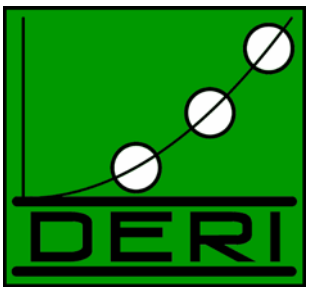

The Fundamental Premises of the Digital Enterprise Research Institute (DERI) International

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Abstract: DERI International is a collaborative organization of research institutes worldwide that are committed to the realization of the semantic web and semantic web services through collaborative and open methods and in accordance with the five fundamental DERI Premises: first, a core technology in support of problem solving environments; second, a conceptual model for service-oriented computing (Web Service Modeling Ontology (WSMO)); third, Web Service Modeling Language (WSML) a family of languages that provides formal semantics for WSMO models; fourth, a Web Service Execution Environment (WSMX) that supports reasoning and mediation in WSMO compliant solutions; and fifth, Triple-Space Computing, a new communication paradigm for services based on the Semantic Web paradigm. This document provides DERI's motivating vision, its five fundamental premises, and the first steps in defining DERI International.

Keywords: Semantics, ontologies, service-oriented computing, service-oriented architectures (SOA), semantically enabled service-oriented architecture (SESA), semantic web, semantic web services, problem solving, Web Service Modeling Ontology (WSMO), Web Service Modeling Language (WSML), Web Service Execution Environment (WSMX), Semantics Execution Environment (SEE), Triple-Space Computing, DERI International.

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1 MAKING SEMANTICS A PILLAR OF COMPUTER SCIENCE

Computer science appears to be in a period of crisis. The globalization trend is moving programming jobs from Europe and the US to low-labor countries such as China or India. This appears to place computer science research and departments at risk of being considered as working on obsolete technology. However, the opposite is true. Computer science is on the verge of a new generation of computing that is leading to innovation not only in computing but also in business, science, and all other endeavors that depend on computing.

Times of crisis are also times of innovation and can lead to paradigm shifts. Computer science is entering a new generation. The previous generation was based on abstracting from hardware. The emerging generation comes from abstracting from software and sees all resources as services in a service-oriented architecture (SOA). “A service-oriented architecture is essentially a collection of services. These services communicate with each other. The communication can involve either simple data passing or it could involve two or more services coordinating some activity. Some means of connecting services to each other is needed.”[12] In a world of services, users are concerned only about the services and not about any software or hardware components that implement the service. Service-oriented computing is rapidly becoming the dominant computing paradigm.

A Service-oriented world will have billions of services. Computation will involve services searching for services based on functional and non-functional requirements and an interoperating with those that they select. However, services will not be able to interact automatically and SOAs will not scale without *signification mechanization of service discovery, negotiation, adaptation, composition, invocation, and monitoring as well as service interaction requiring data, protocol, and process mediation*. Hence, machine processable semantics are critical for the next generation of computing, SOAs, to reach its full potential. Only with semantics can critical subtasks can be automated leaving humans to focus on problem solving.

The goal of *Semantically Enabled Service Oriented Architectures* (SESA) is to place semantics at the core of computer science to realize the potential of the next generation of computing. SESA will provide a next generation operating system that provides seamless and transparent integration of billions of services on a global scale. Semantic descriptions will enable computing to become a utility, just as electricity is today.

While a decade of research on the semantic web with its focus on defining semantics of data [13] has led to a deeper understanding of data semantics, the scalable semantic description of services is still in its infancy. DERI intends to lead in this direction with our SESA project and through collaboration with the international research community.

