up the innovation process or the value chain (not to be confused with the supply chain), and allocating resources to the high value processes. Similarly, IT solutions deployed in support of enterprises have to "move up the stack" in order to (1) deliver greater value, and value-for-money, to enterprises; (2) enable rapid service deployment in response to changing business needs and shrinking innovation cycles; and (3) minimise the need for integration and migration.

The ISU provides interoperability as a technical, commoditised functionality, delivered as services. Value-added functionalities, for which customers would be willing to pay a premium, would flow above the ISU. The provisioning of such functionalities and related customised/localised services is an issue for the market.

The ISU is conceived to be a basic "infrastructure" that supports information exchange between diverse knowledge sources, software applications, and Web Services. It will make use of the new generation of Web technologies and enable knowledge-oriented collaboration as described in the next two Grand Challenges. Conceptually, the ISU constitutes the next "layer" of *open* cyberspace, as depicted in Figure 3. The figure depicts a conceptual view, not a functional view or a technical view.

Implicit to the ISU is an important proposition: interoperability as a technical functionality is a public good – non-rivalrous and non-exclusive. Just like the Internet and the Web, the ISU needs to be available for all to use, exploit and build upon. It must be open and be shared. It needs to be trusted. It needs to be independent of, rather than an extension to, particular enterprise software solutions provided by technology vendors.

The precise degree of interoperability that an enterprise desires and obtains in practice, however, remains a business decision of the enterprise.

The following describes the main areas of research that fall within the scope of this Grand Challenge. Note that they do **not** prescribe or establish, in respect of the ISU: 1) how it should be built; 2) the individual services; 3) the validity and sustainability of specific business models; and 4) specific ownership, operational and governance models. These issues and their inter-relationships need to be explored within the research to be carried out. Their validation, including the method of validation, is also part of the research work.

[52] Report of European Commission Consultation Workshop on Enterprise Interoperability Research, 10 January 2006, Brussels, page 40-42, ftp://ftp.cordis.europa.eu/pub/ist/docs/directorate_d/ebusiness/20060110_report.pdf

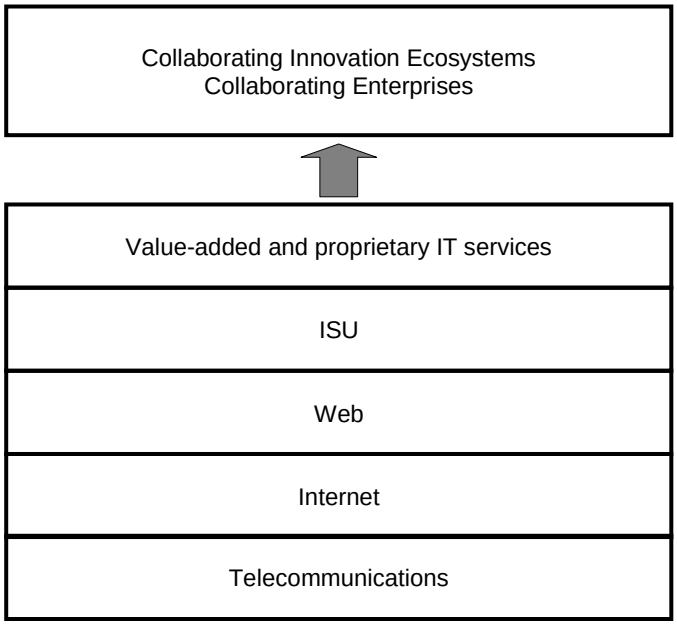


**Figure 3 Conceptual View of the ISU**

### 5.3.1 ISU Design Principles

The basic design principles of the ISU will be a determining factor for its utility and success. They need to encapsulate the rationale for the ISU and maintain its principal characteristic as an open infrastructure that supports heterogeneity, flexibility, usability, and continuous evolution. The central need to enable enterprise and ecosystem collaboration must be "designed into" the ISU, as a starting principle.

The ISU is premised on several specific views of the evolution of IT functionalities. First, IT functionalities will be delivered as services that may reside anywhere and be invoked anytime. Additionally, the precise location of these services and the means to access them will not be pre-determined. Accordingly, the ISU should make use of the principle of end-to-end (the "E2E Argument") that underpins the design of the Internet. This principle emphasises functional decentralisation, peer-to-peer communication, and intelligent end-points.

Second, the ISU protocol design must leverage open standards and specifications. In particular, modular software building blocks should be preferred over hierarchical layering. A key idea is that the ISU must enable the exchange of information and knowledge that is meaningful to computers. This contrasts with the current Internet and Web, which require a human in the loop.

Third, the ISU must support transparency – what goes in is what comes out. Transparency makes it possible for additional, value-added capabilities to be built on top of the ISU and for potential new services to be added to the ISU without changing the core.

Fourth, the ISU must be able to work within a clearly defined set of minimum circumstances for message transactions, so that there is a predictable and uniform environment for the ISU services and value-added services that leverage the ISU. The quality of service under these circumstances needs to be similarly defined, and guaranteed. Such definition and guarantees need to be provided by the ISU provider to the ISU users.

Fifth, because the ISU is by nature a system of systems, scalability needs to be built into the ISU at the outset. This concerns in particular stable and reliable information propagation across multiple systems to a growing number of end-points, determined dynamically and in real-time. This concerns also inter-working with and transitioning from existing systems.

*Example research challenges*[53]
They include: the infrastructure and related services (T2.4); methodologies for interoperability (T4); reference models for distributed environments (T5). The research would benefit greatly from past results and ongoing research on the architecture and design of the Internet and the Web. The scientific concepts, methods and principles from the research work on the Science Base for Enterprise Interoperability Grand Challenge (Chapter 8) are highly relevant. They need to be applied to the creation and development of the ISU.

### 5.3.2 ISU Services

The ISU aims to minimise the need and associated costs of enterprises, notably SMEs, to create information infrastructures that enable integration with different OEMs in different sectors. It does this by providing a basic information infrastructure that has information objects, ontologies, and metadata repositories as its core. The ISU should be able to provide and guarantee basic information exchange over the Internet and the Web. It should provide transparent semantic reconciliation. It needs to be able to handle payload and message flow with a pre-defined level of quality of service.

Potential ISU services include:

- Services that facilitate real-time information sharing and collaboration between enterprises such as reasoning, searching, discovery, composition, assembly, and delivery of semantics automatically
- Services that leverage emerging Web technologies (see Chapter 6) for enabling a new generation of information-based applications that can self-compose, self-declare, self-document, self-integrate, self-optimise, self-adapt, and self-heal, among others[54]
- Services that support knowledge creation, management, and acquisition to enable knowledge sharing between virtual organisations (see Chapter 7)
- Services that help connect islands of interoperability by federating, orchestrating, or providing common e-business infrastructural capabilities such as digital signature management, certification, user profiling, identity management, and libraries of templates and interface specifications
- Services that support the next generation of e-business services such as verification of credentials; reputation management; assessment of e-business capabilities; assessment of collaboration capabilities; facilities for data sourcing, integrity, security and storage; contracting; registration and labelling; and payment facilities, among others.

