International Congress on Environmental Modelling and Software

4th International Congress on Environmental Modelling and Software - Barcelona, Catalonia, Spain - July 2008

Jul 1st, 12:00 AM

The Growing Importance of Open Service Platforms for the Design of Environmental Information Systems

Thomas Usländer

iEMSs 2008: International Congress on Environmental Modelling and Software
Integrating Sciences and Information Technology for Environmental Assessment and Decision Making
4th Biennial Meeting of iEMSs, http://www.iemss.org/iemss2008/index.php?n=Main.Proceedings
M. Sànchez-Marrè, J. Béjar, J. Comas, A. Rizzoli and G. Guariso (Eds.)
International Environmental Modelling and Software Society (iEMSs), 2008

The Growing Importance of Open Service Platforms for the Design of Environmental Information Systems

Thomas Usländer, Fraunhofer IITB
thomas.uslaender@iitb.fraunhofer.de

Abstract: Environmental Information Systems (EIS) play a key role in our understanding of the past, current and future status of the environment. In the last 10-15 years, the design of EIS has undergone fundamental changes following both the requirements of the users and the capabilities of the underlying information technologies (IT). This paper first identifies three major trends that have determined these changes: 1) integration of several thematic domains to support interdisciplinary environmental tasks, 2) distribution of EIS to a wider spectrum of users, and 3) permanent functional enrichment with sophisticated functions such as environmental simulations or geo-processing capabilities. It then deduces from these trends the need and the growing importance of open service platforms based on international geospatial standards for the EIS design and its operation. In particular, the open geospatial service architecture of the European research project ORCHESTRA (Open Architecture and Spatial Data Infrastructure for Risk management) is presented in the context of the Web service architectures of the standardisation organisations W3C, OASIS and the Open Geospatial Consortium (OGC). The paper concludes with an overview about ongoing research topics such as the integration of sensor networks, the exploitation of semantic technologies and design methodologies for service-centric computing.

Keywords*:* Environmental Information System; Open Geospatial Service Platform; Service-Oriented Architecture; Open Geospatial Consortium

1. INTRODUCTION

Environmental Information Systems (**EIS**) play a key role in our understanding of the past, current and future status of the environment. Usually based on large databases that are indirectly (offline) or directly (online) coupled to environmental sensors they allow the user to query and process environmental information and visualize it in thematic maps, diagrams and reports. More advanced functions cover, for instance, the estimation of future values of environmental parameters based on simulation or stochastic models as a basis for decision-support or early warning.

In the last 10-15 years, the design of EIS has undergone fundamental changes following both the requirements of the users and the capabilities of the underlying information technologies (**IT**). This paper first identifies the major trends that have determined these changes, deduces the growing importance of open service platforms for the EIS design and concludes with an overview about ongoing research topics.

On the one hand, the described trends reflect longstanding experiences in the design, deployment and operation of regional and national EIS gained in a German cooperative research network between stakeholders and IT providers [Mayer-Föll et al 2007]. On the other hand, the paper summarises the requirements, IT research topics and latest results of European research projects in the domain of environmental risk management aiming at establishing the basis for a so-called "Shared Information Space for the Environment in Europe (**SISE**)" as requested by the European Commission [Coene and Gasser 2007].

2. TRENDS IN ENVIRONMENTAL INFORMATION SYSTEMS

The following three major trends resulting from the demands of the stakeholders have determined the EIS design in the last years:

1. Domain Integration
2. Wider Distribution
3. Functional Enrichment

2.1 Domain Integration

Domain Integration responded to the demand of enabling the correlation of EIS information and services across various thematic domains, mainly driven by the needs to understand the complex inter-domain relationships in ecological systems. Traditionally, it has been essential for the success and the acceptance of EIS that they are tailored to the thematic domain (e.g. air, water, soil), i.e., that the end user easily recognises in the user interface the notions and names of his/her respective thematic world and the information objects he/she has to deal with. Moreover, the EIS should adhere to the organisational working rules that the end users are used to.

However, thematic information systems had more and more to integrate aspects of other environmental domains in order to handle multi-domain correlation effects. In order to enable a short learning curve, the integrated EIS should follow the same user interaction principles. From the IT perspective, these demands have initially (in the mid and end of the 1990s) resulted in the development of EIS programming frameworks based on mainstream but mostly platform-specific development environments of those days (e.g. Microsoft Active-X, Java/JavaBeans). Non-proprietary middleware technologies such as **CORBA** (Common Object Request broker Architecture) specified by the **OMG** (Object Management Group) could overcome some of the platform-dependencies, but in the end have only been partially successful as standard distributed EIS middleware.

