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D10.3

Report on international standards on architecture principles, metadata, data models and services and improving links with other projects

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1. INTRODUCTION

This report concerns the potential development of an interoperable web portal for the diffusion of data of relevance to MARsite, an FP7 project supported by the European Commission whose objectives are to achieve long-term hazard monitoring and evaluation in the Marmara Sea (Turkey) region by in-situ monitoring of earthquakes, tsunamis, landslides, displacements, chemical-radioactive emission and other physical variables and by the use of space-based techniques. This report covers the proposed architecture of the system, potential data models and relevant services. Certain aspects of the portal are illustrated by a pilot implementation available at: <http://marsite.brgm-rec.fr/marsite/>. Because of the resources available and the timing of this deliverable half-way through the three-year MARsite project (M18, April 2014) many data resources being developed within the project were not available when the pilot portal was being created and hence these data are not accessible through this website. If the philosophy of interoperability through the diffusion of data and services via web services, as detailed here, is followed for the dissemination of these subsequent resources then they should be accessible through this portal.

While undertaking the work detailed here, links to the projects and initiatives listed in the deliverable D10.1 (Favali et al., 2013) were sought and the developments undertaken aimed to be in phase with existing and planned systems. The relationship between MARsite and the other Supersites projects and wider initiatives are highlighted in Figure 1.

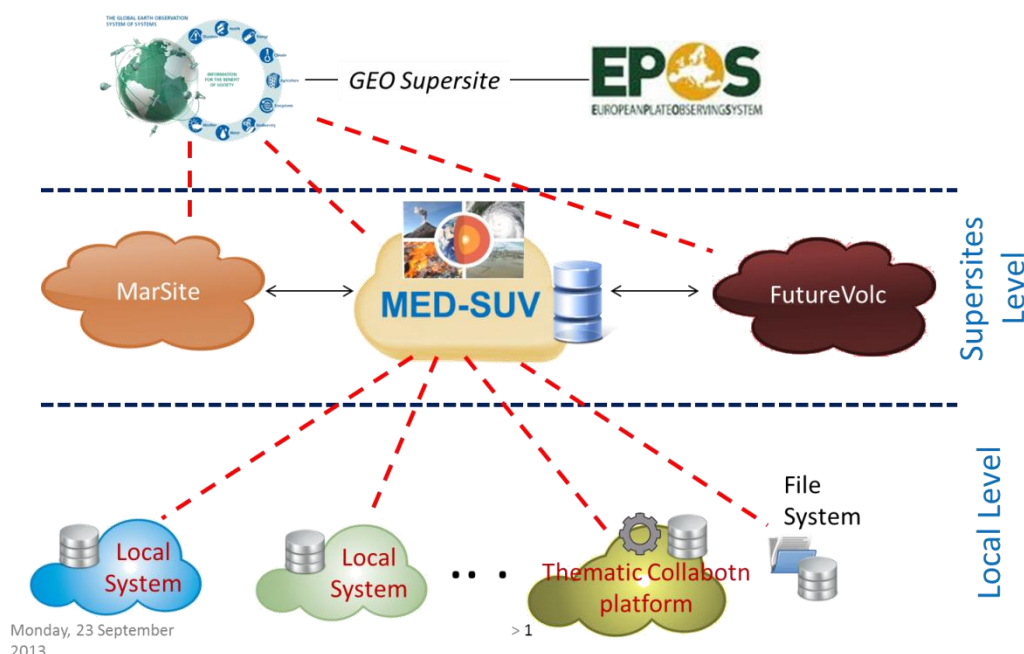


Figure 1: Relationship between MARsite and other systems (source: S.Nativi, CNR, from MedSuv technical meeting 2013).

A distributed system is based on the use of several components, connected over a network (the Internet in our case), that follow standard specifications to exchange information. The interoperability between all components is possible when they observe the specifications (as a contract between them) both in the exchange and in the structure of the information. Accordingly there are no rules on the software technology to use (each provider can select the most relevant for their application) if the specifications are met.

The architecture of a distributed system should implement the “Publish-Find-Bind” pattern. The data and services providers must be able to describe and publish their resources, the users should have the tools to find these resources, and if they meet their requirements, to use them. To publish the resources (datasets and web services) they must be first described by metadata; this is discussed in Chapter 3. Datasets are served according to standard data models (see Chapter 4). Datasets are discovered, viewed, downloaded, and processed by web services (see Chapter 5).

In this introduction we seek to demonstrate the benefits of adopting a distributed approach that is in agreement with the philosophy of the Global Earth Observation System of Systems (GEOSS) and other related initiatives. To do this, in the next section we use [OneGeologyEurope](#), a recently completed European project, as an example.

In Chapter 2 we discuss the design of the architecture of the proposed MARsite system, based on the principles of interoperability and distributed systems, and taking into account several similar or overarching existing architectures. From these architectures, we identify the main components useful for MARsite needs. Next we list the necessary components that are already available, which standards are used, and how to complete the existing standards (mainly concerning the data models) and to develop missing components.

The purpose of this report is not to present a detailed technical document for information technology experts but rather to provide a document that can be read by scientists with limited experience of data dissemination through distributed systems. The aim is to provide a potential model that can be followed by scientific projects with similar scopes to MARsite, e.g. other Supersite projects.

1.1 ONEGEOLOGY-EUROPE AS AN EXAMPLE TO INTRODUCE DISTRIBUTED SYSTEMS

[OneGeologyEurope](#) is an example of a distributed open architecture implemented to deliver a geological map of Europe at a scale of 1:1M. For this, each data provider set up web services to deliver a part of the “European product” (a geological map of Europe at 1:1M) (see Figure 2). The rationale of this distributed system is to ask each provider to deliver its part of the overall product because it knows best how to manage the availability of its portion and the updating of its resources according to its own objectives. It decides when it wants to enter and to exit the network. Nevertheless, to view and access these data as a

whole, the parts must be interoperable. To this end, some rules [defined by international standards organisations like the International Organization for Standardization, ISO, and Open Geospatial Consortium (OGC)] have to be adopted and implemented.

The product can be the result of the assembly of different parts (as in a jigsaw puzzle), as in OneGeologyEurope, or a collection of different datasets to be processed together. In MARSite it is mainly the latter, as most data types are provided by a single organisation and the principal aim is to integrate different types of information (e.g. InSAR images, earthquake catalogues and geochemical measurements) to obtain a better understanding of the scientific questions considered by the project.

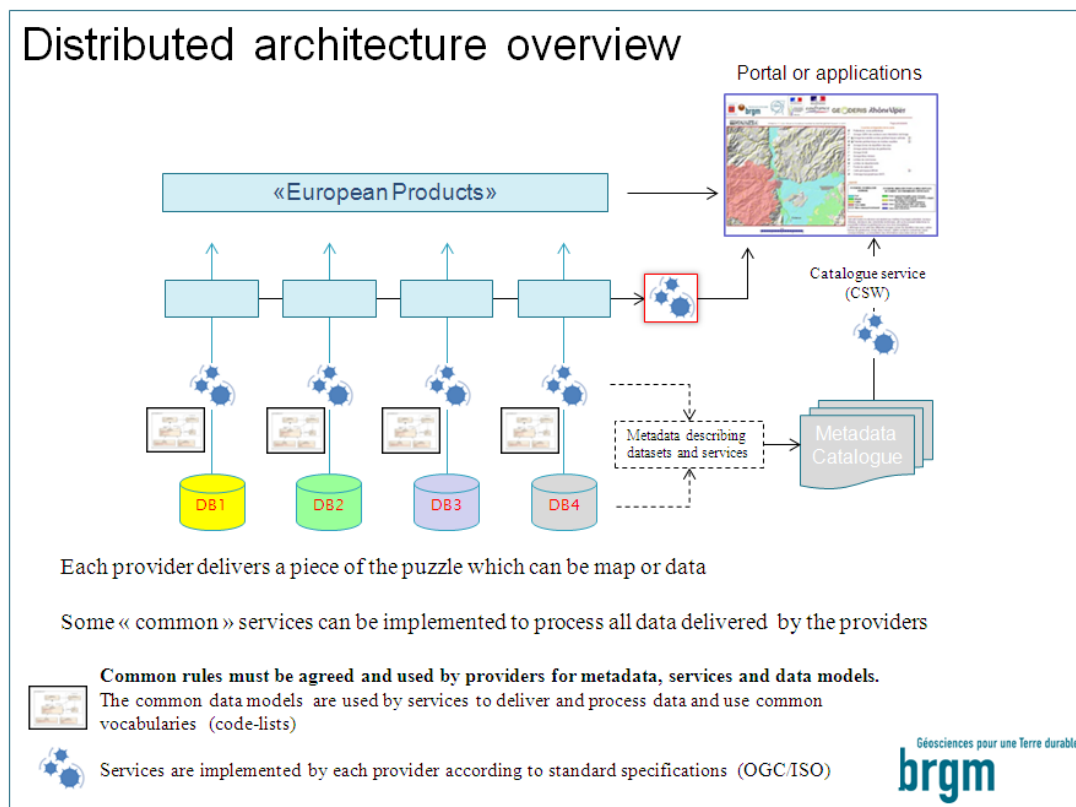


Figure 2: OneGeologyEurope architecture overview

1.1.1 Summary of the general mechanism

Each provider describes its resources (datasets, maps, etc.) by metadata registered in a catalogue. To deliver the data and the maps, the providers set up web services, also described by metadata and registered in a catalogue. The catalogue is used by portals or applications to find available data (and related services) according to various search criteria. To deliver data in an interoperable way, the provider should transform its data according to a common data model specified by a standards organisation. As they implement standard (and public) specifications, the web services can be used by other portals and applications.

1.1.2 The rules to be applied

To make all components of the system interoperable, the providers have to use common rules for:

- Metadata (for example, ISO Standard ISO 19115);
- Services, for example ISO/OGC Web Map Service (WMS) to view data; and
- Data models to deliver the data.

1.1.3 The main advantages of an open and distributed architecture

For the providers the benefits include the following:

- To manage how and when the data are delivered to the users;
- To use existing interoperable web services from other thematic domains to display or process its data, without having to download and manage these “external” data, e.g. topographic maps or bathymetric maps can be displayed directly using a WMS with no need to download the data; and
- To have its data available not only for some well-identified projects but also for other uses as yet unknown.

For the users the principal advantages are the following:

- To access, via portals and applications, various resources in an interoperable way, with no need to develop specific interfaces for each provider; and
- To easily understand the data provided by many providers as they share a common data model and dictionary.

1.2 RELATIONSHIP BETWEEN TASKS 10.2 AND 10.3

The final task in WP10 (Task 10.3), which leads to Deliverable 10.4 (due in M30, April 2015), aims at making discoverable and accessible a large number of European Space Agency (ESA) products that are of interest to the geohazards community of MARsite. These data include both L1 and L2 data and value-added products that will be generated in the project. As far as the value-added products are concerned, Task 10.3 will focus on ESA-hosted processing capabilities offered by ESA thematic exploitation platforms. These will provide users with services for generating value-added products.

In general, processing services will be available to users “as they are”. Researchers and software developers at ESA will design and develop the algorithms of interest and integrate them in exploitation platforms. The users will be enabled to define the set of input data, the

processing parameters, and trigger the execution of the algorithms. Because these services are invoked by the MARsite portal as standard OGC Web Processing Services (see Chapter 5), they can interface with complex underlying layers designed to face demanding computational needs. The obtained results can be published on a dedicated archive and will become discoverable and available through the MARsite portal (Figure 3).

In order to develop the algorithms, ESA will experiment with the use of “sandboxes”, which the GEOWOW project has recently proposed in the context of the GEOSS infrastructure evolution. In particular, ESA will use sandboxes to easily plug-in or implement, i.e. code, new algorithms (Figure 4). This solution makes use of the technology of Virtual Machines and includes middleware providing transparent interfaces to Cloud services, used for scaling-up the processing when increasing the dimensions of the input dataset. In case researchers in MARsite are interested in testing their own algorithms on ESA data, ESA will offer them direct access to dedicated sandboxes.

The use of these thematic platforms removes the need for input product data transfer from the ESA archives to the users resulting in significant savings in effort for the users.