*Example research challenges*
They include: semantics and ontologies (T4); run time aspects of business processes (T2.1); service discovery, brokering, negotiation and mediation (T2.2); non functional aspects (T2.3); role and context based privacy (T2.5.1); intelligent supply chain processes (T2.5.2). Because the ISU services are intrinsically cross-border, the research will also need to cover policy issues such as: implementation of e-commerce legislations (P2); regulation of trusted certification authorities (P5); exchange of data across national borders (P6). It is very likely that additional policy challenges will come to light in the course of the research.

### 5.3.3 ISU Business Case and Ownership

The business case for the ISU is probably one of the most challenging research areas in this Roadmap. It also goes to the heart of the sustainability of Enterprise Interoperability as a value proposition. The key questions are: (1) How can enterprise interoperability be sold as a utility, rather than as an adjunct to a commercial offering? (2) What would be a viable pricing model for technical functionalities delivered as services? (3) Who would be the ISU business partners and what kind of partnership arrangements would be appropriate? and, finally (4) Who would (should) own and/or operate the ISU?

The ISU must be collaborative and sustainable. It must also be underpinned by good governance. But should it be profit-making? Preliminary discussions[55] suggest eBay and ASP as possible business models. Other alternatives may include Salesforce.com, the new generation of Web services connectivity providers, and the latest "Web 2.0" community-based service providers. The emphasis is on minimum usage cost – use what you need and pay for what you use – in order to promote wide

[53] See Section 4.5 for an explanation.
[54] The "self-*" characteristics and properties and future services have been described, among others, in the concept of the Service-Oriented Knowledge Utility (SOKU) in *Future for European Grids: GRIDs and Service Oriented Knowledge Utilities – Vision and Research Directions 2010 and Beyond,* January 2006.
ftp://ftp.cordis.europa.eu/pub/ist/docs/grids/ngg3_eg_final.pdf
[55] See footnote 52.

usage. Note that ISU service pricing is very much part of the on-going discussion of software pricing, which is generally transitioning from a product-based model (by the box, per licence) to a service-based model (by transaction, subscription, advertising).

If the main purpose of the ISU is to support and enable collaboration, should the ISU itself be a collaborative endeavour? Several models are possible – between private entities, as a public-private partnership, or a completely public organisation. In addition, should there be a separation between the ownership and the operation of the ISU, so that the operation of the ISU could be outsourced? Various arguments have been advanced for these options. The nature and pricing of the ISU services will depend upon the answers to these questions. Moreover, the ownership model will, to a large extent, drive its governance, which in term will influence its initial credibility.

*Example research challenges*
They include: business interoperability and society (B3); business models for interoperability (B4); decentralised governance of business processes (B9); SME-related economic and deployment considerations (B10); interoperability and digital ecosystems (B12); business Interoperability and quality (B13).

### 5.3.4 ISU Regulation

Business innovation can be driven by the market or by regulation. Since interoperability is considered to be a "public good", what would be the appropriate regulatory framework for the ISU? Specifically, what would be the precise scope of ISU operation and geographic coverage, so that it promotes openness and competition on the supply side, while ensuring fair and equal access on the demand side? What would be the mechanism for safeguarding these and other fundamental principles of the ISU? What would be the appropriate governance model for the ISU? How should this model be decided upon, and by whom? What would be the legal status of the ISU? Would it be appropriate to allow for and even foster competing ISUs? How would the ISU be regulated, and by whom?

Considerations would include (possibly statutory) obligations for universal or near-universal service provision within a defined geographic region, possible legal protection of the ISU, liability of the ISU and related dispute resolution and redress mechanisms, service agreements of the ISU with customers and business partners, and software and patent protection. A fundamental question here is whether, and to what extent, should policy instruments be used to promote and support the ISU.

*Example research challenges*
They include: harmonisation of national implementation of EU Directives supporting e-commerce (P2); software licences for distributed and portable applications (P4); exchange of data across national borders (P6); trans-European limited liability incorporation (P7); business interoperability and society (B3); technology trajectory of interoperability (B11). The research must take into account the rapidly changing nature of the software industry and the likely direction and impact of accelerating technology evolution.

## 6. Grand Challenge: Web Technologies for Enterprise Interoperability

### 6.1. Strategic View

This Grand Challenge is about researching new Web technologies for Enterprise Interoperability. It seeks to apply the concepts, technologies and solutions flowing from developments in Web technology to address the problems of Enterprise Interoperability.

In its present form, the Web has already had a disruptive impact on how capital, labour, and technology are used in most world economies. The Web has changed profoundly the manner in which customers interact with enterprises, how enterprises interoperate, and how enterprises and people organise work. The Web has endangered or has had a substantial impact on the business models of a large number of significantly diverse industries. Examples include the newspaper industry, the advertising industry, the banking industry, the airline industry, the book retail industry, the yellow pages industry, used car sales industry, auction houses, public libraries, stock brokerages, video rental services, and more recently even the cable TV industry and the voice telecommunications industry, to mention just a few. In the process, new players have established their place in the market and most of the old players have had to adapt their business models to the Web, offering new services or enhancing existing services. The Web has also facilitated the process of globalisation by enabling Enterprise Interoperability and the expansion of global logistic and production chains. But foremost, and through the advent of powerful search engines (in particular, Google) and novel collaborative tools (e.g. Wikipedia), the Web has made available a wealth of information to a great many people worldwide, unleashing numerous resources and possibilities.

In our view, current developments in Web technologies (e.g., so called “Web 2.0” and Web SOA) are associated with the process of building a more powerful operating system for a platform called the Web, an operating system that will grow more powerful in the near future.

It is submitted that **Web technologies will have a growing impact on how companies do business** online and how networked businesses interact and transact with one another. Some novel Web technologies appear to challenge existing patterns in the provisioning and supply of Enterprise Interoperability solutions, and the use of such solutions. Specifically, it is anticipated that novel Web technologies will result in a rich set of design principles, technologies and solutions to transform businesses’ capability to work seamlessly with other businesses, and to better meet customer needs. It is expected that the research work of this Grand Challenge will lead to strategic technical developments that facilitate and catalyse a new era in Enterprise Interoperability.

### 6.2. Problem Statement

Like previous technologies such as electricity, telecommunications, and computer technology, **the Web will in time become a basic building block of future enterprises**, a platform where business is conducted and where enterprises interoperate. Thus, in order to improve efficiency and remain profitable, Enterprises will have to adapt their business models around the Web as a platform. In summary, the first issue is one of survival for enterprises. **Enterprises that do no adopt solutions based on Web technologies will be competitively disadvantaged.**

The second more important issue is that Web technologies represent an enormous **opportunity for growth and profits**, an aspect of particular relevance in the context of rapid technological innovation and of increased competition through globalisation. Current Web technologies are neither sufficiently sophisticated to support Enterprise Interoperability, nor have they been widely deployed in internal enterprise processes. An improvement in Web technologies will allow **the delivery of novel and improved services.** This will come about through a better interaction with end users, and more powerful Enterprise Interoperability capabilities, allowing enterprises to realise a greater proportion of their interactions online. In addition, the wide adoption of standardised Web technologies in displacement of proprietary (vendor-based) management information systems, will contribute to a reduction in system integration costs, risks, and implementation times.