One of the technical obstacles of CORBA has been the tight coupling of client components to remotely accessible objects which led to problems in the robustness of the whole distributed applications. Nevertheless, CORBA laid the basis for thinking in terms of "distributed architectures" based on the notion of "interfaces" specified in a platform-neutral interface definition language. As the middleware battle between Active-X/.NET and CORBA was not decided definitely in the IT market, "Web services" have emerged as the middleware of choice also for distributed Web-based EIS applications crossing thematic and organisational boundaries. The European Commission [2008] follows this trend in their ambition to conceive a "Shared Environmental Information System (**SEIS**)" in Europe. End-user institutions are expected to make investments to "render their existing systems interoperable and link them to an integrated system of systems".

2.2 Wider Distribution

The trend towards wider distribution responded to the demand to open up the EIS to a wider spectrum of users (from employees in environmental agencies, over politicians in ministries up to the citizen) as well as to design the functions of an EIS as callable units from other applications. This trend has been mainly driven by European and national directives such as the European Directive [2003/4/EC] on Public Access to Environmental Information or the Water Framework Directive (**WFD**) [Directive 2000]. At the technical level these directives resulted in the requirements to offer environmental information in a variety of formats and aggregation levels to a multitude of users.

An example is given WFD implementation requirements. The aim of the WFD is to ensure that all European waters, these being groundwater, surface or coastal waters, are protected according to a common standard. As the WFD requires a water management policy centered on natural river basin districts instead of administrative and political regions, the agencies have to co-ordinate their work, possibly across national borders. However, the WFD is not only a fundamental rethink of the EU water policy, its implementation is also a challenge for the supporting information technology (IT) and, especially, for a WFD-specific information management [Usländer 2005].

Already in the WFD monitoring phase, there is a huge need for harmonisation and possibly standardisation to achieve an efficient implementation of the WFD within Europe. The Common Implementation Strategy established by the European Commission currently foresees three different WFD "products":

- Seamless and harmonised geometric data (e.g. topological consistency)
- Centralised WFD database (1st phase) with a data exchange based on ESRI shapefile format or the Geography Markup Language (**GML**).
- Federation of spatial WFD data servers (2nd phase) based on the standards and recommendations of the Open Geospatial Consortium (**OGC**) and aligned with other pan-European activities on spatial data integration such as **INSPIRE** (Infrastructure for Spatial Information in the European Community).

Today, we are in the transition between the 1st and the 2nd phase: Data is currently exchanged based on **XML** (Extended Markup Language) schemas (either agreed between the EU and the member states or within the member states) whereby investigations about the best architectural choice for the 2nd phase is the subject of European research projects and the implementation of the INSPIRE Directive [2007].

The IT answer to these demands has been essentially influenced and pushed forward by the growing acceptance of the World Wide Web as "computing platform" and not only as information medium. The initial driving forces of "Web Services" have been to better overcome enterprise firewalls and to provide an elegant platform-neutral solution in the middleware battle. However, the acceptance of "service-oriented architectures (**SOA**)" also for the design of EIS resulted from the encouraging perspective in deploying an EIS as a set of re-usable components (services) with well-defined interfaces. These services shall be callable from the Intranet/Internet, thus offering environmental information in an "open" manner to an increasing and heterogeneous user community.

2.3 Functional Enrichment

The trend towards functional enrichment followed the demand to make more sophisticated functions directly available within an EIS, such as environmental simulations or geo-processing capabilities. This helps to lower the purchase, development, user training and maintenance costs. Here, the SOA approach as described above has helped a lot as these functions may also just be loosely-coupled with the EIS as a remote Web service instead of being provided in stand-alone systems, e.g. a Geographic Information System (GIS). Standardised geospatial Web services (e.g. the Web Map Service) as specified by the OGC have captured the generic parts of such remote functions.