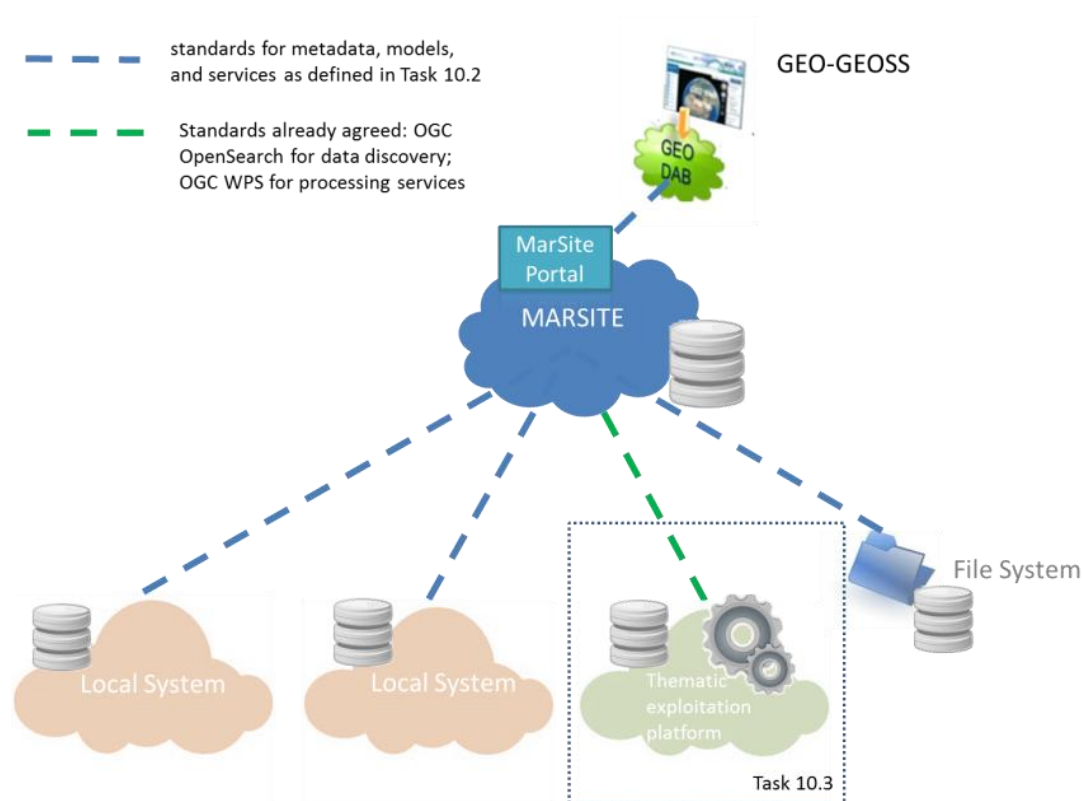


Figure 3 - High level architecture proposed in MARsite. Task 10.3 is focused on developing and providing access to ESA thematic exploitation platforms.

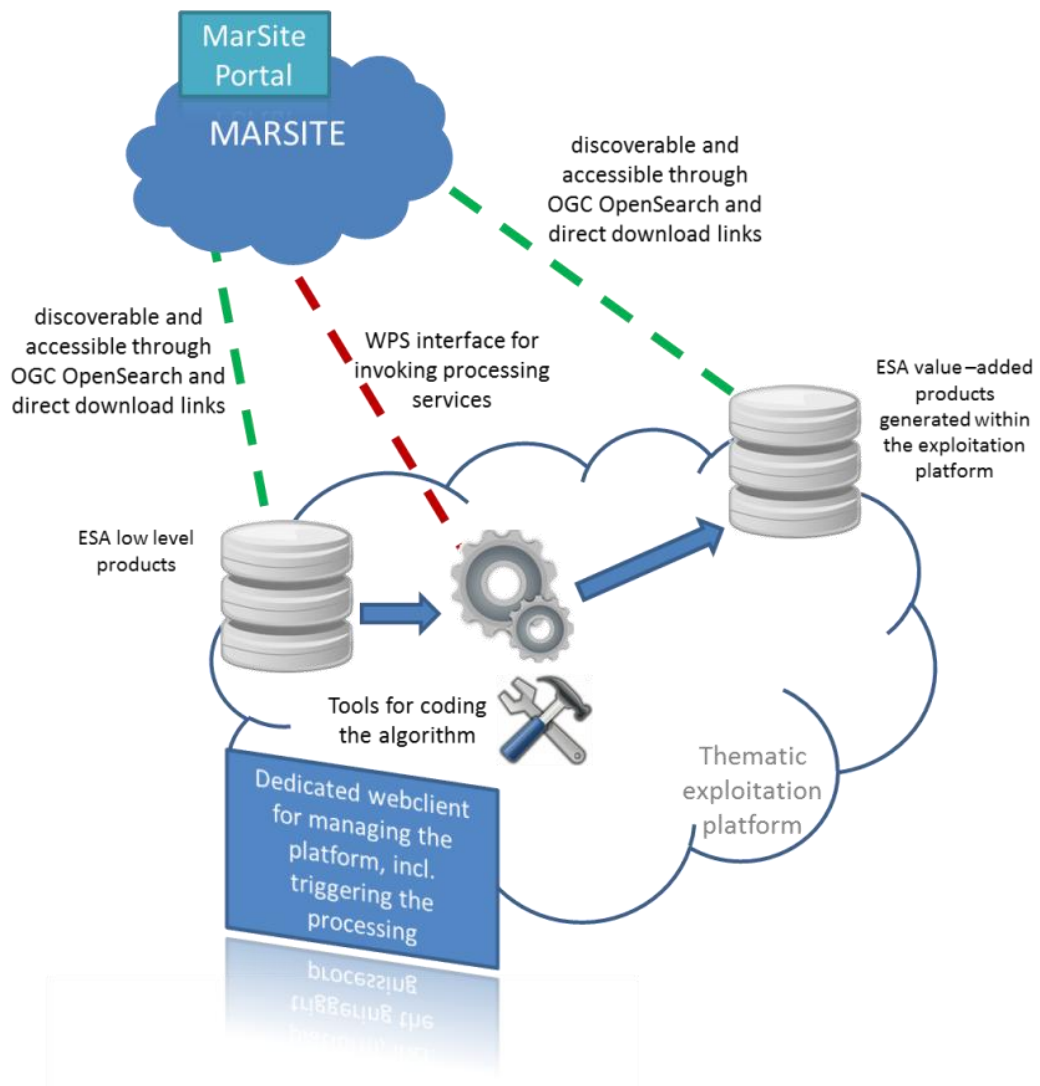


Figure 4 - ESA thematic exploitation platform.

2 OVERVIEW OF EXISTING ARCHITECTURES AND THEIR RELATION TO MARSITE

This chapter presents various existing architectures of relevance to MARSite. The list does not aim to be exhaustive but the most important systems that need to be considered when developing the MARSite architecture and portal are presented. The aim of this chapter is to outline the current situation so that developments made in MARSite are not in contradiction with existing initiatives.

2.1 OVERARCHING ARCHITECTURES

This section discusses the very high level structures to which MARSite is related.

2.1.1 GEOSS and GEO Supersite initiative

GEOSS aims to provide decision-support tools to a wide variety of users. As with the Internet, GEOSS will be a global and flexible network of content providers allowing decision makers to access an extraordinary range of information at their desk. This 'system of systems' will proactively link together existing and planned observing systems around the world and it will support the development of new systems where gaps currently exist. It will promote common technical standards so that data from the thousands of different instruments can be combined into coherent data sets. The 'GEOPortal' offers a single Internet access point for users seeking data, imagery and analytical software packages relevant to all parts of the globe. It connects users to existing databases and portals and provides reliable, up-to-date and user-friendly information. This is vital for the work of decision makers, planners and emergency managers.

Supersites is an initiative of the scientific geohazard community. The Supersites provide access to space-borne and in-situ geophysical data of selected sites prone to earthquake, volcano or other geohazards. The initiative began with the "Frascati declaration" at the conclusion of the Third International Geohazards workshop of the Group of Earth Observation held in November 2007 in Frascati (Italy). The recommendation of the workshop was "to stimulate an international and intergovernmental effort to monitor and study selected reference sites by establishing open access to relevant datasets according to GEO principles to foster the collaboration between all various partners and end-users". This recommendation is formalized as GEO task DI-09-010.

From an infrastructure point of view, the core of GEOSS is the GEOSS Common Infrastructure composed, among other parts, by the GEO WebPortal and the Discovery and Access Broker (Figure 5). From the GEO Web portal a user can discover, access and use GEOSS Resources, such as services and software providing access to catalogues, processing services and portals; and Earth Observation (EO) data catalogues and repositories.

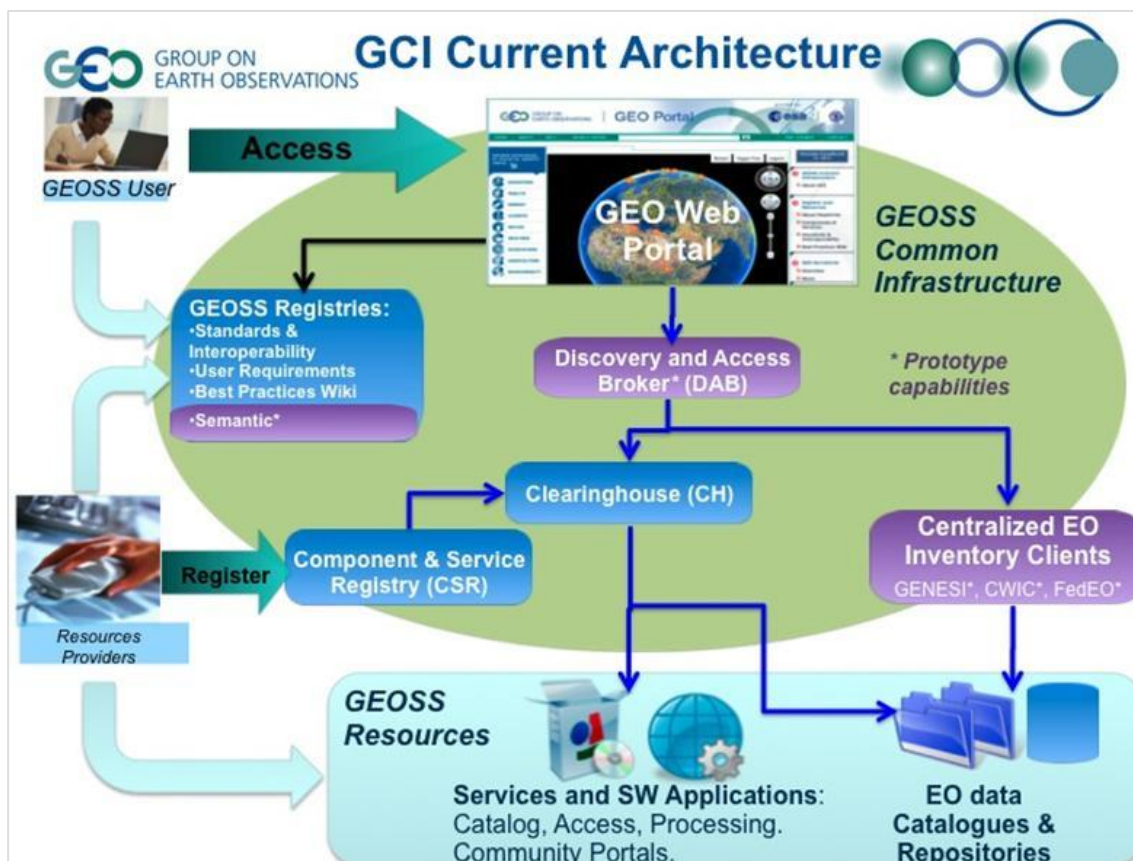


Figure 5: GEOSS architecture overview

To make this possible, some common rules and components have to be implemented. Specifically, a clearinghouse where providers register resources (thanks to registry services), where resources are services and software or EO clients, also registered in a centralized inventory, are required. As these two ways to access resources use different standards and formats, a brokering approach has been implemented with a [EuroGEOSS Discovery and Access Broker](#) enabling the portal to be independent of these various catalogues. The portal also gives access to registries on common rules and standards that have to be used to improve access and interoperability. Possible evolutions and enhancements of the GEOSS architecture are currently being investigated and proposed by the GEOWOW project (see Section 2.3.1).

The relation among the MARSite system, GEOSS, Supersites, and other related systems is represented in Figure 1. In this architecture, originally proposed in the MedSuv project, three layers are identified. On the top layer we have global (or very large) initiatives such as GEOSS, Supersites and EPOS. MARSite, MedSuv and FutureVolc projects are in the middle layer and contribute to the upper level system (or system of systems). MARSite can be considered and designed as federation of resources, which include local systems, thematic

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collaboration platforms, following the example of OneGeologyEurope (see Figure 2) and must be compliant with the INSPIRE architecture (Figure 6).