### 6.3. New Ideas

This Grand Challenge proposes a classification of the research areas based on the key features of Web technologies in relation to potential Enterprise Interoperability solutions. The focus is on where the value creation occurs.

We designate the first topic as an Enterprise Interoperability Operating System (OS), which aims at developing a more powerful Internet OS and the building of new applications based on the integration of distributed network resources. The focus is on client-side application delivery, and thus client-side value creation.

The second topic we consider is mashup technologies. The differentiation to the former topic is in what creates the added value. We submit that with mashup technologies, value creation arises from the usage of databases and content from diverse remote Web resources. The emphasis is on building derived services based on combined distributed content databases accessible through APIs, often carried out by third parties with no relation whatsoever to the parties making the data available.

The third topic is Web Service Logic Execution Environment (SLEE) for Enterprise Interoperability, and with it we mimic developments in the telecommunications industry. Web SLEE aims at minimising system integration costs of heterogeneous elements (nodes) in different enterprises, by ensuring that the network elements (nodes), through resource adaptors, are able to execute functions ordered by a remote entity.

The fourth and last topic is Web community, and with it we recognise that there can be substantial value created in using the Web as a platform, for example, to conduct transactions, to exchange knowledge, to enable social networks, to deliver services among only a subset of nodes in the Web, or to support peer-to-peer communications between two parties. The emphasis is on assigning the benefits created by these types of services to the nodes that belong to the subnet. Our expectation is that these benefits will far exceed those offered by early Web solutions like Intranets.

For this Grand Challenge, it is important to consider (to the extent that it is feasible and applicable to the proposed research ideas), which existing architectures can be used as a starting point for further research. Candidates could include the ebXML Architecture and associated ISO technical specifications on ebXML, as well as architectures related to Web Services.

#### 6.3.1 Enterprise Interoperability Operating System

The emphasis of this topic will be on the research and development of Web Operating System enhancements to client-side applications for Enterprise Interoperability solutions.

The aim of the research challenge is to enhance the value of the service provided by the enterprise and/or to improve the value of the service the enterprise provides to its customers using the Web platform. A key idea is to provide the customer with a much higher degree of control than now in the configuration of the service and the delivery of the service. Customer “self-service” should be possible. In the context of networked organisations this means pushing out control from the centre to the edge, and brokering rather than orchestration. Such developments involve lightweight programming models that allow for loosely coupled systems.

The research challenge includes research and development in semantics and ontologies for service specification, and enhancements to the Web Operating System to support improved transactions with consumers. It also includes research and development in the architecture of applications to support both better consumer service and greater interoperability with other enterprises. Finally, it includes research and development in tools and methodologies for quality improvements to Enterprise Interoperability software and applications, and in the use of intelligent agents and adaptive systems for improved service rating, pricing, and payment procedures.

In summary, the aim of this research challenge is to develop solutions that raise the value of the services offered by an enterprise that offers its services on the Web platform, through more powerful technological capabilities. It is also about the development of software APIs that are independent of both operating systems and the programming paradigm. In addition, this research challenge aims at

enhancing the Web platform operating system to support improved service transactions with the end user (customer).

*Example research challenges*[56]
They include: interoperability of enterprise models (T1.1); usability of enterprise modelling (T1.2), in particular its focus on generating flexible, adaptable solutions for Enterprise Interoperability; monitoring of business processes (T1.3.3); part of the research areas in service discovery, brokering, negotiation and mediation (T2.2); interoperability frameworks and architectures (T3.1), particularly regarding interoperability methodologies (T3.1.4).

### 6.3.2 Mashup Technology Solutions for Enterprise Interoperability

The aim of this research challenge will be on the research and development of solutions to enable Enterprise Interoperability characterised by the use of data and content available on the Web. It aims at allowing enterprises to enhance existing services or to offer new services. These services leverage the diverse Web platform data and content, creating added value.

There is considerable potential for the creation of new or derived businesses and services based on the use of existing databases. One recent example of such novel applications is HousingMaps.com, which combines the mapping capabilities of Google Maps with housing listings from Craigslist ("Mashing the Web", The Economist, Technology Quarterly, 2005). Current services and content could also be enhanced by using other content available on the Web.

The potential goes beyond the use of existing data and pooling of data from existing multiple sources. The examples of Yahoo and Amazon in the eCommerce market show how users can generate vast amount of new contents, and in this process, transform existing services (a directory service in the case of Yahoo and a catalogue service in the case of Amazon) into entirely new services and value propositions. The implication is that data should be totally unbundled from existing applications and systems such as SCM, PLM and ERP, which are traditionally based on information silos and information packaging in a pre-defined manner.

The challenge aims at research and development in semantics, ontologies, and APIs for data and content location, exchange, and access; tools for assessment and monitoring of data quality and consistency; tools and procedures for data and content retrieval rating, pricing, and payment; tools and procedures to support transactions between enterprises related to the acquisition or use of databases and contents; and procedures and policies for addressing data privacy and intellectual property issues.

In addition, the research challenge needs to address information management within and beyond the corporate and sector environments, and ultimately in a global context. The aim is to help create a pool of continuously improved information to replace the present silos of hard-to-find, hard-to-access and usually incomplete information.

In summary, the aim of this research challenge is to develop solutions to enable and facilitate the data and content dimension of Enterprise Interoperability using resources available on the Web platform, and new resources which are expected to be continuously added to the Web platform.

*Example research challenges*
They include: exchange of data across national borders (P6); service discovery, brokering, negotiation and mediation (T2.2); ontology infrastructure (T4.2).

### 6.3.3 Web SLEE Solutions for Enterprise Interoperability

The emphasis of this topic is on the research and development of Enterprise Interoperability solutions whereby a producer application is able to request the execution of a function by a remote Web resource (e.g. an enterprise) or in a distributed architecture (e.g. virtualisation of e-services).

The research challenge includes the research and development of semantics and ontologies for remote function specification, identification, access and joint-composition, as well as the specification of APIs and resource adaptors for different enterprise function execution. Furthermore, it includes tools for assessment, monitoring, and reporting of remote function execution including alarm, error

[56] See Section 4.5 for an explanation.

reporting and logging; tools and procedures to support transactions between a request-producer enterprise and one or more request-executing enterprises; tools and procedures for remote function rating, pricing, and payment; procedures and policies for addressing data privacy and intellectual property issues.

*Example research challenges*
They include: interoperability of enterprise models (T1.1); usability of enterprise modelling (T1.2); run time aspects of business processes (T2.1); business process ontology (T4.1); ontology infrastructure (T4.2).

### 6.3.4 Web Community Solutions for Enterprise Interoperability

The aim is to develop tools and solutions to ensure that when enterprises decide to interoperate using Web technologies, they are able to do so while assured that the value that is being created can be appropriated in its entirety by the parties or social networks that are part of the collaboration agreement.