The emergence of these IT solutions has created a more challenging vision: an ″ideal″ IT support that would make information available on demand for the end users and would enable the service providers to offer high-quality services at considerably lower cost in a plug-and-play manner. As illustrated in figure 1, EIS applications of various types running in control or information centres, tailored to the analysis of environmental data or to its visualisation in maps or diagrams, have to be coupled with data of various types such as geospatial thematic data, documents or information about environmental phenomena observed by monitoring stations, cameras or satellites – a vision formulated by Denzer [2005] of a functionally rich but generic platform as a need to effectively build environmental decision support systems.

An essential element of such an ideal IT support is an "open geospatial service platform" which provides seamless access to resources (information, services and applications) across organisational, technical, cultural and political borders, thus overcoming real-world heterogeneity and assuring a sustainable investment for the support of future, yet unknown requirements. "Open" hereby means that service specifications are published and made freely available to interested vendors and users with a view to widespread adoption. Furthermore, an open service platform makes use of existing standards (e.g. ISO and OGC) where appropriate and otherwise contributes to the evolution of relevant new standards.

3. OPEN GEOSPATIAL SERVICE PLATFORM

3.1 The ORCHESTRA Architecture

Based on a systematic analysis of system requirements, the European research project **ORCHESTRA** (Open Architecture and Spatial Data Infrastructure for Risk management) has specified and implemented a reference model and a series of architecture services that provide the generic and platform-neutral functional grounding of such open geospatial service platforms [Klopfer and Kannellopoulos (eds.) 2008]. This Reference Model for the ORCHESTRA Architecture (**RM-OA**) has been accepted as a best-practices document for architectural design by the OGC [Usländer 2007a]. Figure 1 shows the abstract principle how a geospatial service platform may couple applications and data sources.

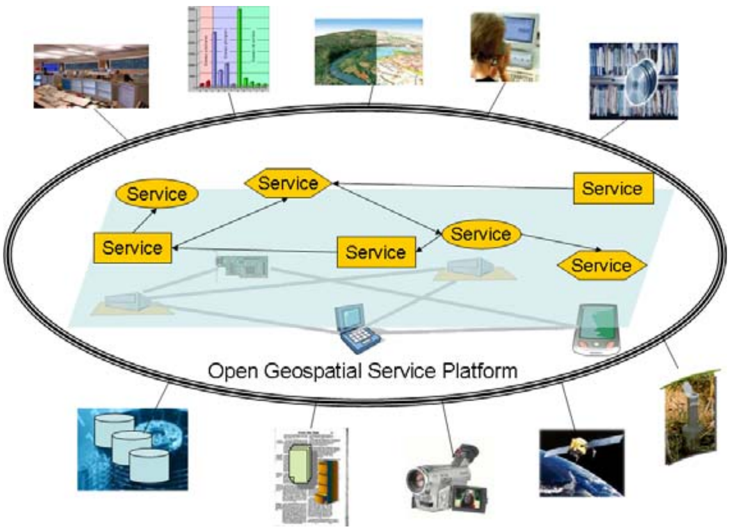

Figure 1. Open Geospatial Service Platform

The RM-OA is built upon two main pillars: a process model and a conceptual model. The ORCHESTRA process model applies an incremental, iterative approach for the analysis and design phases. Usually, a multi-step breakdown process across several abstraction layers is necessary to analyze user requirements and map them to the capabilities of a service platform. As illustrated in figure 2, ORCHESTRA distinguishes between an abstract service platform that is specified independently of a given middleware technology and a concrete service platform.

The abstract design phase leads to platform-neutral specifications following the rules defined in the RM-OA for the abstract service platform. They represent the functional, informational and non-functional requirements of the problem domain. The concrete design phase maps the abstract specifications to a chosen concrete service platform. Currently, this is the ORCHESTRA Web Services platform based on the Web Service Description Language (WSDL) bound to the SOAP protocol, and a GML profile as the current mainstream service platform technologies for geospatial applications. In the engineering phase the platform-specific components are organized into service networks taking into account the qualitative requirements and translating them into operational policies.

In practice, these individual phases are often interlinked and repeated in an iterative fashion. Sometimes the abstract design phase is not required. Furthermore, existing service and OGC service standards for Web services make a pure top-down approach impractical. Thus, in practice, a middle-out design approach is often the appropriate method.