Furthermore we are convinced of the relevance of our work to the industrial and business community. Today's industrial enterprises face tremendous competitive pressures. Global competition, together with market demand for customized product delivered just in time, place tremendous pressures on business enterprises. The emerging global economy is rapidly replacing local markets. The emergence of open markets, reductions in trade barriers, and improvements in transportation and communications links have led to a situation where local competition and markets operate in the context of global standards. This open infrastructure allows manufacturers to respond to these challenges by working more closely with their suppliers, distributors and customers, and by building **extended enterprises** across the whole value chain. Further these shared business processes and 'Extended Enterprises' are truly global, viz. 'Design in the USA.... Manufacture in Asia.... Distribute and Sell in Europe'. Such extended enterprises present great challenges in terms of redesigning business processes to create sustainable competitive advantage. Extended and Virtual Enterprises [16] [17] co-operate very closely across the supply chain; on the inbound logistics side large enterprises have very close relationships and shared business processes with their key suppliers; on the outbound logistics side enterprises are tightly coupled through shared business processes with their distributors and major customers. The shared business processes are mediated using e-Business systems and the Web; if 'machine to machine' integration and negotiation are to be realised then the Semantic Web and Web Services are necessary. The key to the full realisation of the potential of the Extended Enterprise lies in its translation to a true **Digital Enterprise** using Semantic Web and Web Services Technology.

Our scientific objective is to achieve a better understanding of how semantics can become a critical component in modern computer engineering that develops a new generation of operating systems which enables resource sharing on a global scale. Typically in the past semantics has been studied in Artificial Intelligence for isolated computing or human tasks (e.g., simulating or achieving human intelligence with a computer). Our objective is to make

semantics a pillar of the software architecture of the next generation of computing. This leads to three research challenges:

- How can we make practical use of semantics in computing?
- How can we provide reasoning on a scale required for worldwide resource sharing?
- How can we provide semantic methods that can deal with the heterogeneity and dynamic aspects of a rapidly changing world of billions of services?

In a nutshell, we want to participate in this paradigm shift in computer science that is turning a crisis into an opportunity to help create a new, vast improved generation of computing.

2 THE VISION: THE NEXT GENERATION OF COMPUTING

We are entering the fourth phase of the convergence of computing and communication. This final phase is called Semantic Web Services. The four phases, depicted in Figure 1 below, are defined in terms of the computing and communication realms and how they interact. Communication can involve one individual in communication with another (1: 1) or one individual in communication with many (1: many). In the age where the computer is the network, computing can involve humans interacting with humans, semi-automatically, via the network or it can involve machines interacting with machines automatically via the network.