Staff of large corporations are currently able to access their business e-mail and Intranet resources using a VPN corporate network, or to access their corporate e-mail using RIM's Blackberry solution, for example. On the other hand, the last few years have also seen a dramatic impact of peer-to-peer technology, in particular that related to file exchanges but also to Voice over IP (VoIP) telecommunications. Other related recent technologies include for example tag-based folksonomies, or specific protocols like FOAF (Friend of a Friend) and XFN (XHTML Friends Network), both for social networking, which enhance site functionality or allow subnets of end-users to interact without centralised Web sites. Thus, more and more applications that run on top of the web (or internet protocol) are being developed for groups of users.

The research challenge includes the research and development of semantics and ontologies for subnet specifications, location, access, and joint-composition, and the specification of APIs and resource adaptors to support subnet transactions. In addition, it includes tools, procedures, and policies for supporting knowledge management and intellectual property protection, tools and procedures to support transactions between enterprises in a subnet, and tools and procedures for subnet services rating, pricing, and payment. In summary, the aim of this research challenge is to develop solutions that enable enterprises to operate with other organisations in subnets using the Web as a platform, while being assured that their intellectual property, knowledge, and the value that is created can be fully appropriated by the transacting entities.

*Example research challenges*
They include: SME digital ecosystems (T1.5.5); infrastructures and services non-functional aspects (T2.3).

## 7. Grand Challenge: Knowledge-Oriented Collaboration

### 7.1. Strategic View

The term "virtual organisation" is used throughout this document[57] to mean, generally, a grouping of legally distinct or related enterprises coming together to exploit a particular product or service opportunity, collaborating closely whilst still remaining independent and potentially competing in other markets or even other products/services in the same market. Virtual organisations emerge from innovation ecosystems, where enterprises have the ability and expectation to collaborate closely with one another: collaboration is a key strategic objective, at all levels of management and operation, and is supported by ICT systems.

Achieving the vision of evolving ecosystems of large and small enterprises forming virtual organisations (VOs) to exploit product and service opportunities through ever shortening life cycles requires a close collaboration and rapid, reliable decision making. The field of Enterprise Interoperability focuses on the controlled sharing of information between enterprise systems, allowing decisions to be based on accurate and complete information, whilst respecting issues of commercial confidentiality of enterprise information.

There is substantial enterprise value in information, and particularly asymmetric access to information. Business success hinges on having access to the right, valuable information. Today information (and by inference knowledge) is accessible to any enterprise worldwide, and unprecedented information quantities are created yearly, with stark implications for Enterprise Interoperability. First, enterprises should expect to experience a heightened level of competition, as competitors have access to the same information and knowledge. Second, the opportunities to profit from new information and knowledge are brief, since information asymmetries dissipate quickly and economic theory predicts that with perfect information arbitrage opportunities will be scarcer. Third, enterprises with inadequate access to the right information and knowledge at the right time will likely be unable to compete profitably. Fourth, societal (and enterprise) systems previously incorporated only a small portion of new information, a filtering mechanism that has allowed society to distinguish the most important information from noise, but which may suppress recognition of opportunity. In summary, sound and adequate Enterprise Interoperability decision making requires more powerful business intelligence platforms, which have to be able to gather relevant information and knowledge in near real-time for nearly every activity of the enterprise, to distinguish valuable information from noise, and to quickly incorporate valuable information in the enterprise knowledge base.

The next phase of development of deeper functionality of Enterprise Interoperability is 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 terminate successful VOs: such knowledge imparted to newly-collaborating enterprises, developed by each enterprise to ensure its ability to exploit opportunities, and shared (with limits) through a VO, will be a driver for new enhanced collaborative enterprises, able to achieve the global vision of Enterprise Interoperability.

Research in response to this Grand Challenge will be a key enabler for the application of enterprise software and information interoperability research results. It will address the major barrier to successful exploitation of interoperability presented by the lack of experience and knowledge available to potentially beneficiary enterprises.

Knowledge-oriented collaboration builds on state-of-the-art research on Enterprise Interoperability. Data and information sharing is a clear pre-requisite to application and interoperability of knowledge oriented support for collaborative, virtual organisations. Process, service and enterprise models are fundamental: collaboration knowledge is knowledge of how to adapt and re-combine such models as VOs evolve.

[57] The editors note that a number of other terms are used with similar, if not actually equivalent, meaning, referring to the grouping of enterprises/organisations or to a single organisation within the group (e.g. virtual enterprise, networked organisation, networked enterprise, etc.). The term "virtual organisation" has been selected from these.

However, the research proposed here moves beyond these applications of knowledge to support interoperability of information systems, and exploits achieved interoperability by applying knowledge-oriented techniques to deliver direct benefits of collaboration to the enterprise and VO.

## 7.2. Problem Statement

This Grand Challenge addresses two primary needs identified by enterprises in successfully forming and exploiting VOs.

**Rapid and reliable formation of collaborative consortia to exploit product opportunities**
To remain competitive in rapidly changing markets, enterprises need to be able to come together rapidly to form collaborative VOs, in order to exploit new product and service opportunities. In order to do this, they must first be able to identify potential VO partners with the correct core competencies and collaborative capabilities. Subsequently, they must be able to follow a reliable process of negotiation, transparent to potential partners and recognised as best practice for the market/industry/sector, leading from initial approach to ultimate contractual commitment to product or service delivery, and to enterprise and VO IPR protection. This process must be capable of recognising and quantifying the risks to all partners throughout negotiation, and on to VO operation.

**Application of enterprise and VO knowledge in operational and strategic decision making in VOs, leading to enhanced competitiveness and profitability**
At all stages of a product or service life-cycle, competitiveness is reduced when decision making is inconsistent or sub-optimal. This is particularly a problem in the VO, where each partner has a local interest in making locally optimal decisions, and almost certainly has incomplete understanding of the impact of decisions on the VO as a whole. Even enlightened decision making, which recognises that local interests may ultimately be best served by considering the interests of the VO as a whole, must be based upon partial knowledge of the VO capabilities and constraints as a whole, whether an individual enterprise is making local decisions or whether a VO co-ordinator is making decisions at higher level. Enterprise and VO knowledge and information is not yet fully exploited to inform such strategic and operational decision processes.

## 7.3. New Ideas

### 7.3.1 Knowledge for Collaboration

Research tools and methodologies are needed for acquiring, retaining and accessing the expanding range of knowledge[58] available within individual enterprises and in VOs to enhance efficiency and productivity in collaboration, maximising the benefit of both long and short term knowledge sharing, whilst maintaining necessary commercial confidentiality and encouraging mutual trust.

In this context, knowledge is an instrument to drive and support collaboration. Knowledge users are, potentially, contributing to the body of knowledge on collaboration. Whilst some knowledge may be freely shared within enterprises or some VOs, commercially valuable knowledge may be made available as a product, thus contributing to a knowledge economy.

Enterprise knowledge relevant to the formation and operation of collaborative ventures will include, though not necessarily be limited to, the following categories. Figure 4 depicts the sources of these categories of knowledge, and their contribution to the enterprise needs identified in Section 7.2.

***Enterprise core competence***
This is knowledge of the enterprise's own capabilities and capacities, strengths and weaknesses, and technical IPR. We might see a fractal view of the enterprise as a collaboration of its internal functions.