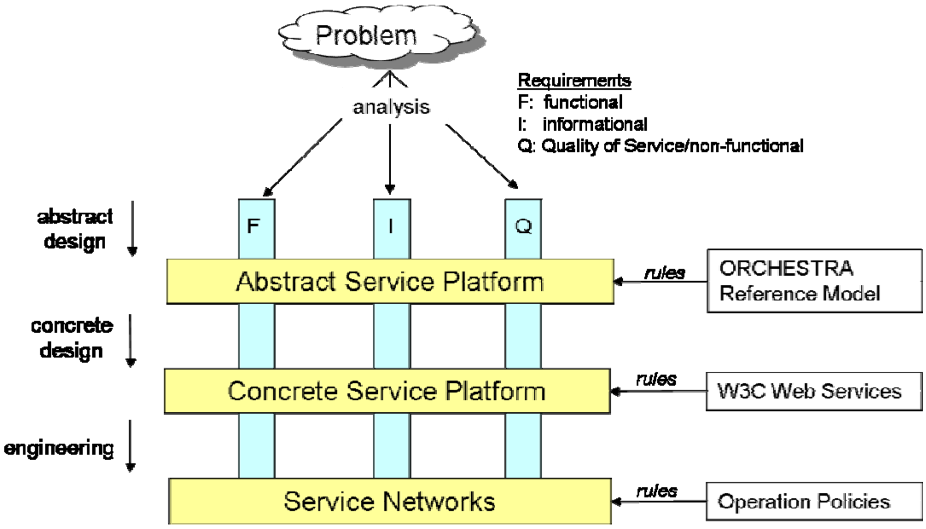

Figure 2. Abstract and Concrete Service Platforms

However, what is required is a clear structure for the documentation of the ideas and the results of the design phases. ORCHESTRA has adopted the ISO Reference Model for Open Distributed Processing [1998] for this task and has interpreted it for the design of geospatial service architectures. One major step forward in the RM-OA is a uniform meta-model for both the information and the service models that extends and complements the ISO 19109 General Feature Model [2005]. The key concept in the uniform meta-model is to put in the forefront the "interface type" as reusable specification unit. This allows the service designer to combine interfaces to new service types according to the functional requirements of the user. An example is a diagram rendering interface as an extension to a map service to enable visualisation of information in both map and diagram layers.

3.2 ORCHESTRA Architecture Services

Table 1 lists the major architectural interface and service types that have been specified in the ORCHESTRA Architecture on the abstract as well as on the concrete service platform level. This list of generic services has been systematically derived from system and user requirements in the thematic domain of risk management. However, their scope is intended to be independent of the application domain. Note that these services types consist themselves of a set of interface types that may also be attached to other service types.

4. ONGOING RESEARCH ACTIVITIES

There are ongoing research activities for service-centric distributed applications which are of high relevance to the future design of open service platforms for EIS. Some of them are highlighted in the following sections.

4.1 Semantic Web Services

There is ongoing research work in the field of semantic extensions of the Web (Semantic Web) which has already led to a series of basic recommendations of the World Wide Web Consortium (**W3C**) such as the Resource Description Framework (**RDF**) as a general method of modelling information as statements about resources in the form of subject-predicate-object expressions, and **OWL**, the W3C Web Ontology Language to define and instantiate ontologies.

Table 1. List of Major ORCHESTRA Architecture Services and Interfaces

Service and Interface Type Name	Application
Basic Interface Types	Enable a common architectural approach for all ORCHESTRA Services, e.g. for the self-description of service instances (capabilities), synchronous and asynchronous interactions, transactional support and access to knowledge basis.
Annotation Service	Generates specific meta-information from textual sources and relates it to elements of an ontology (e.g. concepts, properties, instances).
Authentication Service	Proves the genuineness of principals (i.e. the identity of a subject which may be a user or a software component) using a set of given credentials.
Authorisation Service	Provides an authorisation decision for a given context.
Catalogue Service	Ability to publish, query and retrieve descriptive information (meta-information) for resources of any type. Extends the OGC Catalogue Service by additional interfaces for catalogue cascade management and ontology-based query expansion.
Coordinate Operation Service	Changes coordinates on features from one coordinate reference system to another.
Document Access Service	Access to documents of any type (e.g. textual documents and images).
Feature Access Service	Selection, creation, update and deletion of feature instances and feature types available in a service network. Corresponds to the OGC Web Feature Service but is extensible by a schema mapping interface.
Map and Diagram Service	Enables geographic clients to interactively visualise geographic and statistical data in maps (such as the OGC Web Map Service) or diagrams.
Name Service	Encapsulates the implemented naming policy for service instances in a service network
Ontology Access Service	Supports the storage, retrieval, and deletion of ontologies as well as providing a high-level view on ontologies.
Service Chain Access Service	supports the creation of an executable service instance based on an explicit description of a service chain.
Service Monitoring Service	Provides an overview about service instances currently registered within service network incl. status and load.
User Management Service	Creates and maintains subjects (users or software components) including groups (of principals) as a special kind of subjects.