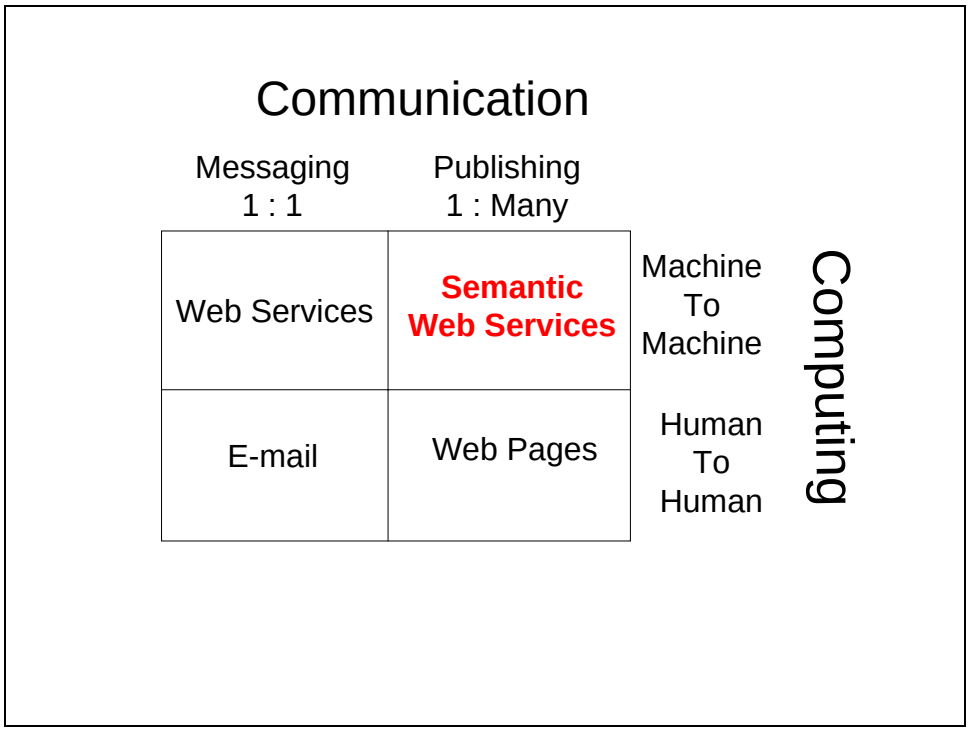

Figure 1: Four Phases of Computing / Communication Convergence

Phase one, characterized by E-mail, was enabled by the Internet and involved one human communicating with one or a small number of humans. This revolutionized communications and computing and furthered their convergence. Phase one lead to enormous scaling of message-based computing/communications that was achieved by miracles of network and infrastructure engineering. While well suited to messaging or brief communications, it was not well suited to publishing.

Phase two, characterized by web pages and enabled by the World Wide Web, permitted a human or a human organization to communicate with the entire networked world. Phase two led to massive innovation and growth in computing, communication, and their convergence, what we call web (or publishing)-based computing/communications. It led to business innovation and economic growth. Phase two scaling was also achieved by network and infrastructure engineering.

We are entering *phase three*, characterized by Web Services, which is being enabled by Service-oriented Computing (SOC), and which will revolutionize computing and communications based on message-based computing. Message-based computing permits the composition and re-composition of services as required to meet changing requirements. This contrasts with the inflexible architectures of conventional computing. *This technical flexibility will contribute to the greater goal of business flexibility – the ability to modify automated business processes with ease*. Phase three message-based computing achieves computing/communication convergence since you can compute longer without communicating and *vice versa*. Phase three leaves the realm of human-to-human networking and enters the 1:1 quadrant of machine-to-machine networking. In phase three, a machine, or a service on a machine, requests one or a small number of services (on other machines). The publish-

subscribe paradigm of message-based computing falls into the realm of one service, or a small number of services, subscribing to a single service. Scaling in phase three involves enabling 1:1 service interactions - matching a service request to a service offering and adapting (integrating) the service protocols, processes, and data. Scaling will be limited by syntactically based, semi-automatic means for service discovery, selection, orchestration, and adaptation.

In *phase four,* enabled by knowledge technologies, *service interactions will be created dynamically by knowledge-based service discovery, selection, orchestration, and adaptation.* Interactions will move from the 1:1 realm of message-based computing to the 1:N realm of full publish-subscribe. Scaling in phase four over phase three will be comparable in order of magnitude to that of the shift from e-mail based to web-based communications. We envisage a growth in technical and business innovation moving from Web service-based computing/communications to Semantic Web Services comparable to that experienced in the movement form the Internet to the World Wide Web. This movement has already been predicted for the Web moving to the Semantic Web. The prediction here is for the movement of all computing, e.g., information systems, from web services to services that can interact dynamically to adjust to changing requirements.

DERI is committed to realizing phase four by means of five fundamental premises.

3 FIVE FUNDAMENTAL PREMISES FOR REALIZING SEMANTIC WEB SERVICES

The Digital Enterprise Research Institute (DERI) (www.deri.org) is committed to making the semantic web and semantic web services real. This commitment is based on five fundamental premises. Each premise consists of a **long-term goal** and an associated **set of concepts** and where reasonable, **reference implementations**, plus a **roadmap** to their realization and implementation in practice.