[58] Knowledge in this context encompasses:
- Enterprise information, shared VO information, and public information (possibly commercially available)
- Information about how to find, access, and retrieve the above (meta-information)
- Understanding of the above (ontologies and other semantic tools)
- Expertise, procedures and heuristics to effectively apply the above.

***Process knowledge for VO formation***
This is knowledge of best practice in formation of a VO, critical factors in VO development, legal issues, risk analysis, and application of tools such as maturity gate planning; it also includes moderation knowledge about collaboration and interoperability issues likely to be critical to partners.

***Process knowledge for partner selection***
This is knowledge of potential partners' core competencies, collaboration and interoperability capability, and reliability in collaboration.

***VO operations management knowledge***
This includes the VO enterprise model to support decision making, knowledge of interoperability issues within the VO applied to ensure communication, and moderation knowledge about operational factors likely to be critical to partners.

*Example research challenges*
They include: business challenges of collaboration (B1, B2, B4, B9, B10); technical challenges in enterprise business knowledge (T1); ICT systems (T2); methodologies for structuring and sharing collaboration knowledge (T3); the semantic and ontological issues of common understanding of knowledge (T4); knowledge discovery (T5).

### 7.3.2 Tools for Knowledge Management/Collaboration/Generation to support Enterprise Interoperability

These will support interoperability of services and functions, and include tools that support firms when they, for example, outsource part of their processes, i.e. tools that generate internal enterprise knowledge (performance metrics, error and problem reporting, benchmark comparisons) during interoperation with other enterprises. The focus is on aiding enterprises to manage the logistics of the process of interoperation well.

Decision support tools based on shared VO knowledge will be derived from current and previous collaboration experience, and from publicly available knowledge of best practice.

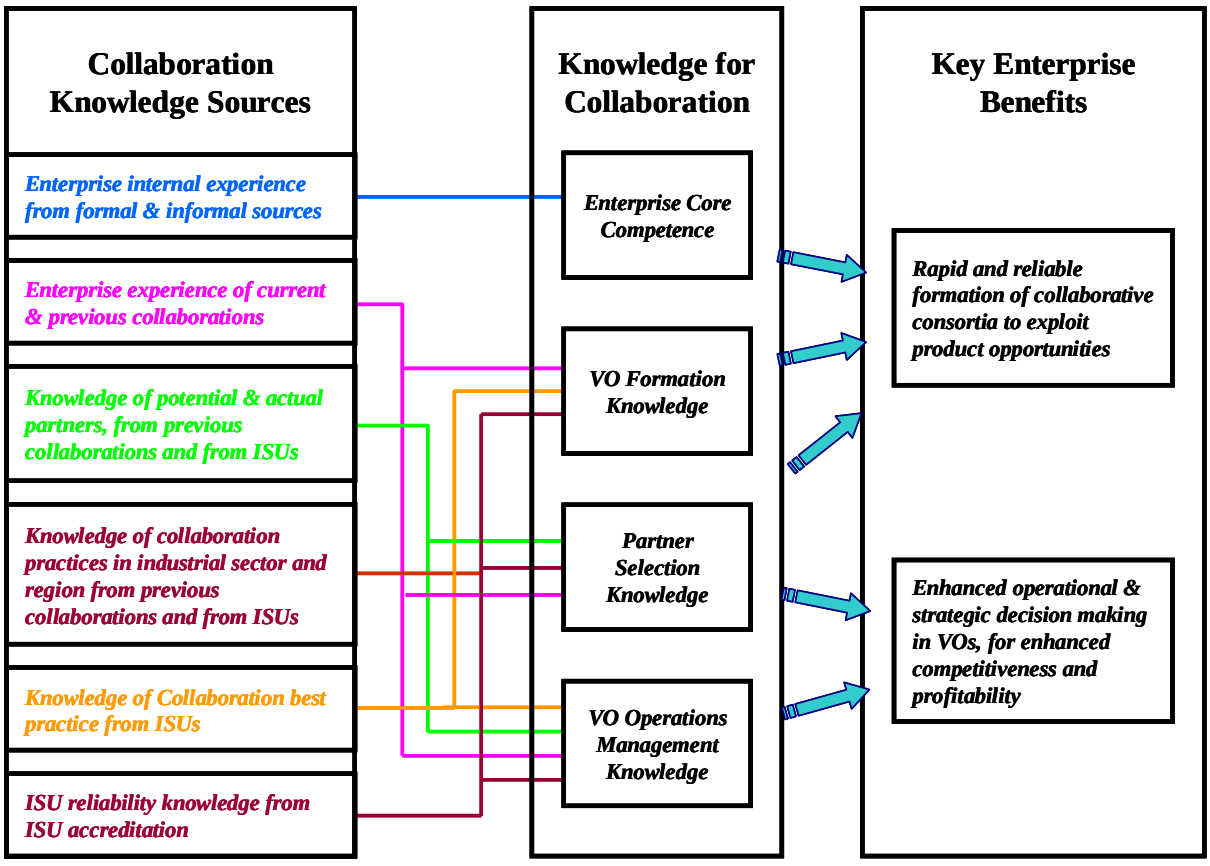


**Figure 4 Enterprise Benefits of Knowledge Oriented Collaboration**

Knowledge driven moderation of strategic and operational decision making by members of a VO will lead to reduced risk of costly decision conflict.

Collaborative performance management will help control the execution of business processes by comparing process requirements with data collected during process execution.

The application domain is not restricted to manufacturing/supply chain interoperability. Future collaborations will include product design and design of the dynamically evolving VO, to proceed through manufacturing system design, and through the product life-cycle to include management of obsolescence.

Besides tools to acquire and exploit knowledge and information available within the enterprise or VO, and through the Interoperability Service Utility (see the ISU Grand Challenge in Chapter 5), knowledge based search agents may be applied to find Internet or other available sources of business intelligence to support collaboration decisions.

*Example research challenges*[59]
They include: interoperability and usability of enterprise models (T1); SME economic and deployment considerations (B10); enhancing interoperability support for SMEs (T1) through enhanced understanding of agreements and contracting in relation to interoperability (T1); ICT systems (T2); semantics and ontology (T4).

### 7.3.3 Repositories of Collaboration Knowledge and Best Practice

The application of enterprise knowledge generated through the experience of collaboration using interoperable systems will enable and facilitate the creation of successful VOs, and the effective establishment of collaboration based on interoperability.

Collaboration knowledge bases will be repositories of knowledge of best practice in collaboration (e.g. partner selection, establishment and operation of collaborating VOs exploiting enterprise interoperability capabilities). Knowledge includes description of processes to adopt to pursue successful knowledge-oriented collaborative working together with analysis of solutions available, benchmarking (i.e., comparison of features) and key performance indicators.

Risk inherent in collaboration will be reduced through availability of repositories of best and worst practices, results and solutions, available both within an enterprise and externally.

*Example research challenges*
They include: business challenges in identifying performance indicators (B6, B7); best collaboration practice (B3); benchmarking protocols (B8); technical challenges in defining effective interoperating knowledge and information structures (T1, T2, T4, T5); acquisition, storage and access technology (T2, T4).