Work on semantic extension of Web Services (Semantic Web Services) is carried out in various research projects and is currently reflected in various competing submissions to the W3C, e.g. **WSMO** (Web Service Modelling Ontology) and **OWL-S** (OWL-based Web service ontology). It is too early to anticipate which of these technologies and frameworks will be dominating the market in the future as their practical relevance has only rarely been validated in real-world applications. However, the use of ontologies and related Semantic Web Services is one of the promising approaches to match between heterogeneous environmental data schemas and service types.

4.2 Integration of Sensor Networks

The European research project **SANY** (Sensors Anywhere) extends the ORCHESTRA architecture by the inclusion of sensors and sensor networks of various topologies [Havlik et al 2007]. The resulting Sensor Service Architecture is based on the OGC Observation and Measurement model [Cox 2007] and includes the service types of the OGC Sensor Web Enablement working group (see table 2). SANY organizes the service spectrum in a hierarchy of functional domains as illustrated in figure 3. Whereas the Sensor Domain is dominated by proprietary solutions, a high percentage of the required functionality is covered by the application and tailoring of the generic ORCHESTRA and SANY service types.

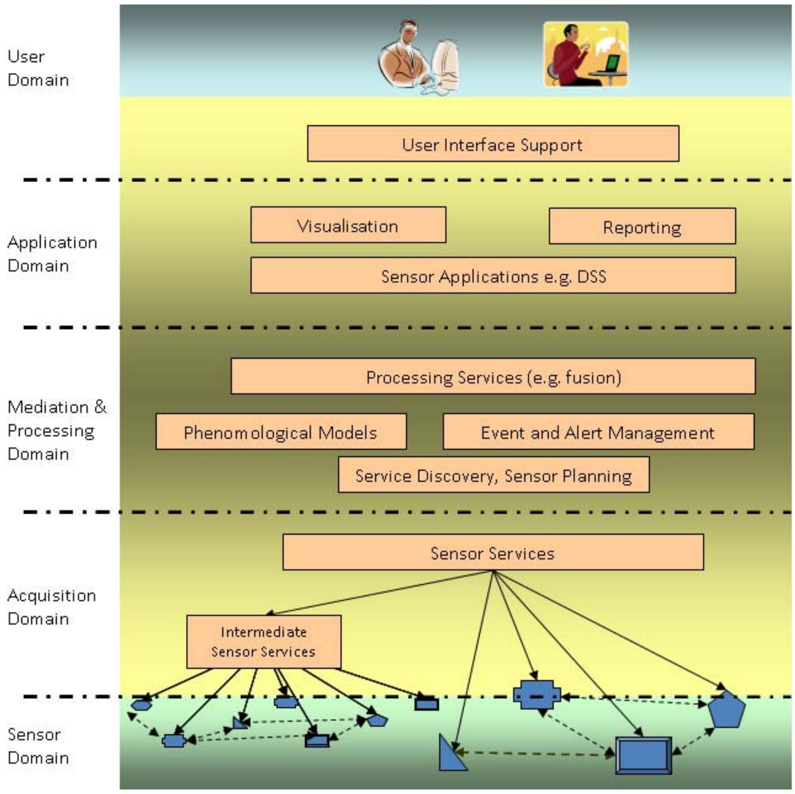

Figure 3. Functional Domains of the SANY Sensor Service Architecture

Table 2. List of Service Types of the OGC Sensor Web Enablement Group

Service and Interface Type Name	Application
Sensor Observation Service	Provides access to observations from sensors and sensor systems in a standard way that is consistent for all sensor systems including remote, in-situ, fixed and mobile sensors.
Sensor Alert Service	Provides a means to register for and to receive sensor alert messages.
Sensor Planning Service	Provides a standard interface to task any kind of sensor to retrieve collection assets.
Web Notification Service	Service by which a client may conduct asynchronous dialogues (message interchanges) with one or more other services.