While DERI's research contributions involve the development of technologies and reference implementations, DERI is committed to realization in practice via collaborative open, international standards and open source software. DERI will contribute a framework and other reference implementations to the open source community for shared development and innovation of industrial strength technology. DERI will also contribute to and collaborate through international standards activities such as OASIS and W3C. **This strategy is intended to encourage collaboration on research and development from the worldwide community to achieve concurrence on core concepts and technology while providing common platforms as a basis for innovation and competition.** DERI believes in the network effect of the open source and open standards community to achieve better results faster than more isolated, research and development strategies. DERI will strive to achieve leadership in each area of DERI's five fundamental premises.

> **Disclaimer:** The document is not meant as an umbrella that covers all activities from all DERI sites. For example, DERI Galway has activities on semantic desktops and DERI Korea on semantic eHealth. Neither of them are directly addressed in this document. Here, we only characterize some core beliefs common to all DERI institutes. Like a minimal ontological commitment it specifies the minimal amount of concepts all sites are supposed to share.

3.1 First Fundamental DERI Premise

The first fundamental long-term goal of this research is **the development of core technology in support of problem solving environments**. A problem-solving environment provides all the computation resources (e.g., information and functional services) required to address all issues in the problem domain in the terms and paradigms of the problem domain. For example, an employee payroll problem-solving environment provides all the resources, services, information, and tools necessary to fulfill employee payroll functions within a distributed work environment that includes all individuals required to support the employee payroll function, exclusively in employee payroll terms defined by the relevant organization.

The **set of concepts** developed by DERI to support the long-term goal of problem solving is a ***Semantically Enabled Service-Oriented Architecture (SESA).*** A SESA is an SOA enhanced by semantics. Conventional technology is rapidly being replaced by SOA technology to overcome the inflexibility and complexity of fifty years of conventional computing. Semantic enablement of SOA is required to increase the level of automation required to permit SOA to scale up and to be dynamic. Core SOA functions, service description, discovery, selection (match), orchestration (composition), and mediation or adaptation (protocols, processes, and data) will be enhanced with semantics. An example for such a problem solving environments is **the semantic desktop[14],** a semantically enhanced environment that supports workers in a specific problem-solving domain.

The **roadmap** to the realization of an SESA is an open standards process to develop an SESA framework. The framework incorporates the fundamental DERI premises. DERI will take leadership to establish an open, international SESA framework.

3.2 Second Fundamental DERI Premise

The second fundamental long-term goal of this research is **the development of a conceptual model for service-oriented computing**, which we call the **Web Service Modeling Ontology (WSMO**)[7] [6]. WSMO provides a conceptual model for adding semantics to service-oriented solutions including service-oriented architectures. The three-layered Figure 2 below is a simple depiction of the conceptual model. The top layer depicts the problems to be solved. The bottom layer depicts the basic resources required to solve the problem. The middle

layer depicts the meditation or reasoning that maps or mediates between the solution specification and its resolution by the resources.