### 7.3.4 Assessment of Collaboration and Production Capabilities of Registered Enterprises

This is related to the idea of the ISU which may also provide such a service (see Chapter 5). These may be generally available, restricted to particular domains (e.g. industrial sectors), or subscription based. Frameworks for the assembly, establishment and operation of VOs may underpin such knowledge.

*Example research challenges*
The technical challenges here are likely to be addressed primarily under the ISU Grand Challenge. But there are significant policy challenges (P6, P7) associated with: the business models for and regulation of entities providing such assessment; authentication of knowledge and information held and disseminated; determining responsibility and liability for losses incurred through the use of inaccurate, outdated or incomplete knowledge used in creation or operation of VOs.

### 7.3.5 Knowledge Representation Tools

Structures and an access infrastructure are needed for interoperable storage of acquired knowledge. Enterprise knowledge and especially knowledge of different enterprises in a VO cannot be represented using a single paradigm (for instance, production rules, semantic Web technologies,

[59] See Section 4.5 for an explanation.

genetic algorithms etc. may each be the appropriate knowledge paradigm for knowledge in different domains of interest to the VO). Storage of and access to such non-homogeneous knowledge through non-specific knowledge applications must be understood and a knowledge interoperability infrastructure defined. Knowledge-oriented tools must be interfaced with enterprise information systems to achieve enhanced performance in VO decision making at the operational level especially.

This research must also address tools and procedures that support knowledge management and, in particular, in separating collaborative knowledge from enterprise internal knowledge. Issues of security and confidentiality of proprietary versus shared knowledge within the VO must also be investigated to establish a framework for knowledge storage and access which protects IPR, without hindering legitimate sharing of knowledge and information.

*Example research challenges*
They include: business challenges (B1, B2, B4) and policy challenges (P5, P6, P7) in defining the storage and access framework; business challenges in identifying the sources and applications for knowledge to be shared through the VO; technical challenges in designing, specifying and implementing appropriate tools (T1, T2, T3, T4, T5).

### 7.3.6 Acquisition of Knowledge

Data discovery (data-mining) tools founded on knowledge of how to access information through the knowledge and information interoperability infrastructures will be applied across VOs to generate both VO knowledge for current operational use, and enterprise knowledge to inform future collaborations. Recent research has investigated the acquisition and structuring of enterprise knowledge from informal communications and can be extended to facilitate acquisition of VO knowledge.

Additionally, this challenge includes collection of knowledge regarding experience of operating a VO, and how this knowledge can be used in the creation and definition of future VOs. Re-planning and/or reconfiguration of collaboration are other situations where collaboration knowledge is needed.

*Example research challenges*
They include: business challenges to define interoperability frameworks (B1, B2) and objectives (B6, B7); technical challenges in enterprise knowledge management (T1); technical challenges in semantics and ontologies (T4).

### 7.3.7 Business Intelligence

Research is needed on methodologies and tools for discovering, accessing and exploiting the growing body of business intelligence available through public and commercial sources worldwide, in conjunction with enterprise and VO intelligence and knowledge.

*Example research challenges*
They include: business challenges in determining the ways in which the enterprise can benefit from business intelligence and incorporate its application into its processes (B1, B2, B4, B11); technical challenges in ICT systems (T2); technical challenges in the understanding of knowledge acquired from sources external to the enterprise and its culture (T4).

### 7.3.8 Symbolic and Visual Representation of Processes

Research in modelling of enterprise processes will lead to tools that aid enterprises in the representation of their internal functional processes so as to facilitate enterprise interoperability, tools that aid in the enterprise's internal knowledge generation to support Enterprise Interoperability. The focus is on aiding firms to identify their internal interfaces for enterprise interoperability (related to T3 and T5).

*Example research challenges*
They include: interoperability impacts and models (B1, B2, B3, B4, B6, B7); technical challenges in ICT systems (T2); semantics and ontology (T4); and generic modelling (T5).

### 7.3.9 Accessibility to Stakeholders

It is essential that all tools supporting interoperability, including those envisioned in this Grand Challenge, remain accessible to SMEs. Infrastructures must be put in place to allow affordable use on a pay-to-use basis rather than through massive IT investment. Human interfaces to knowledge-

oriented collaboration support tools are critical to successful take-up. In particular SMEs have limited resources to apply complex tools to support knowledge-oriented collaboration, and the required investment in staff development and initial knowledge base population must be small for such stakeholders.

*Example research challenges*

The policy challenges (P4, P5) and business challenges (B5, B8, B9) and especially SME related economic and deployment considerations (B10) challenges may be addressed primarily under the ISU Grand Challenge. There are also technical challenges in the human interfacing and staff education (T1, T2, T4, T5).

# 8. Grand Challenge: A Science Base for Enterprise Interoperability

## 8.1. Strategic View

The Vision of this Roadmap considers the potential value of Enterprise Interoperability beyond the technical domain to much broader developments in business, the economy, and the society. In affirming this value, we argue that Enterprise Interoperability must be considered in conjunction with developments in these other areas – in fact, it must leverage those developments in order to maximise the value. The Vision further suggests that Enterprise Interoperability will never be able to achieve this maximum value, as long as it is subject to market hype, the continuous waves of technology "fashion", and the occasional abrupt technology "surges" of the past. Rather, it has become critically important to establish Enterprise Interoperability on a more solid and rigorous base of science and, specifically, scientific principles.

The present Grand Challenge is about creating that "science base" by combining and extending the findings from other established and emerging sciences. This fundamental advance will allow Enterprise Interoperability solution providers to engineer solutions on rigorous, scientific theories and principles, rather than craft them based on the latest technologies and rules of thumb. It is submitted that without such a foundation, future Enterprise Interoperability research will deliver only fragmented and unpredictable results that will have increasingly limited application and marginal impact.

The Grand Challenge is expected to help mainstream Enterprise Interoperability by

- Providing a science base for engineering Enterprise Interoperability solutions of higher quality, dependability, and reliability
- Making Enterprise Interoperability more demonstrably cost-effective for end users
- Laying a long-term foundation for coherent and visionary Enterprise Interoperability research with broad impact
- Enabling the establishment of a multi-disciplinary Enterprise Interoperability research community
- Providing an infrastructure to support the diffusion of ideas, education, research, and training.

The Grand Challenge is envisaged to establish a new direction for European research and entirely new concepts, approaches, practices and impacts for both "eBusiness" and the emergent "Innovation Ecosystems". Accordingly, the Grand Challenge is **a challenge for the Enterprise Interoperability research field as a whole** – one that will enlarge the perspective, concepts, and application of Enterprise Interoperability so that it can become an enabler for innovation and value creation.

## 8.2. Problem Statement

The market is saturated with technology-based solutions that claim to support interoperability for enterprises. It also shows a profusion of interface standards and specifications that make the same claim. Yet, enterprises still cannot exchange information easily and transparently. There are several reasons for this.