4.2 Web Service Paradigms

Looking at the technical foundation for the open service platforms, there is an ongoing discussion about the basic Web service paradigm to be used. The OGC services have been designed before the W3C standards SOAP and WSDL have been accepted. Thus, they are still specified with an http/**KVP** (key-value pair) binding. Although the OGC Technical Committee has decided in June 2006 to provide additional WSDL/SOAP bindings for the OGC service interfaces, they have not yet reached the status of accepted OGC standards. Furthermore, the mass-market in the Geospatial Web tends towards another paradigm, the RESTful web services [Richardson and Ruby 2007]. RESTful web services aim at accessing and manipulating uniquely identified resources based on a uniform interface with commonly agreed, well-defined semantics. It is usually discussed together with its realization in a Web environment i.e., based on the basic technologies of the World Wide Web.

Following the RM-OA, the SANY project understands a Resource-Oriented Architecture (ROA) as a platform-independent concept to be integrated into the service meta-model [Usländer 2007b]. At the level of the concrete service platform, there will be basic rules (e.g. to use http) and defined but conditional extensions (e.g. to use WSDL/SOAP or to provide RESTful Web services) depending on the needs of the environmental applications.

5. CONCLUSIONS AND RECOMMENDATIONS

Technologies for service platforms have continuously changed in the past and are expected to change in the future. Nevertheless, an "open" approach with functionally rich service platforms based on standards is indispensable when aiming at providing interoperable solutions. The ORCHESTRA and the SANY projects try to provide robust and sustainable architectures that may cope with technological changes. Semantic technologies will emerge but have to be integrated step-by-step into the existing open geospatial service platforms.

REFERENCES

Coene, Y. and R. Gasser, Joint Operability Workshop Report "Towards a single information space for Environment in Europe", Frascati, ftp://ftp.cordis.europa.eu/pub/ist/docs/environment/sise-workshop-report_en.pdf, 2007.

Cox, S, Observation and Measurements – Part 1: Observation Schema. OGC Document 07-022r1, OpenGIS Specification, 2007.

Denzer, R., Generic Integration of Environmental Decision Support Systems – State-of-the-Art, Elsevier Journal Environmental Modelling and Software 20, pp. 1217-1223, 2005.

Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy, 2000.

Directive 2003/4/EC of the European Parliament and of the Council on public access to environmental information and repealing Council Directive 90/313/EEC, 2003.

Directive 2007/2/EC of the European Parliament and of the Council establishing an Infrastructure for Spatial Information in the European Community (INSPIRE), 2007.

European Commission, Communication from the Commission to the Council, the European Parliament, The European Economic and Social Committee and the Committee of the Regions - Towards a Shared Environmental Information System (SEIS), COM (2008) 46 final, 2008.

Havlik, D., Schimak, G., Denzer, R. and Stevenot, B, SANY (Sensors Anywhere) Integrated Project. In: D. A. Swayne and J. Hrebicek, [Ed.], *Proceedings of the ISESS 2007*, 22-25 May 2007, Prague, Czech Republic.

ISO/IEC 10746 Reference Model for Open Distributed Processing, 1998.

ISO 19109 Geographic information -- Rules for application schema, 2005.

Klopfer, M. and I. Kannellopoulos (eds.), ORCHESTRA – An Open Service Architecture for Risk Management, http://www.eu-orchestra.org/docs/ORCHESTRA-Book.pdf, ISBN 978-3-00-024284-7, 2008.

Mayer-Föll, R. and W. Geiger (eds.), Wissenschaftliche Berichte Forschungszentrum Karlsruhe FZKA 7350, UIS Baden-Württemberg, F + E-Vorhaben KEWA Phase II 2006/2007, http://www2.lubw.baden-wuerttemberg.de/public/uis/kewa1, 2007.

Richardson, L. and S. Ruby, RESTful Web Services. O'Reilly Media, Inc. ISBN-10: 0-596-52926-0, 2007.

Usländer, T., 2005. Trends of environmental information systems in the context of the European Water Framework Directive. *Elsevier Journal Environmental Modelling & Software 20*, 1532-1542, 2005.

Usländer, T. (ed.), Reference Model for the ORCHESTRA Architecture Version 2. OGC Best Practices Document 07-097, http://portal.opengeospatial.org, 2007a.

Usländer, T., Integration of Resource-Oriented Architecture Concepts into the OGC Reference Model. OGC Document 07-156, http://portal.opengeospatial.org, 2007b.