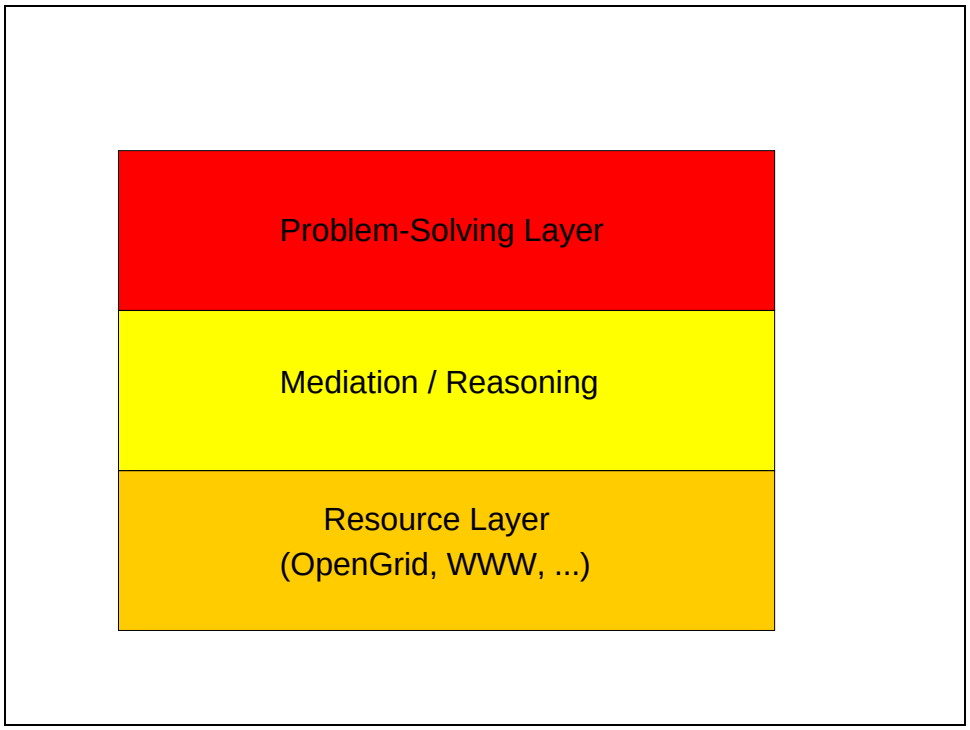

Figure 2: WSMO: Three layer Conceptual Model

The **set of concepts** developed by DERI to realize this goal (WSMO) constitue the conceptual model. WSMO consists of **goal definitions** (or specifications) for producer and consumer services, **semantic web services** that implement services and **mediators** - declarative and procedural means to facilitate interoperability at the level of matching service requests with service offerings - and adaptation of the related data, protocols, and processes, and ontologies on which semantic specification and processing is based. Problems are specified in terms of **functional** and **non-functional specifications**. Semantic web services add interface descriptions that specify **communication** and **cooperation of** services (i.e., choreography and orchestration).

The **roadmap** to realization of WSMO is an open standards process to develop the WSMO conceptual model that included the above concepts. The WSMO conceptual model provides the core concepts for subsequent fundamental premises and their related open standards. DERI will take leadership to establish an open, international WSMO conceptual model.

3.3 Third Fundamental DERI Premise

The third fundamental long-term goal of this research is **the development of the Web Service Modeling Language (WSML**)[8] [9]. *WSML is a family of languages that provides formal semantics for WSMO models on top of XML and RDF*. Its four major dialects, depicted in Figure 3 below, form a lattice based on rule languages and description logics, as well as on their minimal and maximal intersection.