Traditionally, Enterprise Interoperability solutions are linked closely to specific market sectors, application areas, and technology trends. They generally work well within the particular, self-defined, static environment for which they were designed. However, they cannot be modified easily to deal with changing technologies. Moreover, the solutions from one provider are, frequently, incompatible with the solutions from another. More specifically, they are designed to meet developers' needs rather than users' needs (see Grand Challenge in Chapter 5), they are incompatible with the emerging Web technologies (see Grand Challenge in Chapter 6), and they do not support enterprise-wide decision making (see Grand Challenge in Chapter 7).

On the research side, the central problem is that researchers, even if they are one step ahead of the providers, are also technology bound. The existing concepts, methods and techniques are inadequate because they resolve the same problems using the next generation technology. This approach cannot keep pace with the demands of enterprises as they collaborate and compete within a process of

technology-enabled *business* innovation that is transforming the rules of the game and the nature of business. With a view to the future, Enterprise Interoperability research needs to break away from specific technology boundaries and be based on solid and rigorous scientific theories and principles.

To summarise, the present Grand Challenge asks the question, "What are those scientific theories and principles?"

### 8.3. New Ideas

This Grand Challenge aims to open up the field of Enterprise Interoperability research by extending, assimilating, and integrating developments from both established and emerging sciences. It involves a fundamental shift in focus from a technology base – asking questions and investigating possible answers with reference to specific technologies – to a science base – asking questions and investigating possible answers with reference to scientific principles and concepts. The overall expected result is a "science base" for Enterprise Interoperability. This will comprise:

- A new set of concepts, theories, and principles derived from established and emerging sciences
- Associated methods, techniques, and practices for solving Enterprise Interoperability problems.

Enterprise Interoperability then becomes an engineering activity, which has three consequences:

- Decoupling the research from particular technologies and product strategies of providers
- Emphasising the ability to test, measure and validate certain attributes of the solutions, such as predictability, reliability, conformance, operations, and control
- Using this ability to redefine what is "optimal" in Enterprise Interoperability and identifying the conditions for achieving that optimum.

Table 1 provides a list of **indicative scientific disciplines** whose ideas, propositions and findings could provide a starting point for the proposed science base[60].

**Table 1 Indicative research areas**

| Science base for Enterprise Interoperability<br>Indicative research areas | |
|---|---|
| • Systems/Complexity science | • Services science |
| • Network science | • Economic science |
| • Information science | • Social sciences |
| • Web science | |

#### 8.3.1 Systems/Complexity Science

Enterprises have many structures and relationships. Understanding their interactions is considered a major factor in contributing to the success of interoperability solutions and the performance of the entire enterprise. Implicit in both is the view that enterprises are complex, adaptive "systems". Moreover, with reference to the vision of this Roadmap, they are also components within one or more innovation ecosystems. Preliminary theories have been advanced in specific scientific disciplines, such as biology and ecology, to explain the importance of and the evolution of complexity in these "systems". Some researchers have attempted to extrapolate these results to a "general systems theory" that could explain the importance of and the behaviour of systems in all fields of science. This theory views all systems as dynamic, "living" entities that are goal-oriented and that evolve over time. Complexity science, generally considered as a branch of systems science, has been developed to address the emergence, adaptation, evolution, and self-organisation of systems. In particular, it concerns the coupling and interactions of the parts within these systems in a non-linear fashion.

[60] It is important to emphasise that it is not the purpose of the present Grand Challenge to (re-)define / (re-)classify the various scientific fields or disciplines, or to enter into the general debate about the nature of science, and what may or may not constitute or merit the label of "science". In addition, it is recognised that the inter-relationship between science, invention, research and technology development is a subject of debate. Within the context of the present Grand Challenge, a fundamental assumption is that Enterprise Interoperability is multi- and inter- disciplinary, cross-cutting and cross-domain. The research work in this field therefore must relate to and can potentially benefit from the research work in other fields.

On this view, such a theory could be applied to enterprises, with the ISU (see Chapter 5) providing the underlying infrastructure that enables the enterprise collaboration relationships.

*Example research challenges*[61]
They include: interoperability and system behaviour and adaptability (T2); the "system" aspects of interoperability, from software component design to organisational structure to the "IT fabric" that provides communication, collaboration and coordination facilities (T5); the technology trajectory of interoperability as a complex system (B11); interoperability of digital ecosystems as complex systems of systems (B12).

### 8.3.2 Network Science

The ability and capability of enterprises to collaborate has been closely linked to the ability and capability of enterprises to interoperate. Within European research under FP6, a key premise is that Enterprise Interoperability is a key enabler for "networked organisations". The concept of networks as a representation of objects that are connected by some underlying structure has been applied to numerous problems in applied mathematics, engineering, and computer science. Specifically, network science has been concerned with the impact of structure on behaviour. In recent years, new advances in network science have been used to relate performance problems to communications structures including the Internet, the Web, and Grids.

On this view, Enterprise Interoperability, which could be viewed as a performance criterion for the ISU, could be subject to the results of network science. The interoperability of enterprises could be a particular function or characteristic of network structures.

*Example research challenges*
They include: Enterprise Interoperability and the efficiency of networks (B3) (B9), e.g. random networks, scale-free networks, small world networks, pervasive networks, social networks, clustered networks; possible "basic laws" that govern networks and the interoperability of networks (B11); interoperability of digital ecosystems as certain kinds of networks (B12).

### 8.3.3 Information Science

Information is among the most strategic assets of an enterprise. Its exchange has been the primary focus of Enterprise Interoperability since the invention of the computer. Over the years, that focus has broadened from the simple transmission of data values and data structures to the complicated exchange of information semantics and knowledge bases. Information science studies the intrinsic properties and characteristics of information, such as how to use mathematics to represent them, how to deal with uncertainty in information, what are the fundamental units of measure, what are useful metrics, how to measure those uncertainties and metrics, and so on.

On this view, information science could potentially transform our understanding of the characteristics of information and information types that are generated by and exchanged between enterprises.

*Example research challenges*
They include: the semantic aspects of interoperability (T4), in particular definition of the basic properties and characteristics of information; the meaning and/or "common understanding" of information objects; the construction, use and dissemination of information objects; comparison between information objects; measurement of information objects.

### 8.3.4 Web Science

The application of new Web technologies to Enterprise Interoperability is a Grand Challenge addressed in Chapter 6. In addition to this, in Spring 2006, a new "Web Science" was put forward as a specific *research agenda* that can help identify, with reference to the continuous evolution of the Web, "what needs to stay fixed and where change can be profitable"[62]. Three major ideas are driving this new "Web Science": (1) the Web needs to be studied and understood as an analytic discipline as other physical sciences; (2) the Web needs to be engineered as a synthetic discipline, as for computer science; and (3) the Web is simultaneously an infrastructure of artificial languages and protocols at the micro scale and a system of human interactions governed by conventions and laws at the macro

[61] See Section 4.5 for an explanation.
[62] *A Framework for Web Science*, Tim Berners-Lee, Wendy Hall, James A. Hendler, Kieron O'Hara, Nigel Shadbolt & Daniel J. Weitzner, Foundations and Trends in Web Science, Issue 1, now Publishers, Spring 2006.

scale. Accordingly, Web Science is an inter-disciplinary research agenda for driving Web development in both scientifically and socially useful ways.