2.1.2 INSPIRE architecture

The INSPIRE directive (May 2007) aims to create a spatial data infrastructure within the European Union. This will enable the sharing of environmental spatial information among public sector organisations and better facilitate public access to spatial information across Europe. INSPIRE architecture (Figure 6) is organised in three layers (note that the Applications and Geoportals layer is not required by INSPIRE):

- A data layer with all datasets described by their metadata, and registers;
- A service layer with the Network services (discovery, view, download, transformation and invoke service) and the spatial data services. All of these are described by their metadata and process spatial data (or metadata for the discovery service). The registry service is a particular example of a spatial data service; and
- A GeoRM (Geo Right Management) layer to address when necessary the issues of authentication, payment and so forth.

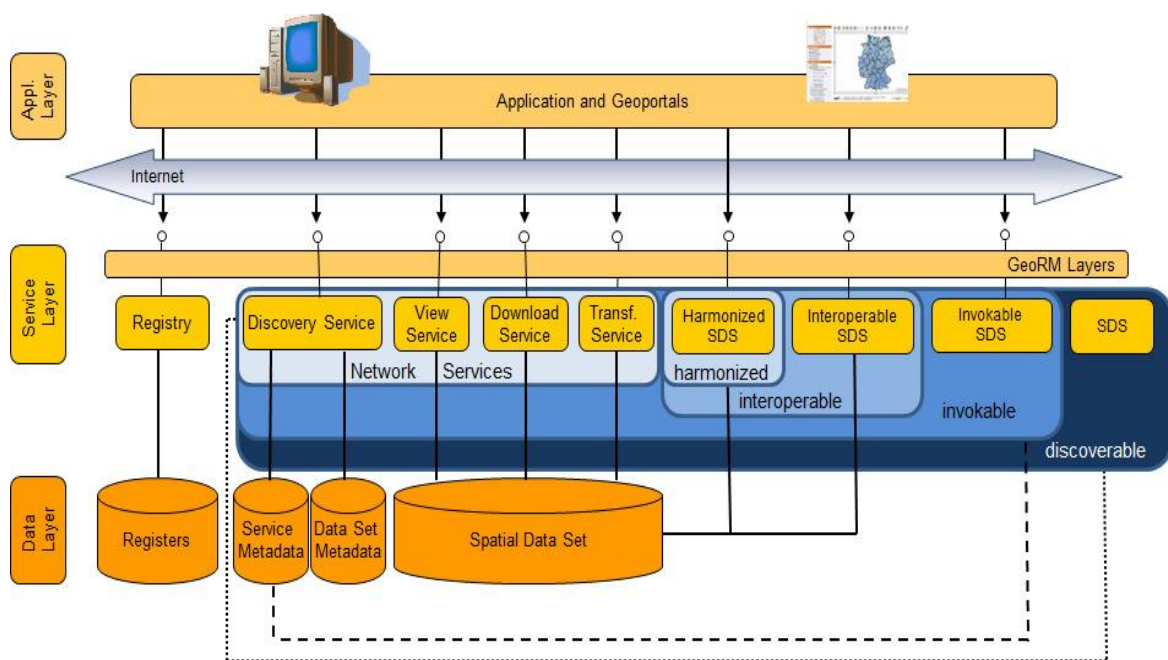


Figure 6: INSPIRE architecture overview

2.2 ESFRI PROJECTS

The European Strategy Forum on Research Infrastructures ([ESFRI](#)) is a strategic instrument to develop the scientific integration of Europe and to strengthen its international outreach. The mission of ESFRI is to support a coherent and strategy-led approach to policy-making on research infrastructures (RIs) in Europe, and to facilitate multilateral initiatives leading to the better use and development of research infrastructures, at the European and international level. Two infrastructures of ESFRI are EPOS and EMSO, whose architectures are discussed below.

2.2.1 EPOS

The European Plate Observing System ([EPOS](#)) is the integrated solid earth sciences RI to promote and make possible innovative approaches to better understand the physical processes controlling earthquakes, volcanic eruptions, unrest episodes and tsunamis, as well as those driving tectonics and Earth surface dynamics. The EPOS architecture is outlined in Figure 7.

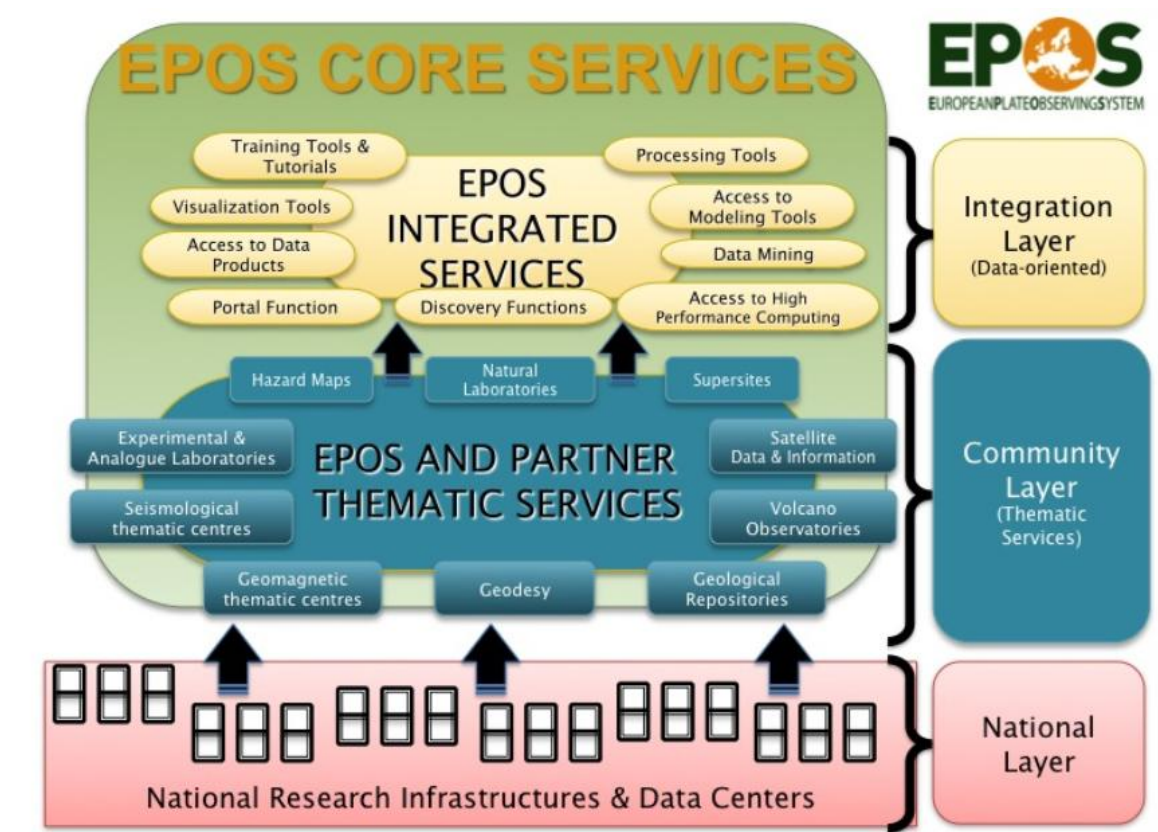


Figure 7: EPOS architecture overview

The EPOS Core Services provide the top-level service to users, including access to multidisciplinary data and metadata, virtual data from modelling and solid Earth simulations, data processing and visualization tools as well as access to high-performance computational facilities. EPOS will enhance data processing and modelling capacity and capability as well as developing new theoretical and numerical tools to harness computational power in a distributed European architecture.

To give access to resources provided by national research infrastructures and data centres, EPOS has defined two layers of services:

- The thematic services are to make thematic data from a specific community available to EPOS, and provide services to a specific community. These services also include cross-disciplinary integrated observatories providing applications that integrate data and deliver products.
- The integrated services are IT services and services providing access to interdisciplinary data and information from all the EPOS thematic services in an integrated fashion. They consist of discovering, viewing, accessing, processing data, and also access to high-performance computing.

2.2.2 EMSO

The European Multidisciplinary Seafloor and water column Observatory ([EMSO](#)) is a large-scale European RI of the ESFRI roadmap composed of fixed-point, seafloor and water-column observatories with the basic scientific objective of near- and real-time, long-term monitoring of environmental processes related to the interaction between the geosphere, biosphere, and hydrosphere. It is geographically distributed at key sites in European waters, spanning from the Arctic, through the Atlantic and Mediterranean Sea to the Black Sea.

The EMSO data infrastructure has been conceived to use the existing distributed network of data infrastructures in Europe and to use the INSPIRE and GEOSS data sharing principles. A number of standards have been set forth that will support state-of-the-art transmission and archiving of data along with the recording of metadata thereby ensuring interoperability that allows for more straightforward use and communication of data. Importantly for such an advance in ocean “big data”, EMSO is exploiting the power of European Grid Infrastructure to create a data infrastructure to serve the wide communities of scientists studying marine mammals, acoustics, oceanography, geology, geophysics, high energy astro-particle physics and ecology.

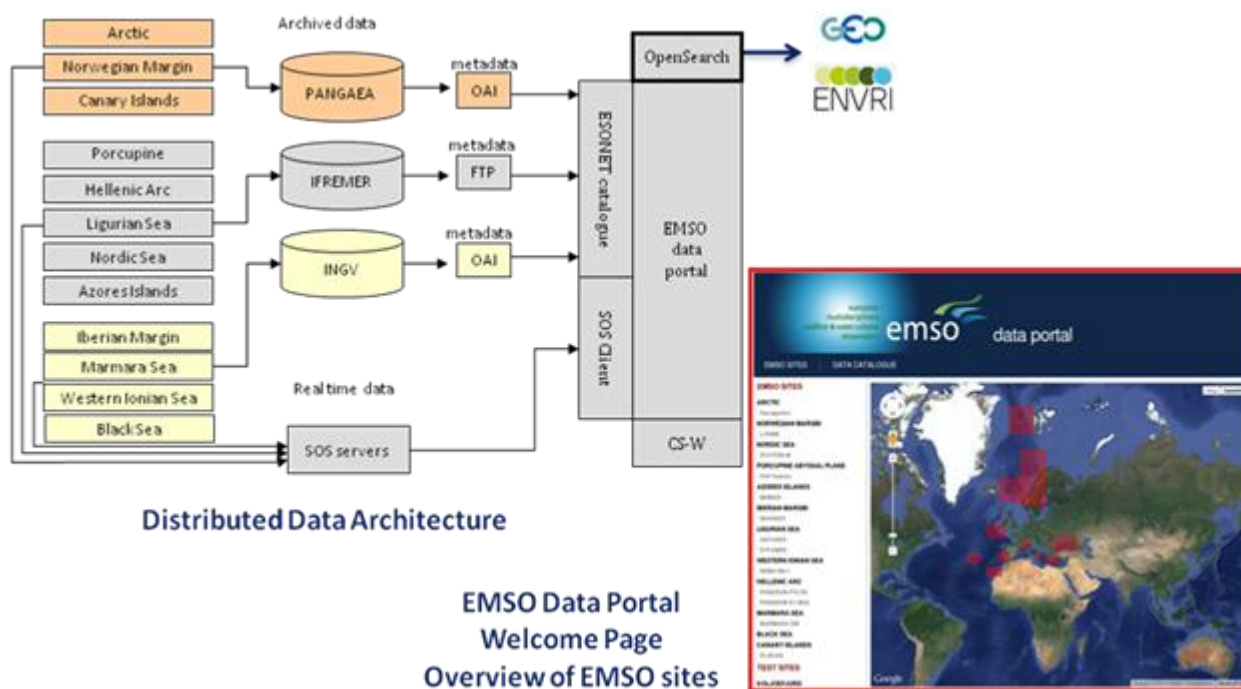


Figure 8: EMSO architecture overview

The data infrastructure for EMSO is designed as a distributed system (Figure 8). EMSO data collected, either continuously or during experiments at each EMSO site, are stored locally and organised in catalogues or relational databases run by the institutes responsible for the regional EMSO nodes. The data management architecture presently includes sub-systems that are at a different development stages and which relate to the following functions:

- Data acquisition;
- Data curation;
- Data access; and
- Data processing.

The EMSO data acquisition sub-system collects raw data streams from EMSO observatories as provided by sensor arrays of varying geometry and various instruments. The currently practiced data management strategies address real-time as well as archived and delayed-time data within the EMSO-distributed data information system. Real-time data are intended as *in situ* measurements continuously acquired by the sensors and immediately transmitted to land via cables or via acoustics and satellite connections to feed the data information system. These measurements can have a wide range of sampling rates from very high (e.g. bioacoustics and seismology) to low rates (e.g. physical oceanography and geomagnetism). Whereas real-time is immediately available, the so called delayed-time data

are those stored locally at the nodes and which become available for the data management system only after visits during dedicated ship expeditions when the instruments are recovered or maintained.

