d4SCIENCE-II

PROJECT FINAL REPORT

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Project deliverable: DNA1.7

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Project Objectives

The major project aim was to develop technologies for enabling interoperation of diverse data e-Infrastructures that are running autonomously thereby creating an e-Infrastructure Ecosystem. This Ecosystem has the power to serve a significantly expanded set of communities dealing with multidisciplinary challenges whose solution is currently beyond reach. In particular, the project planned to create an initial ecosystem composed of at least the GENESI-DR and DRIVER repository e-Infrastructures, and other important thematic repositories maintained by international organizations, like INSPIRE, AquaMaps and FAO Infrastructure (The D4Science Ecosystem, Figure 1). By exploiting the resulting ecosystem, the project also aimed at supporting a number of Virtual Research Environments offering innovative functionality for facilitating scientific activities.

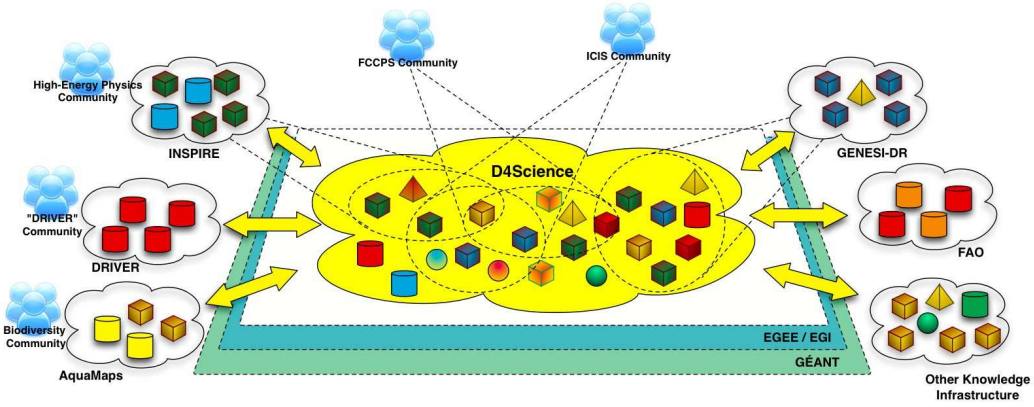

Figure 1: The D4Science Ecosystem

Ten contractors and a sub-contractor participated in the project activities:

1. European Research Consortium for Informatics and Mathematics (ERCIM, France)
2. Consiglio Nazionale delle Ricerche (CNR-ISTI, Italy)
3. National and Kapodestrian University of Athens (UoA, Greece)
4. European Organization for Nuclear Research (CERN, Switzerland)
5. Engineering Ingegneria Informatica SpA (ENG, Italy)
6. University of Strathclyde (USG, United Kingdom)
7. Universität Basel (UNIBAS, Switzerland)
8. European Space Agency (ESA-ESRIN, Italy)
9. International Center for Living Aquatic Resources (WorldFish Center, MY)
10. 4D SOFT Software Development Ltd. (4D-Soft, Hungary)

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To succeed in its overall mission, the work performed in the two years of the project was articulated in the following five major areas of activities:

1. gCube Development and Maintenance Activities
2. e-Infrastructure Management
3. Virtual Research Environments Development and Enrichment Activities
4. Communication, Dissemination and Training Activities
5. Coordination and Management Activities

Below a brief description of the objectives of each area and of its main achievements is given.

i. gCube Development and Maintenance Activities

One of the major objectives of the project was to enhance the gCube[1] technological capabilities in order to enable D4Science to hold together and interoperate with all data e-Infrastructures that participate in the ecosystem. In particular, the project aimed at extending gCube with new mechanisms that not only enable interoperability but also minimize the need to use ad-hoc solutions for discovering, accessing and using resources published by various, heterogeneous data e-Infrastructures.

Main achievements

The gCube system was progressively enriched in the course of the project through a continuous delivery process which consisted of a total of 13 releases, i.e. 5 major releases and 8 maintenance releases.[2]

The production of these releases followed a strict cycle coordinated with the Service and Joint Research Activities. Software Integration, Testing, Distribution and Documentation tasks were performed in order to, respectively, take care of building and packaging the gCube software, check its deployment capabilities, functionalities and performances, and diffuse suitable documentation of the gCube software through a public web distribution site (http://www2.gcube-system.org/, Figure 2).

As a general policy driving the design and development, generic solutions to harmonization, integration and interoperability problems were preferred to specific ones when possible. G*eneral-purpose frameworks* were integrated in the gCube system to address these problems. These frameworks facilitate reuse in multiple contexts thus enlarging the application domains served and reducing future development costs.

In particular, a number of *standards* were implemented and a set of *mediator frameworks* that can be configured to address different interoperability scenarios were developed. As a result of this activity the D4Science infrastructure is now able to interact with all those resource providers and consumers that implement the supported standards or can be served by the supported class of mediators.