On this view, the Web could become a basic building block of future enterprises (Chapter 6), which raises the possibility of aligning enterprise systems design with the scientific and architectural principles of the Web.

*Example research challenges*
They include: a new Web- and information- centric view of the world as the context for interoperability; evolution from the enterprise integration hub to the "global integration bus"; new architectural approaches and design techniques for interoperability and their potential applications for Enterprise Interoperability. This new science potentially impacts all technology domains (T1 – T5), including their classification, interpretation and description of research issues.

### 8.3.5 Services Science

Services are increasingly replacing tangible products as units of value and exchange in large areas of economic activity, particularly for the developed world. Specifically, services rely on a "co-production relationship" between the provider and the client in a transaction, with both simultaneously creating and capturing value in the transaction process. The development of a services-driven economy is epitomised by the software industry itself, where software is becoming increasingly commoditised and can be delivered as a service over a network. On this view, the service industry needs to be regarded as a collection of interacting and interoperating systems. It has been suggested that a new level of integration is required for this to happen.

Services science has been proposed as a new discipline[63]. Among its assumptions is that as the costs for conducting transactions within and among enterprises fall, technology can enable new types of inter- and intra- company services.

*Example research challenges*
They include: Enterprise Interoperability as a set of services simultaneously produced (by the provider) and consumed (by the client), with each being individuals, organisations or automated systems (T2.2); new business methods to create and capture value (B4); business interoperability and quality (B13); new technology tools to re-engineer processes (T2.1); new organisational culture and practices to motivate and align people (B3); new performance metrics and measurement techniques on effectiveness and efficiency in the performance of services work, software licenses for distributed and movable applications (P4).

### 8.3.6 Economic Science

The traditional concept of value is linked to economic cycles and productivity levels. However, the development of the Internet, the Web, and Web 2.0 as "social movements" challenges this concept. Critically, the Vision in this Roadmap raises three important questions. First, can a cogent economic case be made for interoperability as a common good or even a public good? Second, to what extent is interoperability a source of sustainable competitive advantage at the level of the firm? Third, what is the contribution of interoperability to efficiency, effectiveness and productivity?

From a business viewpoint, the economics of interoperability is intrinsic to the impact it has on enterprise performance. Yet, business sophisticated models that relate the costs of interoperable products and services to performance do not exist. Therefore, systematic research work on a comprehensive value proposition for interoperability is required.

*Example research challenges*
They include: interoperability, competitive advantage and innovation cycle (B11); interoperability and productivity (including the "ICT productivity paradox") (B8); interoperability and shareholder/stakeholder value (B4); business models for interoperable products and services (B4), leading potentially to a new value proposition for interoperability; the economic consideration of SMEs as a main driver for innovation and value creation (B10).

### 8.3.7 Social Sciences

There is a growing view that technology is a "social construct" that changes over time. To the extent that enterprises operate within a society, they too are socially constructed. Both are subject to the

[63] "Architecture of On Demand Business", IBM T.J. Watson Research Center, May 2004. http://domino.research.ibm.com/comm/www_fs.nsf/pages/index.html

conventions, practices, opinions, and other characteristics of the social environment, which may or may not be codified into law. Interoperability as a utility-like capability within innovation ecosystems cannot be decoupled from that social environment. People are very much part of that environment – from decision-making to interpretation of meaning to assessment of measurement to attribution of value, benefit and impact.

On this view, social sciences could have a significant role in contributing to a new "science" of interoperability-enabled business and collaboration models. That would need to include the nature of business relations, human-machine relations, and the "social" elements of interoperability projects.

*Example research challenges*
They include: the social context for Enterprise Interoperability, theories and practices of community development, interoperability and consensus building, the role of standards and specifications for interoperability (all in relation to B3).

### 8.3.8 Remarks

Additional related sciences and disciplines may be identified at a later stage, with the following additions already suggested during the final stages of developing this Roadmap:

- Social networks science
- Community science
- Business network governance science
- Business content sciences
- Decision science
- Change management science

**The overall aim is to stimulate ground-breaking research in Enterprise Interoperability**, rather than to pre-judge the suitability of particular areas of research, to pre-select a definitive list of relevant lines of enquiry, or to speculate on the likely outcome of scientific research. The important point is, however, that Enterprise Interoperability is by nature a multi-disciplinary, cross-cutting, engineering activity. As such, it must be based on rigorous scientific methods and principles. This is, in our view, the only way to ensure that Enterprise Interoperability adds value to business innovation.

Finally, validation, simulation, demonstration and testing in a business context, as well as effective dissemination and education, must be an integral part of the research activity.

## 9. Concluding Remarks

This Roadmap positions Enterprise Interoperability research as a key contributor to business innovation. It begins by describing the current situation and the problem space in Enterprise Interoperability. Despite many years of effort in research and beyond, islands of interoperability persist. Full alignment between technical capability and business need is still largely missing. Specifically, a single, monolithic solution for Enterprise Interoperability rested on proprietary protocols and captive markets is untenable in a climate of change, unworkable in real businesses, and strategically undesirable for promoting innovation and growth. Enterprises must innovate in order to survive. They must collaborate in order to innovate and to compete. The Roadmap presents an ambitious, long-term vision in which interoperability will be a utility-like capability that enterprises can invoke on the fly in support of their business activities. Enterprises will exist as nodes in innovation ecosystems. In this future, enterprise interoperability will be a key feature of the business fabric of all ecosystems. To accomplish this, a new approach to addressing business issues, break-through technology solutions, and supporting policy measures will be needed.

Four Grand Challenges in Enterprise Interoperability research are proposed for realising the Vision. They address creating an overall system (the ISU) for providing enterprise interoperability as a utility-like capability, leveraging the Web as a basic building block for future enterprises, knowledge sharing between enterprises collaborating as virtual organisations, and establishing a science base for engineering solutions to Enterprise Interoperability problems. Specific Research Challenges in support of the Grand Challenges are given as examples.

Overall, building on the current assets and legacy, this Roadmap presents a new and strategic direction for Enterprise Interoperability research in a climate of profound change, where great opportunities – and risks also – beckon. We believe that this direction will re-focus Enterprise Interoperability as a mainstream research field that provides tangible benefits for European enterprises, and make those enterprises more competitive and valuable in a globalising world. We also believe that by judiciously setting its research objectives and prioritising resources, Europe has a substantial leadership potential in this field. That research must be underpinned by openness in mindset and in action, by collaboration in theory and in practice, and by outreaching to all stakeholders in Enterprise Interoperability and in neighbouring disciplines. The research work must lead to results that add value to enterprises, and help enable open, competitive markets in both supply and demand of solutions.

The Roadmap is a collective effort of all interested stakeholders for all interested stakeholders. Specifically, it is submitted to the European Commission as an input to the FP7 programming. However, for the Roadmap to remain relevant, it must be subject to regular review and updates in the lifespan of FP7. Our final proposal therefore is that the current open, inclusive initiative in developing the Roadmap should be maintained within the framework of FP7.