The EMSO data access sub-system enables discovery and retrieval of data housed in data resources managed by a data curation sub-system. EMSO offers data discovery via a [common metadata catalogue and web portal](#). The portal is based on the brokerage system [panFMP](#) and uses Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) or simple file transfer via FTP/HTTP to harvest metadata from EMSO distributed regional node data archives and the information data systems PANGAEA (Data Publisher for Earth & Environmental Science), MOIST (Multidisciplinary Oceanic Information SysTem) and CORIOLIS (In situ data for Operational Oceanography). The EMSO data portal is also reachable through the [EMSO website](#).

The EMSO data portal offers machine-human as well as machine-machine search facilities and discovery services based on the collected metadata. This includes a simple web-based user interface (a data search engine) which is offered at the EMSO data portal in the style of Google. In addition the data portal offers a common discovery service following the OpenSearch specification including the OpenSearch-Geo extension. An OGC Catalogue Service for Web (CS-W) interface is currently under development.

A centralised data export service for these archived data is not implemented or planned. Therefore, unless each EMSO data archive offers its own NetCDF data transformation service (see above) data requests are not yet processed by the EMSO data portal but are redirected to the hosting data archives which provide their own data access services for data retrieval.

Access to real-time data is also offered via the EMSO data portal. EMSO has chosen to implement core standards of the OGC Sensor Web Enablement (SWE) suite of standards, such as the Sensor Observation Service (SOS) and Observations and Measurements (O&M) to deliver real-time data. These interfaces and formats are used to offer a common, web-based SOS client that provides interactive visualizations of real-time data.

Centralized data-processing sub-system that aggregate the data from various resources and provides computational capabilities and capacities for conducting data analysis and scientific experiments are not yet implemented for EMSO. Once more regional EMSO nodes and their data archives support NetCDF data export it is envisaged to introduce data visualization and plotting services to the EMSO data portal. However, presently data processing services such as visualization and data-mining as well as statistical services are exclusively provided by each regional node and its responsible data centre.

2.3 OTHER MULTIDISCIPLINARY INFRASTRUCTURE PROJECTS

This section details the other infrastructure projects that are of relevance to MARSite.

2.3.1 GEOWOW

GEOWOW (GEOSS Interoperability for Weather, Ocean and Water) is an FP7 project. The major challenge of this project is to improve data accessibility and to evolve GEOSS in terms of interoperability, standardization and functionality, while specifically addressing three (Weather, Water and Ocean Ecosystems) of the nine Societal Benefit Areas (SBAs).

In the perspective of an enhanced GEOSS, GEOWOW has considered and is considering different categories of stakeholders, from data scientists to decision makers, to citizens and has elicited their requirements. The analysis of the elicited requirements has led to the identification of the underlying need for the following functionalities:

- Efficient data discovery, including results ranking;
- Streamlined data access, including harmonization of the results presentation;
- GEOSS resources accessibility and exploitability from external clients: this would allow community specific portals and applications to benefit from the GEOSS resources via high performance geo-processing services;
- Data registration mechanisms, including support for registration in the GEOSS Data CORE (Collection of Open Resources for Everyone); and
- User registration, authorization and authentication, including single-sign-on.

The main objective of GEOWOW is to support the above identified requirements in coordination with the other actors involved in GEOSS and, moreover, to provide capabilities that support the GEOSS SBAs, specifically the ones directly represented in GEOWOW (Weather, Ocean and Water). The final goal is to improve the availability and accessibility in the GEOSS context of data and resources.

Specifically, GEOWOW is responding to the need to enhance the discovery and access of the GEOSS resources via the EuroGEOSS Discovery and Access Broker. The GEOSS resources accessibility and exploitability is achieved via Component Development Enablers: these are generic components that once customized to the community needs allow data access and processing from community specific clients, support the development and validation of models and providing the necessary interfaces to the providers of computing resources.

Moreover, components that are specific to the SBA infrastructures are being evolved in the framework of GEOWOW with the main goal of improving the availability and accessibility in

the GEOSS context of the SBA data and resources. These components can make use of, interface and/or integrate (after opportune customization) the above mentioned ones.

Different communities can benefit from GEOWOW developments in various ways, according to their needs and their usual working habits, introducing different usage patterns. Figure 9 and Figure 10 depict, respectively, a usage pattern for decision makers and multidisciplinary scientists (A) and one for specific domain scientists (B). It is worth noting that there may be multiple usage patterns for the same community, i.e. these patterns are only examples of those that are expected to be the most common.

In the first example (Figure 9), the decision makers or the multidisciplinary scientists, access GEO information via the GEO Portal or specific clients based on their needs; in both cases the portal communicates directly with an Information Broker that allows access to heterogeneous data and resources shared through different service buses.

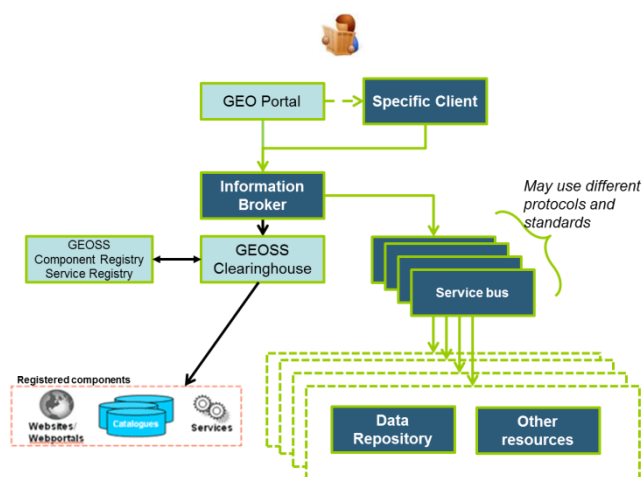


Figure 9: Usage pattern A: Decision makers and multidisciplinary scientists

In the second example (Figure 10), scientists are willing to access low-level data (e.g. observations and raw data), either via a community-specific client (also discoverable and accessible from the GEO Portal) or a machine-machine interface. We may even assume that they know exactly where to find the needed information, so they can access directly a specific service bus, while they may still benefit from brokering additional information through resources they do not know. This kind of user may also benefit from new geo-processing components, which can be used to generate higher level products, indexes, or indicators, exploiting cloud computing if needed. The results may be registered in GEOSS to make them discoverable and accessible by other users.

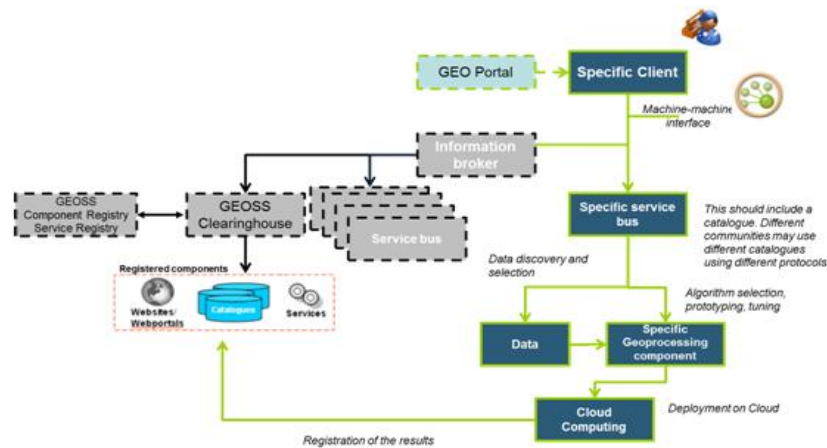


Figure 10: Usage pattern B: Specific domain scientists

It is worth clarifying that the components referred to as “Specific Clients” in both the pictures above could be different “Client Applications” used in the various SBAs (a specific SBA may have different client applications) as well as “SBA Community Portals” (a specific one for each SBA). This usage pattern is closely related to the concept of Thematic Collaboration Platforms, and example implementations are the Virtual Research environment considered in ENVRI (see Section 2.3.3) and the ESA Supersite Exploitation Platform (see Section 2.3.4).

2.3.2 GENESI-DEC

Ground European Network for Earth Science Interoperations - Digital Earth Communities ([GENESI-DEC](#)) is an FP7 project that aims to provide reliable, easy, long-term access to Earth Science data via the Internet. The Digital Earth is a visionary concept for the virtual representation of the Earth that is spatially referenced, interconnected with the world’s digital data repositories, and encompassing all its systems and forms, including Earth Sciences, Natural Resources Management, Environmental Monitoring systems and human society dimensions.

GENESI-DEC has made a significant and recognized contribution to designing and implementing a multidisciplinary platform. This platform provides discovery capabilities of scattered and heterogeneous data, easy and fast access to such data, on demand computing resources, and makes easier the dissemination of newly-generated results. The range of data and services made available by GENESI-DEC is extensive. Millions of satellite data, in-situ temperature profiles, data acquired by airborne sensors, sea surface and seafloor data, volcanic data, colour orthophotos and digital elevation models, are available through this platform.

GENESI-DEC is a federation of resources with catalogues that expose OpenSearch interfaces. Search clients, like the GENESI-DEC portal, can use OpenSearch description documents to learn about the public interface of the search engines in the federation. These description documents contain parameterized URL templates that indicate how the search client should make search requests, so allowing different communities to specify the most-relevant parameters for their searches. OpenSearch description documents can be extended with foreign mark-up provided that all foreign elements and attributes are associated with an explicit XML namespace that is distinct from the core OpenSearch format. The project has successfully promoted this approach, by showing its flexibility, its ease of use, and by demonstrating how it can respond to the needs of several different scientific communities. One of the biggest success stories of GENESI is the adoption of OpenSearch by several projects and initiatives so forming a basis for an operational worldwide multidisciplinary environmental federation. The ENVRI project (see Section 2.3.3) is proposing the re-use and evolution of GENESI-DEC to speed up the construction of several European environmental infrastructures allowing scientists to use the data and software from each facility so enabling multi-disciplinary science.

A high-level architecture of the GENESI-DEC platform, with a two-step query approach and OpenSearch catalogue is depicted in Figure 11.

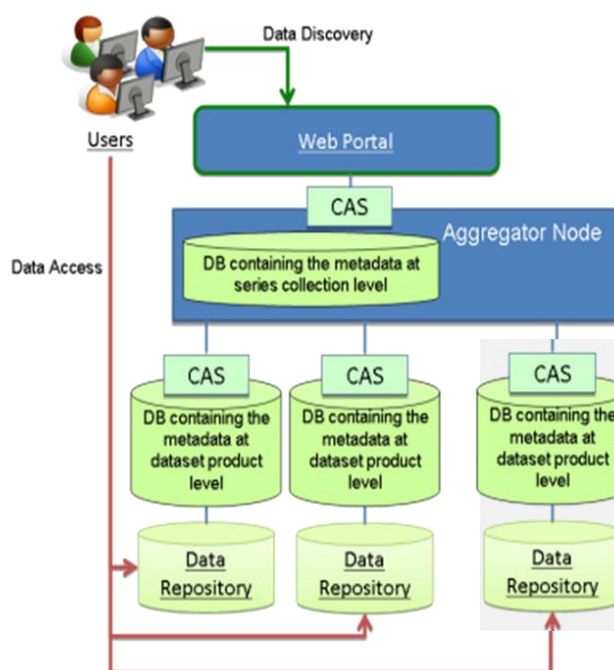


Figure 11: GENESI-DEC high level architecture

2.3.3 ENVRI

Because the laboratory for environmental research is the whole planet, the ENVRI project (Common operations of Environmental Research Infrastructures) is aiming at a number of common policies and technical solutions for the research infrastructures that support this research. The Earth's systems are characterized by a multitude of interrelations on a wide range of temporal and spatial scales. Understanding these systems is not possible simply by extrapolating their behaviour from the single units of which they are composed. These requirements together define an integrated e-infrastructure environment integrating the observatories, sensors, data, software, models and computation facilities at an appropriately large scale.

The ESFRI projects (e.g. EPOS and EMSO) are constructing a major part of the European environmental science research landscape for the coming 20 to 30 years. Realising this potential will ensure that the scientific community derives full value from investments in these large-scale environmental projects, and it will keep scientists at the forefront of global research as they tackle the scientific challenges ahead. The ENVRI objectives are targeted at these common interests of the ESFRI projects:

- to create common solutions for a range of shared problems; and
- to increase the interoperability of the research infrastructures to serve interdisciplinary users.