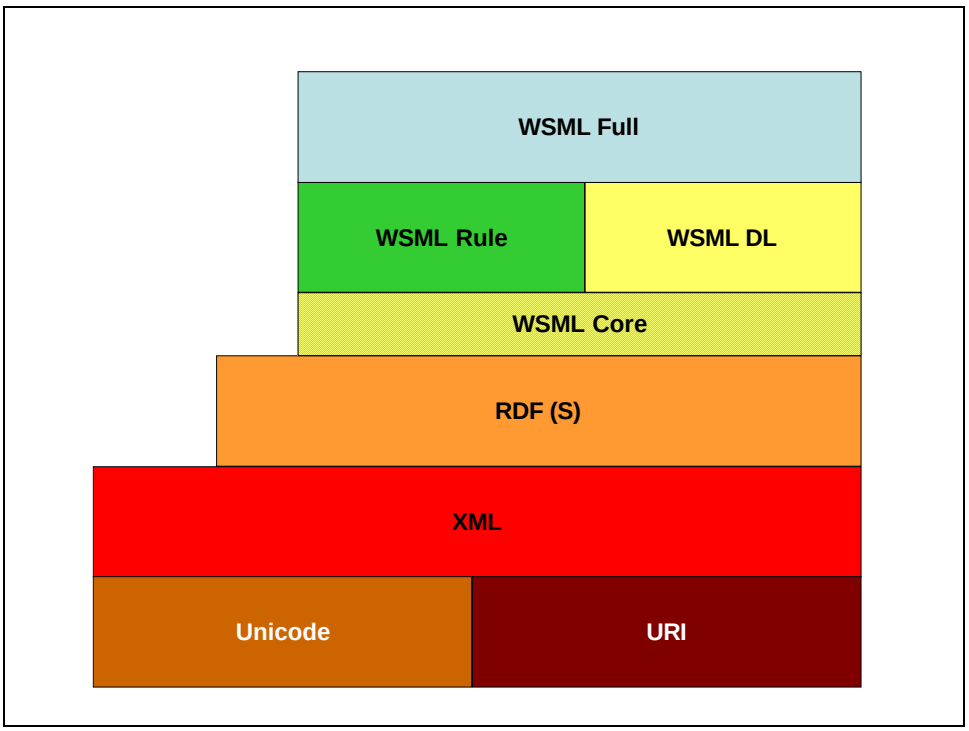

Figure 3: WSML family of languages

The **set of concepts** developed by DERI to realize this goal are the four languages depicted below (WSML Full, WSML RULE, WSML DL, WSML Core) and the underlying standard languages of the semantic web, RDF, XML, Unicode, and URI. DERI is developing reference implementations of WSML Full, WSML RULE, WSML DL, and WSML Core.

The **roadmap to the realization** of the WSML family of languages are the existing open international standards activities.

3.4 Fourth Fundamental DERI Premise

The fourth fundamental long-term goal of this research is **the development of a Web Service Execution Environment (WSMX)** required to support the reasoning and mediation required to support WSMO compliant solutions. WSMX is a reference architecture for the components of an SESA.