Figure 12 shows how interdisciplinary users may want to benefit from the services of different research infrastructures. They are looking for processed data or for raw data from other facilities (even the direct output of sensors) and they also may want to use analytical capabilities of other research infrastructures for their research. The ENVRI project will not create a separate new facility but rather it addresses capabilities that can be taken up by each ESFRI infrastructure or a combination of infrastructures aiming at the delivery of common priority services to users.

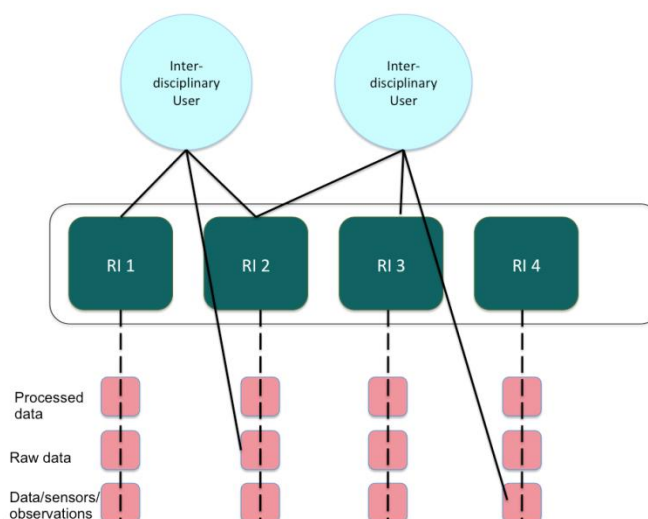


Figure 12: ENVRI multidisciplinary collaboration among research infrastructures

One of the key objectives of the ENVRI is to provide common solutions for data discovery, data integration and harmonisation for the infrastructure projects. The starting points for these tools and services are the results of GENESI-DEC and [D4SCIENCE](#) projects, the first used to enable discovery of data, the second to set up a virtual research environment where scientists can analyse the discovered data.

EMSO, [EISCAT](#), and [EuroArgo](#) started operations to populate the catalogues with their data. Preliminary results are also available for samples of EPOS and [ICOS](#) data. For [LifeWatch](#) data, which are quite different in nature from the other ESFRI data, an analysis of the required metadata is still on-going. All the catalogue interfaces are following the OGC OpenSearch standards. This will guarantee the sustainability of the approach beyond the end of the project.

For what concerns the virtual research environment the project partners have designed and developed a comprehensive and extensible framework enabling the realisation of a scalable and reliable Spatial Data Infrastructure capable of managing the large amount of data available in the research infrastructures participating in the ENVRI cluster. Overall, the developed set of components allows simplification of the integration of the most up-to-date technologies recommended by the open geospatial community by producing scalable and fault-tolerant services to publish, access, visualize, and process large datasets. All of these components rely on and are compliant with OGC standards, thus favouring interoperability.

With regards to the registration of relevant components in GEOSS, ENVRI will take advantage of the recent introduction of the EuroGEOSS Broker in the GEOSS Common Infrastructure and the ability of this broker to link the GEO Web Portal and GENESI-like

resources (as ENVRI OpenSearch catalogues). This will enable GEOSS users to discover and access data available in the federation of ESFRI infrastructures established by ENVRI. ENVRI is closely monitoring GEOWOW so as to be compliant with GEOSS architectural requirements and evolutions.

2.3.4 iCORDI

International collaboration on research data infrastructure ([iCordi](#)) focuses on coordinating a series of cross-infrastructure experiments on global interoperability with a selected group of projects and communities. Each prototype addresses a specific community-driven use case identifying best-of-breed solutions and the remaining challenges.

iCORDI has particularly strong links with large international Earth science collaborations, from both its core partners and through the wider [EUDAT](#) network. Earth and ocean sciences are well represented through CNR and Athena. EPOS and the European Network for Earth Systems Modelling ([ENES](#)) are EUDAT core communities, with EMSO, IAGOS-ERI and ICOS already connected as associate communities.

iCORDI has gathered a portfolio of five proposed prototype activities, covering seismological data processing, marine data interoperability, hydro-meteorological simulation infrastructure and international standards activities.

The effort will be focused on two different dimensions: vertically, demonstrating federated access to distributed datasets within the seismology domain capitalizing on EUDAT results, and; horizontally, debating technology solutions to implement a cross-domain, robust and reliable infrastructure.

2.4 OTHER THEMATIC INFRASTRUCTURE PROJECTS

In this section some other infrastructure projects of relevance to MARsite are presented.

2.4.1 ESA SuperSite Exploitation Platform

The SuperSite Exchange Platform (SSEP) is an e-infrastructure developed by ESA to enable discovery, access, mining and exploitation of EO data in support of the solid Earth science community, with a particular focus on the Geohazard SuperSites, including the Marmara Sea. The SSEP is still under development (currently it is in beta-mode testing) and is designed to exploit the upcoming European Science Cloud being developed within the Helix Nebula initiative, with the contribution of GEOWOW and other ESA activities.

The rationale for SSEP is driven by the increasing volume of Earth science observations, in particular from the new-generation EO satellites, such as the upcoming Sentinels, which

deliver terabytes of data daily. In this context, the simple idea underpinning SSEP is to facilitate data access and exploitation by moving the scientist's desktop (and associated software) to the data, rather than the data to the scientist, thereby enabling ultra-fast data access and processing (transferring a few Megabytes of results rather than several Terra/Petabytes of raw data to the user).

This new paradigm of “flipping the data access issue” is at the heart of the concept of EO-data Exploitation Platforms (SSEP is only one example) and it has already been successfully implemented within the ESA Grid Processing on Demand (GPOD) facility. This idea is now further extended to full virtualization in the Cloud, creating a user-friendly integrated distributed IT environment offering the following key advantages for the data user and providers:

- Rapid access to a wealth of heterogeneous data sets (including EO, in-situ and model data), thereby reaching out to wider communities (e.g. communities with limited experience in remote sensing and poorly connected communities in Europe and Africa);
- Ultra-fast and scalable data-intensive processing on hybrid cloud/grid infrastructure;
- Easy implementation of data and software policy in a controlled software environment, thereby enabling new types of business models (e.g. pay per use pricing model and data rental versus data ownership);
- Traceability of data and workflows, thereby enabling new type of data publishing and easier verification of scientific results;
- Cost-effective approach to data access capitalizing on economies of scale (pay once for storage); and
- Enabling community building through sharing of data, tools and knowledge (e.g. social networks).

The SSEP is still in demonstration phase (v 1.0) and currently includes the following elements:

- Virtual Machine (VM), providing scientists with a “workbench” where they can work and manipulate the ESA EO data supersite archive as if they were in their office. The current VM for SSEP 1.0 is hosted on a Cloud provider in Geneva offering co-location of data storage and cloud processing.
- Virtual Data Archive including the ERS and Envisat SAR archive on supersites, with a web-based interface to easily discover and access data (using http-based query, and open-search).
- Cloud Processing on demand provided by a commercial cloud provider, and scalable on demand.
- Third Party Software/Workflows for SAR processing, including open-source (e.g. ESA toolbox, CNR SBAS, GMTSAR) and commercial providers (e.g. Gamma),

The capabilities of SSEP are increasing and it can be used as a critical EO building block of a distributed global e-infrastructure for supersites, providing scientists with a new way to use and share multiple heterogeneous datasets from federated data providers across communities and observing systems (e.g. EO, seismic and GPS).

2.4.2 NERA

Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation (NERA) is an FP7 project that aims to integrate key research infrastructures in Europe for monitoring earthquakes and assessing their hazard and risk, thereby: improving access to data for research and hazard and risk products and tools and providing services and access to earthquake data and parameters. NERA activities are coordinated with other relevant projects and initiatives and it contributes to the EPOS infrastructure and the Global Earthquake Model (GEM). One specific development of interest to MARsite is the improvement to the [Earthquake Data Portal](#) to use OGC web services. This portal was originally developed during NERIES.

2.4.3 RESIF

The Réseau Sismologique et Géodésique Français ([RESIF](#), French Seismological and Geodesy Network) is developing services allowing seismological data and metadata to be retrieved. The following two web services are currently operational.

- The Dataservice web service gives access to multiple channels of FDSN miniSEED data for specified time ranges.
- The fdsn-station web service returns station metadata in StationXML format (schema). Results are available at multiple levels of granularity: network, station, channel and response. Metadata may be selected based on network, station, location or channel names in addition to time windows, geographic regions or metadata update times.

It should be noted, however, that this project only covers France and hence the services are of limited relevance for MARsite but the technical developments may be of interest.

2.5 HOW MARSITE INTERACTS WITH OTHER PROJECTS/INITIATIVES

The GEOSS broker would be a key element in fitting the MARsite developments into the existing framework of projects and also to link the developments made in Task 2 of WP10 of MARsite with those being undertaken in Task 3.

A way to provide datasets to GEOSS would be to register a MARSite catalogue of metadata as a GEOSS contributor. Then, the GEO Discovery and Access broker would be able to find datasets (and related services to view and download data). As an example (Figure 13), the OneGeology catalogue is registered in the GEOSS registry (see left side of the screen) and then it is possible for the user to search for “geology” (keyword) of “France” (location) and add the map to the viewer.

One of the possible connections to GEOSS is to offer, for the catalogue web service, an interface compliant with the OGC CS-W (Catalogue Service for the Web) specification understood by the GEOSS broker.

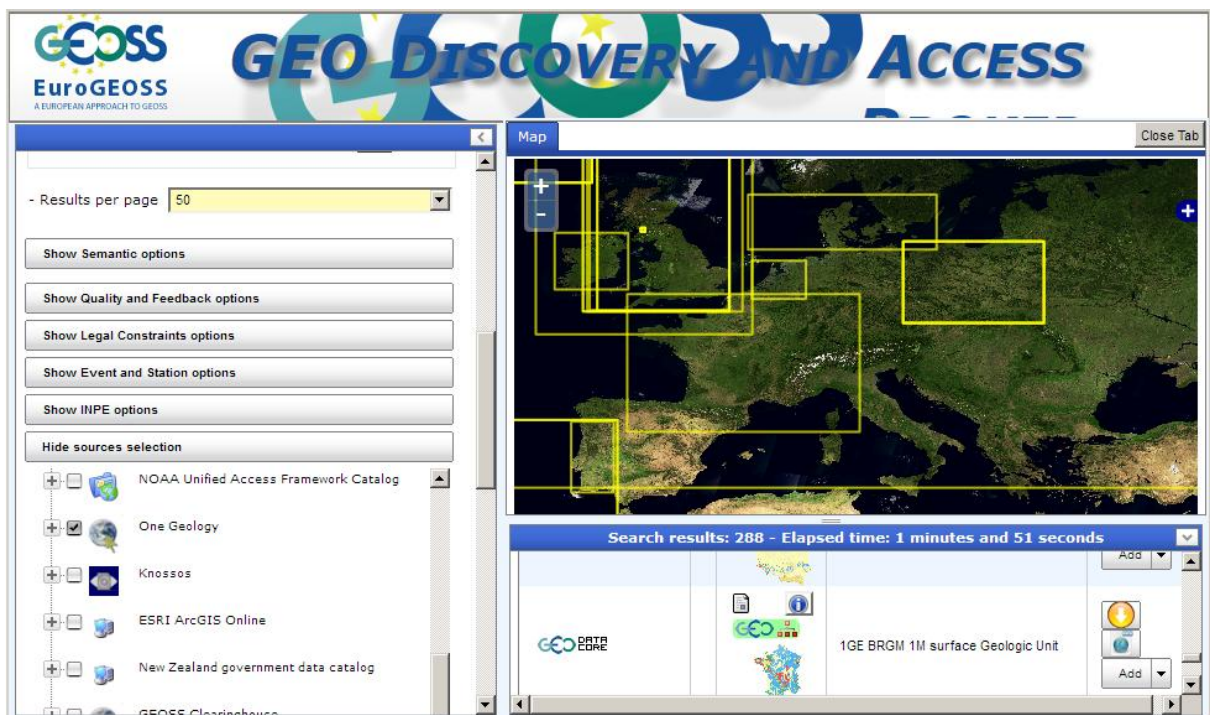


Figure 13: Example of the use of the GEOSS broker

3. METADATA STANDARDS

This chapter discusses the available standards for metadata of relevance to MARsite. Based on this a standard is proposed for the MARsite pilot. Within the context of associated projects and initiatives (e.g. GEOSS and EPOS) the existence of metadata is a strong requirement so that the system developed within MARsite is findable and it can be queried by other systems.

3.1 AVAILABLE STANDARDS

The following three metadata standards are of relevance to MARsite.

- The ISO19115 (for datasets) and ISO19119 (for services) and the related XML encoding ISO19139. This standard is used for INSPIRE metadata.
- The Dublin Core (DC); a mapping between DC elements and ISO elements exists.
- The Common European Research Information Format (CERIF) with a partly different scope than the two other ones. This is the standard adopted for EPOS.

During the Frascati meeting between the partners of WP10 and a representative of MED-SUV (Stefano Nativi) on 26th September 2013 it was decided that the best standards to adopt for MARsite would be those of ISO. This decision was made because ISO standards are recommended by INSPIRE and also they are compatible with CERIF, used by EPOS. However, at present metadata has not been compiled for the MARsite data.

3.2 INSPIRE METADATA

The [INSPIRE metadata elements](#), organised in ten sections, are the following:

1. IDENTIFICATION

- 1.1. Resource title
- 1.2. Resource abstract
- 1.3. Resource type
- 1.4. Resource locator
- 1.5. Unique resource identifier
- 1.6. Coupled resource (only for services and not datasets)
- 1.7. Resource language

2. CLASSIFICATION OF SPATIAL DATA AND SERVICES

- 2.1. Topic category
- 2.2. Spatial data service type (only for services and not datasets)

3. KEYWORD

- 3.1. Keyword value
- 3.2. Originating controlled vocabulary

4. GEOGRAPHIC LOCATION

- 4.1. Geographic bounding box

- 5. *TEMPORAL REFERENCE*
 - 5.1. Temporal extent
 - 5.2. Date of publication
 - 5.3. Date of last revision
 - 5.4. Date of creation
- 6. *QUALITY AND VALIDITY*
 - 6.1. Lineage
 - 6.2. Spatial resolution
- 7. *CONFORMITY*
 - 7.1. Specification
 - 7.2. Degree
- 8. *CONSTRAINT RELATED TO ACCESS AND USE*
 - 8.1. Conditions applying to access and use
 - 8.2. Limitations on public access
- 9. *ORGANISATIONS RESPONSIBLE*
 - 9.1. Responsible party
 - 9.2. Responsible party role
- 10. *METADATA ON METADATA*
 - 10.1. Metadata point of contact
 - 10.2. Metadata date
 - 10.3. Metadata language

This metadata standard includes many fields that are optional and are of limited relevance for MARsite and hence, if implemented subsequently, a selection of these fields could be made to prioritise resources.

3.3 DUBLIN CODE METADATA

The Dublin Core Metadata Element Set is a vocabulary of fifteen properties for use in resource description. These elements are broad and generic and, hence, usable for describing a wide range of resources.

The fifteen elements described in this standard are part of a larger set of metadata vocabularies and technical specifications maintained by the Dublin Core Metadata Initiative (DCMI). The full set of vocabularies, DCMI Metadata Terms, also includes sets of resource classes (including the DCMI Type Vocabulary), vocabulary encoding schemes, and syntax encoding schemes. The terms in DCMI vocabularies are intended to be used in combination with terms from other, compatible vocabularies in the context of application profiles and on the basis of the DCMI Abstract Model.

The Dublin Core Metadata Elements are:

- Contributor: An entity responsible for making contributions to the resource
- Coverage: The spatial or temporal topic of the resource, the spatial applicability of the resource, or the jurisdiction under which the resource is relevant

- Creator: An entity primarily responsible for making the resource
- Date: A point or period of time associated with an event in the lifecycle of the resource
- Description: An account of the resource
- Format: The file format, physical medium, or dimensions of the resource
- Identifier: An unambiguous reference to the resource within a given context
- Language: A language of the resource
- Publisher: An entity responsible for making the resource available
- Relation: A related resource
- Rights: Information about rights held in and over the resource
- Source: A related resource from which the described resource is derived
- Subject : The topic of the resource
- Title: A name given to the resource
- Type: The nature or genre of the resource

3.4 CERIF METADATA

The CERIF data model allows for a metadata representation of research entities, their activities/interconnections (research) and their outputs (results). It has high flexibility for formal relationships; it enables quality maintenance, archiving, access and interchange of research information; and it supports knowledge transfer to decision makers, for research evaluation, research managers, strategists, researchers, editors and the general public.

A CRIS (Current Research Information System) can be implemented using a subset or superset of the full CERIF model for projects, people, organisations, publications, patents, products, services and facilities (equipment in particular) with role-based, temporally-bound relationships.

Objects or entities managed by CERIF are the following:

- Researchers;
- Organisations (Research-performing, Funding);
- Funding Programmes, Calls;
- Projects (Proposed, On-going, Completed);
- Publications, Patents, Data, Products;
- Facilities, Equipment, Services; and
- Addresses, Geographic Bindings, Languages.

All these entities are connected by relationships providing semantics, including roles and time. CERIF is extensible to address richer uses.

4.DATA MODELS

The data displayed and processed by the MARSite portal must be associated with data models that describe the format of the different fields. This chapter describes the models associated with the various sources.

4.1 DATA TO BE MANAGED BY MARSITE

The partners and end users of MARSite are interested in many different types of data related to geohazards in the Marmara Sea region.

Towards the beginning of the project an email questionnaire was sent to partners with the following two questions.

1. Are the data that you will collect (or have collected) for MARSite currently provided through OGC-compatible web services? If so, are they associated with metadata? Could you please provide details (e.g. the address) of the web services? If not, how are these data currently provided to interested users?
2. Would you be interested in serving your data via a web service? If so, do you have the required IT competence in-house or would you require help?

According to the partner's answers, there are different types of situation:

- Data providers without any delivery system, e.g.: SARMAP (kml files and shapefiles), CNR, EUCentre and GFZ;
- Data providers delivering data with ftp and specific formats, e.g.: KOERI, IFREMER via KOERI and INGV;
- Data providers using an existing architecture to deliver data: INGV(MOIST) and EMSC (NERA, with web services); and
- Data providers using an existing architecture to deliver data, but also added-value services: ESA

In general, the survey revealed that the majority of data providers cannot or do not want to become web service providers, and so their data cannot currently be discovered and distributed via the Internet. A way to help them would be to offer a system able to generate web services when they upload data files according to some rules. The European project [InGeoCloudS](#) has developed such a system. It was finally decided, however, that due to the limited number of data resources that would be diffused through the pilot MARSite portal to adopt the more direct solution of BRGM directly creating Web Map Services from the files provided by the different partners.

The following list is a non-exhaustive hierarchy of data compiled based on the MARsite Description of Work:

- Geophysical
 - Seismograms
 - Broadband
 - Onshore
 - Surface
 - Borehole
 - OBS
 - Strong-motion
 - Onshore
 - Surface
 - Borehole
 - OBS
 - Earthquake catalogue
 - Historical
 - Instrumental
 - Geodetic
 - Displacement time-series (GPS) for geo-referenced points
 - Processed GPS (velocity map)
 - Deformation map (INSAR)
 - C-band
 - X-band
 - L-band
 - Harmonized map from INSAR and GPS
 - ShakeMaps (combination of observed ground-motion amplitudes and modelling)
 - Water temperature
 - Water current
 - Air temperature
 - Seismic hazard maps
 - Conductivity of thermal springs
- Geochemical
 - Fluid monitoring
 - Marine multiparameter time series
 - Gas measurements
 - Radon (Rn)
 - Carbon dioxide (CO₂)
 - Methane (CH₄)

- Geological
 - Fault characteristics
 - Lithology
 - Age
- Topographical
 - Onshore digital elevation models
 - Bathymetry models
- Tsunami
 - Water height
 - Water velocity

It was sought to diffuse examples of these different data types through the pilot portal via web services (either via external or internal) but services for many these data types are not currently available. Hence, simple services were created by BRGM to display various data provided by MARsite partners as Excel spreadsheets, text files and so forth. This work is discussed in the next section. The subsequent section discusses existing services that were included within the portal.

4.1.1 Data from within the MARsite consortium diffused via the portal

Table 1 lists the data collected from MARsite partners that is currently diffused through the pilot portal. These data range from point-based time-series of physical measurements to maps covering the whole region. Based on an internal questionnaire to MARsite partners and a literature search, there are no well-established data models for the vast majority of these data and consequently data models were developed specifically for the portal. These developed data models are detailed in the following section.

Table 1: Data collected during MARsite diffused through the portal

Type of data	Providers
Metadata (e.g. location and institute) on seismographic stations (broadband and short period) in region	TUBITAK/GFZ
Metadata (e.g. location and institute) on fluid monitoring stations in region	TUBITAK/GFZ
Metadata (e.g. location and institute) on soil radon stations in region	TUBITAK
Metadata (e.g. location and institute) on GPS stations in region	TUBITAK
Instrumental earthquake catalogue (magnitude \geq 4) for region	KOERI
Instrumental earthquake catalogue (magnitude \geq 2) for region	TUBITAK
CO ₂ concentrations	GFZ
Ground-motion simulations for some scenarios	BRGM
Fault maps (Le Pichon et al., 2001; Armijo et al., 2005; Saroglu et al., 1992; Sengor et al., 2014)	TUBITAK/ITU
Detailed bathymetric (Le Pichon et al., 2001)	TUBITAK

4.1.2 Other data sources from outside MARsite

In addition to data collected during the project, there are other data collections of relevance to MARsite that are available from other organizations and projects. Many of these are not available via web services and, therefore, these are not a priority for dissemination via the portal. However, there are a number of web services that can be easily incorporated into the portal and that could be of potential interest to MARsite partners and other users. In addition, to incorporating these services into the portal some of the most important data collections that it is not feasible to directly embed within the system (e.g. MOIST) are accessible through fixed URLs. This section lists the different data collections that have been incorporated into the portal.

The following Web Map Services (WMSs) are directly accessible via the portal:

- SHARE (hosted by the European Facility for Earthquake Hazard and Risk):
 - Area source model;
 - Seismic hazard map for 475-year-return-period peak ground acceleration;
- PROMINE (hosted by Geological Survey of Finland):
 - Magnetic anomaly;
 - Gravity;
 - Moho depth;
 - Heat flow;
- OneGeology (hosted by BRGM):
 - Bedrock age;
- GEMMA (hosted by Politecnico di Milano):
 - Moho depth;
- EMSC:
 - Moho depth from Euromed reference model of INGV;
 - Real-time earthquake catalogue;
- British Oceanographic Data Centre:
 - General Bathymetric Chart of the Oceans;
- NOAA
 - Tracks of bathymetric cruises;
 - Tracks of gravity cruises;
 - Tracks of magnetic cruises;
 - Tracks of single channel seismic cruises;
 - Tracks of aeromagnetic surveys;
 - Tsunami events;
 - Significant earthquakes.

In addition, other WMS can be easily viewed by a user by specifying their URLs within the relevant box on the portal. This would provide, for example, an easy method of viewing WMSs that are produced by MARsite partners within the final 18 months of the project.

The following data collections are available via the links page.

- MOIST: access to various marine data sets (from INGV-EMSO);
- GENESI-DEC;
- SeismicPortal (NERA):
 - web services for event information (event search, latest events, event detail), and waveform services;
 - the Seismolink web service provides information about networks, stations, channels and, in general, a complete inventory of the available resources; and
 - the Taup web service offers a utility to compute arrival times using a few default velocity model or one provided by the user.

4.2 SOME EXISTING DATA MODELS

In this section some existing data models of potential interest to MARsite are briefly described.

4.2.1 SensorML

SensorML is a standard specified by OGC and it is described thus: *“Sensor Model Language (SensorML) provides standard models and an XML encoding for describing any process, including the process of measurement by sensors and instructions for deriving higher-level information from observations. Processes described in SensorML are discoverable and executable. All processes define their inputs, outputs, parameters, and method, as well as provide relevant metadata. SensorML models detectors and sensors as processes that convert real phenomena to data.”*

SensorML is associated to the OGC Service Observation Service, which provides an Application Programming Interface (API) for managing deployed sensors and retrieving sensor data, allowing access to data through a service (to get observations and measurements, to describe the sensor making the measurements, to describe the service and so forth).