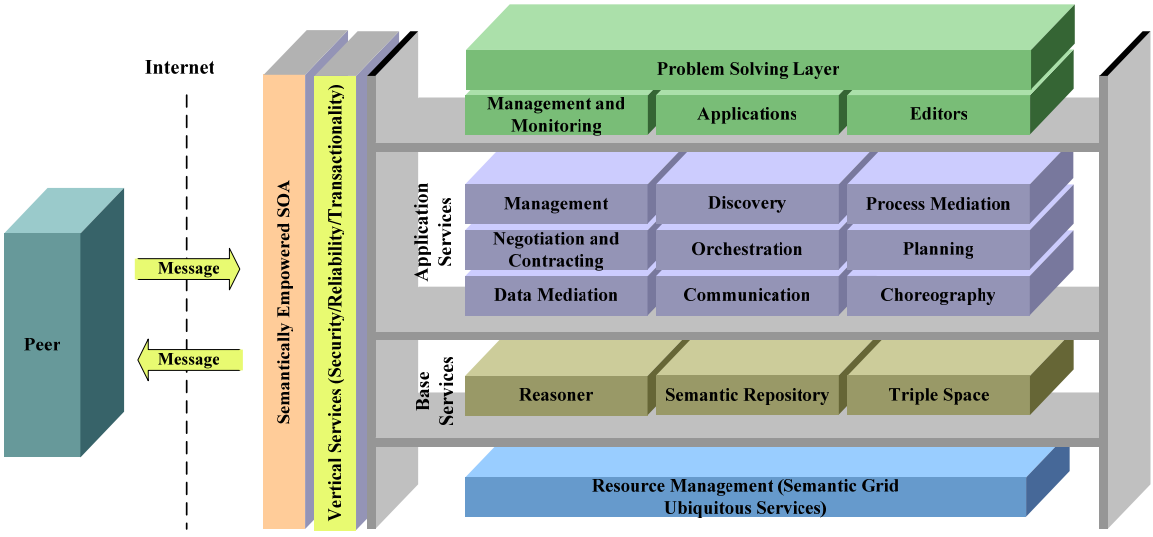

Figure 4: WSMX: A Reference Architecture for SEE

The **set of concepts** developed by DERI to realize this goal are those that constitute **WSMX** [2], illustrated in Figure 4. *WSMX is a reference implementation of a SESA that is compliant with the semantic specifications of WSMO*. WSMX supports semantically enabled discovery, selection, and mediation, as well as service invocation and inter-operation. WSMX is an execution environment for the dynamic discovery, selection, mediation, invocation and inter-operation of the semantic web services providing a reference implementation for WSMO. The development process for WSMX includes defining its conceptual model, defining the execution semantics for the environment, describing architecture and a software design and building a working implementation. DERI contributed WSMX, its reference implementation, to the open source community as a platform for research and development.

The roadmap to the realization of this long-term goal is the OASIS Semantics Execution Environment (SEE) standards activity initiated in November 2005[15] and lead by DERI. OASIS relabelled the WSMX specification to SEE.

3.5 Fifth Fundamental DERI Premise

The fifth fundamental long-term goal of this research is **the development of Triple-Space Computing**, a new communication paradigm for services based on the Semantic Web paradigm.

The **set of concepts** developed by DERI to realize semantically enabled **Triple-Space Computing** is based on a Linda-like ([10], [11]) publish-subscribe, globally accessible information / communication space. Currently, web services require close coupling with the applications that they integrate. Applications communicate via message exchange requiring strong coupling in terms of reference and time. The communication has to be directed to the web service addressed and the communication must be synchronous. If both parties do not implement and jointly agree on the specific way this mechanism is implemented, then the applications must support asynchronous communication. The web is strongly based on the opposite principles. Information is published in a persistent and widely accessible manner.[1] Any application can access this information at any point in time without having to request the publishing process to directly refer to it as a receiver of it's information. While web services use the Internet as a transport media (relying on protocols such as FTP, SMTP, or HTTP), that is all they have in common with the web. DERI is developing a semantically enabled triple space as described in [4][5].

The **roadmap to the realization** of Triple-Space Computing has not yet begun. DERI envisages the need for an open, international standard for information storage and access across the worldwide web and believes that the triple-space model is an excellent candidate. While DERI will contribute to such an effort, DERI believes that the information storage and access community should lead the effort.

[1]For privacy issues, protected sub-fragments of the web can be defined.

4 DERI INTERNATIONAL

DERI International is a collaborative organization of research institutes worldwide that are committed to the realization of the semantic web and semantic web services in accordance with the five fundamental DERI Premises outlined above and employing collaborative and open methods. Research groups within DERI International commit to work together using the following synergistic modalities:

- Open Standardization: Contribution to and participation in open, international standards leading to the realization of the five premises.
- Open Source Software: Selective contribution of software components to the Open Source community to support the development of common platforms and solutions that will stimulate innovation and competition on top of those platforms.
- Research Collaboration: Share research concepts and results and collaborate, where possible, in projects that contribute to the realization of the five premises.
- Resource Sharing: Where appropriate share human, software, hardware resources, etc, towards the achievement of common goals. Such resource sharing might for example take the form of the short term exchange of researchers between laboratories.
- Outreach to business and government: Collaboration in strategies and materials intended to educate relevant organizations to the benefits of and progress towards the realization of the semantic web and semantic web services. Outreach also involves developing case studies and practical applications of research results to further both research and applications in practice.

We refer to members of DERI International who work together using these modalities as Tier 1 or Level 1 members of DERI International.

DERI International also supports its member organizations in the acquisition of funding and the development of business opportunities in order to promote the development and availability of semantic web services.

- Funding Acquisition: Collaborate in developing funding for efforts of DERI International and its participating research institutes.
- Business Development: Collaborate in developing the business potential of DERI International and its participating research institutes, and of the business opportunities arising from research results.

We refer to members of DERI International who engage in such joint activities as Tier 2 or Level 2 members of DERI International.