4.2.2 StationXML

StationXML is a standard managed by the International Federation of Digital Seismograph Networks (FDSN) as an evolution of the Standard for Exchange of Earthquake Data (SEED). The purpose of the FDSN StationXML schema is to define an XML representation of the most

important and commonly-used structures of SEED 2.4 metadata. The goal is to allow mapping between SEED 2.4 dataless volumes and this schema with as little transformation or loss of information as possible while at the same time simplifying station metadata representation when possible. Also, content and clarification has been added where lacking in the SEED standard. An example of StationXML (from http://www.data.scec.org/xml/station/samples/CI_stations.xml) is shown in Figure 14.

```
- <StaMessage xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns="http://www.data.scec.org/xml/station/"
  xsi:schemaLocation="http://www.data.scec.org/xml/station/
    http://www.data.scec.org/xml/station/20111019/station.xsd">
  <Source>IRIS-DMC</Source>
  <Sender>IRIS-DMC</Sender>
  <Module>IRIS WEB SERVICE: http://www.iris.edu/ws/station Networks:
    [CI] level:[sta]</Module>
  <SentDate>2011-02-14T20:00:11</SentDate>
- <Network net_code="CI">
  <Description>Caltech network</Description>
- <Station net_code="CI" sta_code="ABL">
  - <StationEpoch swap_order_16="BIG_ENDIAN"
    swap_order_32="BIG_ENDIAN">
    <StartDate>1976-07-23T00:00:00</StartDate>
    <EndDate>2599-12-31T23:59:59</EndDate>
    <Lat>34.84845</Lat>
    <Lon>-119.22497</Lon>
    <Elevation>1975.0</Elevation>
  - <Site>
    <Country>Mount Abel, Frazier Park, CA, USA</Country>
    </Site>
    <Name>CI-ABL</Name>
    <CreationDate>1976-07-23T00:00:00</CreationDate>
    <SelectedNumberChannels>1</SelectedNumberChannels>
  </StationEpoch>
</Station>
```

Figure 14: Example of StationXML

4.2.3 CityGML

Although it principally has an earth science-focus, MARsite is also concerned with earthquake risk to communities surrounding the Marmara Sea (e.g. Istanbul). Therefore, data models to describe the built environment, such as CityGML, may be important for subsequent developments in the project.

The City Geography Markup Language ([CityGML](#)) is a new and innovative concept for the modelling and exchange of 3D city and landscape models that is quickly being adopted at the international level. CityGML is a common information model for the representation of 3D urban objects. It defines the classes and relations for the most relevant topographic objects in cities and regional models with respect to their geometrical, topological, semantic and appearance properties. Included are generalization hierarchies between thematic classes,

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aggregations, relations between objects, and spatial properties. In contrast to other 3D vector formats, CityGML is based on a rich, general purpose information model in addition to geometry and graphics content that allows virtual 3D city models to be employed for sophisticated analysis in different application domains like simulations, urban data mining, facility management and thematic inquiries. Targeted application areas explicitly include urban and landscape planning; architectural design; tourist and leisure activities; 3D cadastres; environmental simulations; mobile telecommunications; disaster management; homeland security; vehicle and pedestrian navigation; training simulators; and mobile robotics.

CityGML is realised as an open data model and XML-based format for the storage and exchange of virtual 3D city models. It is implemented as an application schema for the Geography Markup Language version 3.1.1 (GML3), the extendible international standard for spatial data exchange issued by the OGC and ISO TC211. CityGML is an official OGC Standard and can be used free of charge.

4.2.4 GeoSciML

GeoScience Markup Language ([GeoSciML](#)) is a Geography Markup Language (GML) application language for geoscience. It is an XML schema for data exchange over the Internet that incorporates the ability to represent geography (geometries, e.g. polygons, lines and points, using the OGC's GML specification) as part of the features that are being exchanged. The range of features being offered for exchange are defined by the domain or subject area of geoscience or the geological sciences.

GeoSciML accommodates the short-term goal of representing geoscience information associated with geological maps and observations, as well as being extensible in the long-term to other geoscience data. It draws from many geoscience data model efforts, and from these establishes a common suite of feature types based on geological criteria (units, structures and fossils) or artefacts of geological investigations (specimens, sections and measurements). Supporting objects (timescale, lexicons, etc.) are also considered, so that they can be used as classifiers for the primary objects.

GeoSciML is based on W3C, OGC and ultimately ISO international standards for data exchange over the Internet. GeoSciML is being designed under the umbrella of the IUGS Commission on the Management and Application of Geoscience Information (CGI) and its CGI Interoperability Working Group.

4.3 EXISTING DATA MODELS FOR EARTHQUAKE CATALOGUES

In this section various data models for earthquake catalogues are described and a proposal is made for a simple OGC-compliant model.

4.3.1 QuakeML

QuakeML is a flexible, extensible and modular XML representation of seismological data that is intended to cover a broad range of fields of application in modern seismology. QuakeML is an open standard and is developed by a distributed team in a transparent collaborative manner. The first part of QuakeML covers basic seismic event description, including moment tensors. The flexible approach of QuakeML allows further extensions of the standard in order to represent waveform data, macroseismic information, probability density functions, slip distributions, shake maps, and others. QuakeML was adopted as a standard for basic earthquake event description by FDSN in June 2011.

The main classes of the UML model of QuakeML are the following:

- EventParameters, Event;
- Origin, OriginUncertainty;
- Arrival , Pick, Amplitude, Magnitude, StationMagnitude, StationMagnitudeContribution;
- FocalMechanism; and
- MomentTensor.

In the hierarchical model, the class EventParameters is made up of Event objects and represents an earthquake catalogue or a seismic bulletin. Event is connected via composition to Origin, Magnitude, StationMagnitude, FocalMechanism, Amplitude, and Pick, which all describe properties of a specific seismic event. An example of QuakeML encoding is shown in Figure 15.

```

<?xml version="1.0"?>
<q:quakeml xmlns="http://quakeml.org/xmlns/bed/1.2"
xmlns:catalog="http://anss.org/xmlns/catalog/0.1"
xmlns:q="http://quakeml.org/xmlns/quakeml/1.2">
<eventParameters publicID="quakeml:ci.anss.org/eventParameters/09082344/1362510261285">
  <event publicID="quakeml:ci.anss.org/event/09082344"
catalog:datasource="ci" catalog:eventsource="ci" catalog:eventid="09082344">
    <magnitude publicID="quakeml:ci.anss.org/magnitude/09082344/Mc">
      <mag>
        <value>1.6</value>
        <uncertainty>0.2</uncertainty>
      </mag>
      <type>Mc</type>
      <originID>quakeml:ci.anss.org/origin/09082344</originID>
      <methodID>quakeml:anss.org/cube/magnitudeType/C</methodID>
      <stationCount>0</stationCount>
      <evaluationMode>manual</evaluationMode>
    </magnitude>
    <origin publicID="quakeml:ci.anss.org/origin/09082344">
      <originUncertainty>
        <horizontalUncertainty>900</horizontalUncertainty>
        <preferredDescription>horizontal uncertainty</preferredDescription>
      </originUncertainty>
      <time>
        <value>1999-04-02T17:05:10.500Z</value>
      </time>
      <longitude>
        <value>-116.9945</value>
      </longitude>
      <latitude>
        <value>33.986</value>
      </latitude>
      <depth>
        <value>17300</value>
        <uncertainty>4300</uncertainty>
      </depth>
      <methodID>quakeml:anss.org/cube/locationMethod/h</methodID>
      <quality>
        <usedPhaseCount>14</usedPhaseCount>
        <usedStationCount>0</usedStationCount>
        <standardError>0.12</standardError>
        <azimuthalGap>115.1999907840007372799410176047186
        </azimuthalGap>
        <minimumDistance>0.01616968</minimumDistance>
      </quality>
      <evaluationMode>manual</evaluationMode>
    </origin>
    <preferredOriginID>quakeml:ci.anss.org/origin/09082344
    </preferredOriginID>
    <preferredMagnitudeID>quakeml:ci.anss.org/magnitude/09082344/Mc
    </preferredMagnitudeID>
    <type>earthquake</type>
    <creationInfo>
      <agencyID>ci</agencyID>
      <creationTime>2013-03-05T19:04:21.285Z</creationTime>
      <version>2</version>
    </creationInfo>
  </event>
  <creationInfo>
    <creationTime>2013-03-05T19:04:21.285Z</creationTime>
  </creationInfo>
</eventParameters>
</q:quakeml>

```

Figure 15: Example of QuakeML encoding

4.3.2 EqXML

EqXML is an XML format that is a superset of information contained by the CUBE format. It is most commonly used with the Earthquake Information Distribution System (EIDS). EqXML will eventually be replaced by QuakeML. An example of EqXML encoding is shown in Figure 16, which presents significant differences to the QuakeML model.

```
<?xml version="1.0"?>
<EQMessage xmlns="http://www.usgs.gov/ansseqmsg">
  <Source>ci</Source>
  <Sent>2012-04-24T23:33:25.489Z</Sent>
  <Event>
    <DataSource>ci</DataSource>
    <EventID>09082344</EventID>
    <Version>2</Version>
    <Action>Update</Action>
    <Type>Earthquake</Type>
    <Usage>Actual</Usage>
    <Scope>Public</Scope>
    <Origin>
      <Time>1999-04-02T17:05:10.500Z</Time>
      <Latitude>33.986</Latitude>
      <Longitude>-116.9945</Longitude>
      <Depth>17.3</Depth>
      <StdError>0.12</StdError>
      <AzimGap>115.2</AzimGap>
      <MinDist>0.01616968</MinDist>
      <Errh>0.9</Errh>
      <Errz>4.3</Errz>
      <NumPhaUsed>14</NumPhaUsed>
      <NumStaUsed>0</NumStaUsed>
      <Status>Reviewed</Status>
      <PreferredFlag>true</PreferredFlag>
      <Magnitude>
        <TypeKey>Mc</TypeKey>
        <Value>1.6</Value>
        <Error>0.2</Error>
        <NumStations>0</NumStations> <PreferredFlag>true</PreferredFlag>
        <Comment>
          <TypeKey>CUBE_Code</TypeKey>
          <Text>CUBE_Code C</Text>
        </Comment>
      </Magnitude>
    </Origin>
    <Method>
      <Algorithm>h</Algorithm>
      <Comment>
        <TypeKey>CUBE_Code</TypeKey>
        <Text>CUBE_Code h</Text>
      </Comment>
    </Method>
  </Event>
</EQMessage>
```

Figure 16: Example of EqXML encoding

4.3.3 QuakeML and OGC/ISO standards for geospatial information

To connect the QuakeML standard to the geospatial world specified by OGC and ISO, and used by INSPIRE, we suggest following some principles adopted by these organisations for data modelling and mainly to display and deliver data in an interoperable way.

To make the data interoperable, the following three recommendations are made:

- To share a common way to describe the geometry of a spatial object by using the GML (Geography Markup Language) standard, which describes the geography of objects (named features) whatever their properties;
- To describe the features of the domain according to common rules; and
- To share common values for properties whose values are chosen from a defined list (named controlled vocabularies, or code-lists, or enumerations).

A way to obtain this interoperable view is to transform on-the-fly the XML stream provided by a server delivering data with QuakeML encoding into XML using the same properties but encoded into an XML structure compliant with ISO/OGC rules. A software component (open source) [eXows](#) extends the capabilities of the OGC Web Services (OWS). It enables the multilingualism functionalities for OWS (INSPIRE compliant) and allows complex features schemas for Web Feature Services (WFS) and WMS getFeatureInfo (GML).

Four earthquake catalogues were collected for display by the portal (from KOERI, which was provided as an Excel spreadsheet; TUBITAK, which was provided as a text file; EMSC, which was available as an external WMS; and NOAA, which was also available as an external WMS). These catalogues use different data models and hence they cannot be easily compared nor are they completely compatible with OGC standards. Consequently for the purposes of the pilot portal a new data model is proposed to which the four catalogues could be converted. This data model is presented here. There are at least two published data models for earthquake catalogues (see above): QuakeML, which is quite commonly used in the seismological community, and EqXML, which is planned to be replaced by QuakeML in existing applications. Because QuakeML is not OGC-compliant, it was decided to start from scratch to develop the data model for earthquake catalogues rather than base it on existing models.

QuakeML is a standard data model describing the domain by many classes. To deliver some data related to an event with a Web Feature Service (standard WFS as specified by OGC and ISO) it is suggested to create a very simple data model (Simple Feature) to be easily managed by many WFS software (Table 2). This simple data model is a “profile” of QuakeML: QuakeML_SF (for Simple Feature), which uses the same attribute names as QuakeML but puts them in one class (Event) with some simplification. The interest of this simple model is also for data providers who want to deliver (or only have) some data related to seismic events. To define this profile, we used the representation of a seismic event as provided by the [Seismic Portal](#) as a simple view of QuakeML in [JSON](#).

Table 2: Proposed data profile for earthquake catalogues.