Thus DERI International offers various levels of participation to research institutes, government agencies, and private enterprises. Participation is contingent of commitment to and the collaborative evolution of the five DERI fundamental premises. The first level of participation involves active contribution to and participation in the relevant open standards and open source activities. This is open to all research institutes worldwide, based on a shared letter of understanding. Successive levels of participation are based on legal agreements with DERI international based on research collaboration, resource sharing, and outreach. A deeper level of participation in DERI International involves a partner being involved directly with funding acquisition and business development.

DERI Innsbruck and DERI Galway are founding members of DERI International. DERI Stanford and DERI Korea are the research institutes to join DERI International. Plans are being made for further expansion.

We envisage DERI International as a federation of organizations and individuals who commit to the five premises outlined in Section 3 and who seek to realize these premises in practice through the various modalities suggested above. Organizations include research laboratories inside and outside universities, and private companies, including developers and users of the technology. Membership is available to those who sign up to the five premises, are able to show that they have capacity to support the realization of those premises and are interested in working collaboratively to do so.

In line with its commitment to open source software, DERI International seeks to be inclusive rather than exclusive in its membership in order to advance the DERI agenda worldwide. Membership confers on the organization or individual who signs up the right to have access to and to participate in all kinds of DERI International communication activities (meetings, conference calls, and mailing lists) where the outputs of the various members are

presented and where the opportunity exists to network freely with the DERI research community and to influence the direction of the ongoing research.

Within DERI International, it is expected that some members will wish to engage in more active collaboration with a view to advancing particular elements of the research programme using the later two modalities identified above. DERI International will facilitate the emergence of such collaborative efforts, while recognizing that such initiatives carry with them certain rights and obligations that are particular to each such agreement. Indeed DERI International seeks to position itself as a vehicle for the emergence and creation of such projects or initiatives, which might take the form of joint papers, joint co funded (third party funding bodies) or individually (i.e. each partner covering his own costs) funded projects, joint submissions to standards bodies, and indeed ultimately business partnerships to create and deliver product where appropriate. In this way DERI International exists on two levels or tiers. Level 1 is the organization or loose federation which meets at least once per year to take the DERI research agenda forward; level 2 is a collection of activities involving subsets of DERI International members who mutually agree to engage in various forms of joint work which advances the DERI research and implementation agenda.

DERI International will be resourced at the level which allows it to maintain a register of members, maintain the DERI roadmap, update the DERI premises when and where it is appropriate as well as the modalities for advancing them, organize the annual DERI International meeting including the development of its agenda and the documentation of its outputs. This resource has been established in the form of a part time project office. As DERI International grows, objectives, requirements, and resources of this project office will be reviewed and adapted accordingly.

4.1 Pending Issues

In the spirit of collaboration, described above, DEI International will work with its partner organizations to address the following open issues.

1. Define roles, responsibilities, and power (reporting) of the Board members. Candidates must be willing to fulfill the requirements; have influence in the required spheres; understand the relevant technology and business directions and goals; and be widely recognized as capable of fulfilling the roles. Once the roles and responsbilities are defined, candidates will be considered.

2. Define roles, responsibilities, and objectives of partner organizations. The roles and responsibilites must be defined in sufficient detail as to define a complete buisness model of DERI International. The roles and responsibilities must be rewarded by benefits that are steps towards the objectives of partner organizations.

3. Define roles, responsibilities, and benefits of an Industrial Board that would receive defined benefits and maybe an Industrial Board membership fee, The Industrial Board, DERI's industrial ecosystem would contribute industrial requirements and participate in joint projects with DERI sites.

4. Define the DERI International business model that will impose a (non-profit) fee structure to cover operating costs. DERI International will be a legal entitiy and will operate as an enterprise (whether for profit or not). Isues to be addressed include: Intellectual Property, non-profit vs for profit status, obligations imposed by funding agencies, roles or partner organizations, the tiers or level structure, and more.

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