Event (JSON format)	QuakeML	QuakeML_SF : Event
"unid":"20090319_0000097",	Event/ publicID=ResourceReference/ResourceID :string	publicID
"orid":438718,	Magnitude/ originID=ResourceReference/ResourceID :string	originID

"flynn_region":"TONGA REGION",	Origin/ region :string	region
"datetime":"2009-03-19T18:17:37Z",	Origin/ time :TimeQuantity/value :datetime	time
"lat":"-22.997",	Origin/ latitude : RealQuantity/value :float	GM_Object/latitude
"lon":"-174.717",	Origin/ longitude : RealQuantity/value :float	GM_Object/longitude
"mag":"7.9",	Magnitude/ mag : RealQuantity/value :float	mag
"auth":"CSEM",	Event/ creationInfo :creationInfo/agency :string	agency
	Event/ creationInfo :creationInfo/agencyURI :string	agencyURI
"depth":"10",	Origin/ depth : RealQuantity/value :float	depth
"magtype":"mw"},	Magnitude/ type :string	magType

To be compliant with OGC, the geometry (location) is described by a common object (GM_Object) for all geospatial objects (so that this property is interoperable whatever the thematic domain). The author is replaced by the agency, and the agencyURI is added to provide a possible link to the web site of the data provider. Figure 17 shows a simple UML representation of this model.

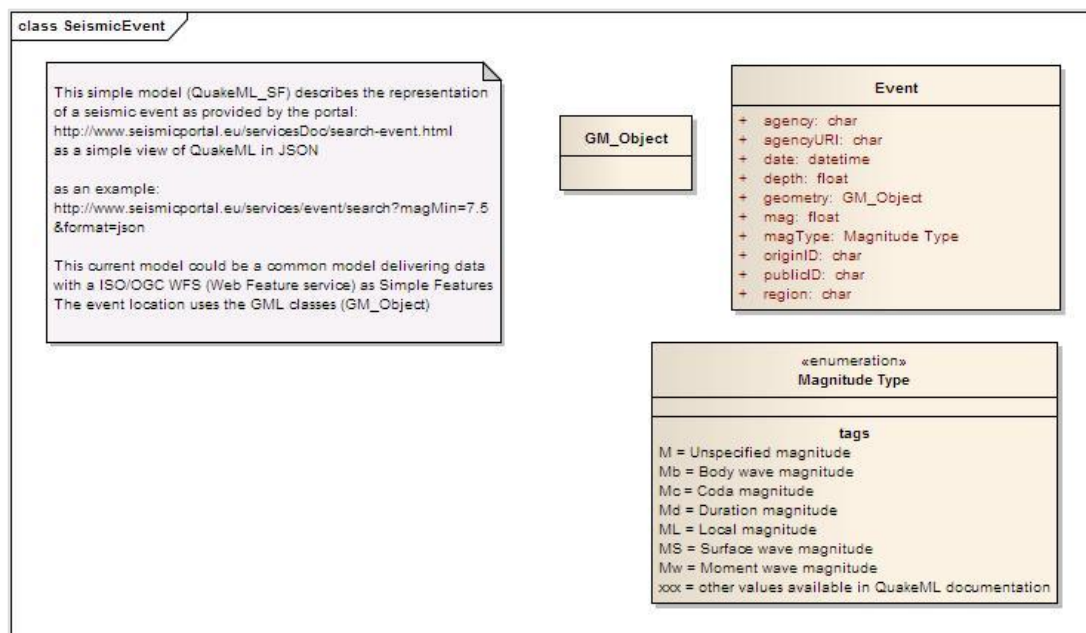


Figure 17: Simple UML representation of this model

For data providers without any web services, this data model could be implemented through a Simple Feature WFS. For other providers who already have web services delivering data according to the QuakeML data model, it could be possible to transform on-the-fly an XML stream (QuakeML format) to a QuakeML_SF format thanks to the eXows software component.

5. SERVICES

The functionalities of the MARsite portal are implemented using OGC-compatible web services, specifically WMS. This chapter discusses OGC-compatible services of relevance to a project like MARsite.

5.1 FUNCTIONALITIES SUPPORTED

Based on discussion with the MARsite partners and experience in developing portals for other projects, web services were chosen to allow the user to undertake the following operations, which cover the principal basic needs of potential users:

- Discover existing data;
- Display metadata;
- View data (maps, tables, graphs, ...); and
- Access/download data.

5.2 STANDARDS FOR SERVICES

This section briefly discusses details of the different services of relevance to MARsite.

5.2.1 Catalogue service

To find and access web services viewing or delivering data, it is recommended to setup a catalogue service on top of a metadata repository. This catalogue service should implement the OGC specification CS-W (Catalogue Service for the Web).

It defines the following operations:

- Get Discovery Service Metadata: Provides all necessary information about the Discovery Service and describes service capabilities;
- Discover Metadata: Allows requesting INSPIRE metadata elements of spatial data sets and services from a Discovery Service;
- Publish Metadata: Allows editing of INSPIRE metadata elements of resources in the Discovery Service (push or pull metadata mechanisms). Editing meaning insert, update and delete;
- Link Discovery Service: Allows the declaration of the availability of a Discovery Service for the discovery of resources through the Member State Discovery Service while maintaining the resource metadata at the owner's location.

One possibility is to setup a metadata catalogue based on INSPIRE/ISO metadata with some “queryable” elements.

The following list is the list of the main search criteria that a discovery service must implement in the discover metadata operation:

- keywords;
- topic category;
- resource title, resource abstract, resource type and resource identifier;
- geographic bounding box;
- temporal extent;
- scale or spatial resolution;
- responsible party;
- language;
- creation and publication dates; and
- service type.

Another option is to setup a catalogue exposing OpenSearch interfaces. Then search clients can use OpenSearch description documents that indicate how the search client should make search requests. OGC has extended the OpenSearch standard with geospatial and time extensions and it is a possible profile for the CS-W 3.0 part 4. The results are provided in various formats (e.g. HTML, Atom, XML/RDF, KML, JSON and WKT) directly integrated in web browsers. There are implementations of OpenSearch in several tools, such as Geonetwork, OpenLayers and Gi-CAT (base of the GEOSS Broker).

As only a few services were developed for the MARSite portal it was not necessary to setup a catalogue. The services could be registered into an existing catalogue (of EMSO/MOIST or EPOS, for example) or directly registered in the MARSite portal.

5.2.2 View service

View Services allow users and computer programs to view spatial datasets. The INSPIRE view service specifications are based on the ISO WMS Specification and also use the OGC™ Styled Layer Descriptor Profile (OGC SLD), and the OGC™ Symbology Encoding Implementation Specification (OGC SEIS). It defines the following operations:

- Get View Services Metadata: Get metadata about a specific view service;
- Get Map: Returns a map for a specified area;
- Link View Service: Allows the linking of view services together.

The OGC Web Map Service 1.3 standard (ISO 19128) was implemented in the pilot portal through MapSever 6.4.

5.2.3 Access/download service

The INSPIRE download services enable copies of spatial datasets, or parts of such sets, to be downloaded and, where practicable, accessed directly. INSPIRE specifies two types of download services:

- A service able to download pre-defined datasets contained in multiple physical files; and
- A service able to provide a direct access to the data, with the possibility to define queries to get a selected subset of the data.

The mandatory operations to implement for both types are:

- Get Download Service Metadata: provides all necessary information about the service, the available Spatial Datasets, and describes the service capabilities;
- Get Spatial Dataset: allows the retrieval of a Spatial Dataset;
- Describe Spatial Dataset: returns the description of all the types of Spatial Objects contained in the Spatial Dataset; and
- Link Download Service: allows the declaration, by a provider, of the availability of a Download Service for downloading Spatial Datasets or, where practicable, Spatial Objects.

In addition, for the optional direct access service, two more operations are included:

- Get Spatial Object: allows the retrieval of Spatial Objects based upon a query; and
- Describe Spatial Object Type: returns the description of the specified Spatial Objects types.

For these two operations, the search capabilities are also implemented. These capabilities include the ability to search by:

- URI of Spatial Dataset;
- Key attributes of spatial objects, including URI and date/time of update;
- Bounding Box;
- Spatial data theme; and
- Combinations of the above.

The download service is implemented using the ISO 19142 Web Feature Service and ISO 19143 Filter Encoding.

5.2.4 Processing services

A processing service is a generic term for a group of services offering a specific function not available from the other web services listed above. As examples there are:

- A thematic analysis service able to display a geological map with only geological units of a certain lithology;
- A statistical service able to compute the number of events of a certain type within a selected area;
- A graph service dynamically delivering a graph of the ground motion time series related to a PSI measuring point; and
- A report service able to deliver a report containing geohazard descriptions of a selected area.

These processing services host functions to process data accessed from a remote service (e.g. a WFS or WCS). They can be generic (compute statistics, for example) or specific to a thematic domain.

To ensure interoperability of such services, it is recommended to follow the OGC Framework specified by the WPS standard (Web Processing Service), and the WCPS (Web Coverage Processing Service) to process gridded data. If MARSite wants to share these services within the INSPIRE community, it is recommended to follow the Spatial Data Services regulation (based on the WPS for the best-defined interface of the possible INSPIRE Spatial Data Services types).

6. PORTRAYAL

So that the user can easily understand the data that is displayed and to compare information coming from the different sources it is important that the portrayal of the data is standardised. For example, symbols indicating earthquake epicentres provided by different catalogues or seismometer locations from different networks should be sufficiently similar (e.g. same shape and size) that they are interpreted by the user as the same object (although it may be useful to use different colour shades to indicate their source). Table 3 presents the portrayal rules defined for the data that was collected within the MARsite project. It should be noted that portrayal rules for external data sources (e.g. NOAA web services, see Section 4.1.2) could not be changed because they are served by organizations that are not partners of the MARsite project. An attempt has been made, however, to take account of these existing portrayal rules when developing rules for the internal data sources.

Table 3: Portrayal rules for data diffused through WMS developed in MARsite

Type	GPS	Seismometers	Soil radon	Fluid monitoring	CO ₂ concentrations	Earthquakes (KOERI and TUBITAK)	Bathymetry
Shape	Pentagons	Triangles	Diamond	Square	Circle	Circle	Shades
Colour	Grey	Green	Pink	Cyan	Bluey grey	Warm tones	Yellows to blues
Shades		Dark=KOE RI Mid=TUBI TAK Light=KOU Olive=GFZ		Dark=TUBI TAK Light=GFZ	Light=0-5% Mid=6-15% Dark=16-50% Darkest=51-100%	Light yellow=2-3 Yellow=3-4 Orange=4-5 Red=5-6 Maroon 6-7 Purple >7	Lightest=shallow water Darkest=deepest water
Size		Small=SP (short-period) Large=BB (broadband)		Small=well Large=spring		Small to large	

7. CONCLUSIONS

This report has detailed the work undertaken for Task 2 of WP10 of MARSite. It sought to show the benefits of using a system of distributed web services respecting international standard for the dissemination of data produced by or of interest to MARSite. Each chapter addressed a different aspect of such a distributed system, namely: metadata, data models, the web services themselves and, finally, the portrayal of the data. Existing standards and systems were summarised, their relevance for MARSite detailed, and ideas for future developments suggested. In order to demonstrate how such a distributed system would work and to clearly show the benefits of adopting such an approach for MARSite, and Supersite projects in general, a [portal](#) was created to serve various data collated or generated within the project or already available online from previous projects.

This task of WP10 is now complete and consequently it is not planned to continue updating the MARSite portal to add data that is collected during the final 18 months of the project. Nevertheless, if partners of MARSite serve the data collected within MARSite using the OGC Web Map Services standard then these data can be easily viewed using the portal, without the need for any changes to the software. This would allow the portal to continue to be a valuable entry point for MARSite partners and also other interested parties, e.g. the wider community studying geohazards in the Marmara Sea area.

It is important that the standards used and, in some cases, developed for this task get accepted by the wider community so that better interoperability between projects (specifically the other Supersites) is assured. Possible methods of encouraging this acceptance are the following. A working group (or Commission) on IT standards for dissemination of geophysical/geochemical data could be established within international scientific associations, such as the European Seismological Commission, International Association of Seismology and Physics of the Earth's Interior (or another branch of the International Union of Geodesy and Geophysics) and International Union of Geological Sciences (where GeoSciML has a Commission). An article in an international peer-reviewed journal could be useful method of increasing understanding of the issues and the developments made within this task. Finally, active contributions of MARSite to the Group on Earth Observations would be another way to ensure future developments.

As noted in the introduction, there is a related task of WP10 concerning access to ESA products that are of interest to the geohazards community of MARSite, which has a deliverable (D10.4) due in M30 (April 2015). In addition, there is an update of the deliverable D10.1 of Task 1 of Task WP10 aiming to establish and improve links to related projects and initiatives due in M24 (October 2014). Both of these deliverables will make use of the work presented here.

8. REFERENCES

Favali, P., Materia, P., Italiano, F. and Douglas, J. (2013), First report on the integration and links to other initiatives, Deliverable D10.1, FP7 MARSite Supersites project.