[1] gCube is the D4Science e-infrastructure enabling system. Its development started in the D4Science project.
[2] The process of producing software releases and exploiting them to maintain and operate the infrastructure continues after the official end of the project.

In the data access area, the identified interoperability challenges led to design a completely new approach based on what was called *Open Content Management Architecture* (OCMA). This architecture set the road for the evolution of the D4Science Content Management services. Starting from the assumptions that (i) content is created, accessed, and distributed in units called documents, (ii) documents are grouped in collections, and (iii) collections are hosted in local management systems called repositories, OCMA defines the way for embracing and hiding the heterogeneity of the location where the content resides and how it is described and accessed. Such architecture also identifies classes of services and assigns to them a specific role. Along this view, a new suite of gCube components was implemented. Plugins were delivered for interfacing known services, e.g.: OAI-PMH compliant repositories.

A generic *gCube Data Transformation Service* (gDTS), responsible for transforming content and metadata among different formats and specifications, was also developed. gDTS lies on top of Content and Metadata Management services. It interoperates with these components in order to retrieve information objects and store the transformed ones. Transformations can be performed offline and on demand on a single object or on a group of objects.The version of gDTS released at the end of the project is also able to exploit the PE2ng, i.e. the Process Execution Engine, as a worker node of its operation, thus facilitating the composition of several transformations into more complex ones.

In the data discovery area, the existing rich set of Information Retrieval (IR) capabilities of the gCube platform was enriched and expanded in the direction of extending the interoperability of gCube Information Retrieval components with external infrastructures and platforms. Needs emerged where external data providers and search engines needed to be integrated in the flow of an IR operation. The direction taken in most of these situations was the creation of a mediator-based approach to identify instances of the external engine and to profile the external engine in the same way internal gCube search providers are profiled. According to this approach, an OpenSearch service, able to interoperate with this protocol was implemented.

In the process execution area, a Workflow and Execution Engine (PE2ng) was designed and

implemented to serve the cause of bridging the gCube enabled nodes with platforms such EGI infrastructure, Condor, and Hadoop. Different cloud platforms were also interfaced in order to profit from elastic computing. This work was partially performed by exploiting synergies with the VENUS-C project. This extension represents a new big step towards the openness of the system.

In the security area, the authorization framework was extended with an Authorization service, an XACML Policy Repository and an XACML Callout Implementation. In particular, the adoption of XACML 2.0, which is an open standard, grants interoperability with external compatible platforms through exchange of policies with the respective XACML Policy Repositories.

Special attention was also dedicated to the scalability of solutions for the existing technology. In particular, the original gCube Information System was revised by making it able to support new standard solutions (WS-DAIX), the Information Retrieval components and their interaction model were revisited to allow better utilization of existing resources and the deployment model was modified by exploiting a new notion: the *virtual platform*. This is a model to be extended for transparently interfacing a potentially unlimited number of hosting environments. The gCube enabling technology was empowered with capabilities for dynamically instantiating platforms (along with their resources) compliant with such a model.

A considerable activity was also dedicated to implement appropriate *Presentation Services* offering the level of user interfaces usability required by the target user communities.

In the security area, an *Authorization framework*, composed by a pluggable Security Library, an XACML Policy Repository and a set of plug-ins for basic secure behaviours was released. In order to enable interoperability with external infrastructures, two extension packages were also implemented to perform controls based on the identity of incoming messages, and to provide VOMS credentials based on user, host or robot certificates.

A number of tools, e.g. BSCW and traditional tools, such as mailing lists and Wikis, TRAC and Subversion (SVN) were maintained for supporting a common environment that could facilitate interaction among the different teams and project tasks. A number of procedures and metrics were also elaborated for measuring the quality of development activities as a further mean to ensure the expected production quality level.

Figure 2: gCube Website

ii. e-Infrastructure Management

The objective of this area was to deploy and ensure the correct, continuous and effective operation of the resources shared through the D4Science Ecosystem while enabling their exploitation by the user communities. This includes the definition of procedures regulating the operation and enrichment of the infrastructure, the provision of appropriate tools for its monitoring and management, the infrastructure management and upgraded by periodically deploying new community-specific resources as well as more consolidated and extended releases of the supporting system, i.e., gCube. This area also includes integration, building testing, and certification of new major gCube releases.

Main achievements

The D4Science Infrastructure was deployed at the beginning of the project starting from the outcomes of the D4Science project. During the project lifetime it was gradually expanded by registering several additional resources, making it interoperable with several infrastructures, creating new Virtual Organizations (VOs) and new Virtual Research Environments (VREs). As a result of this activity, at the end of the project the infrastructure hosts *five Virtual Organizations* and *thirteen Virtual Research Environments*.

The management of the D4Science e-Infrastructure was facilitated by the definition an implementation of clear procedures for monitoring, accounting and incident management and by the formation of a specific support team.

A portal was developed to simplify the deployment of new Virtual Organizations (VOs) and VREs and a number of monitoring tools were deployed allowing administrator with different infrastructure roles to visualize the status of their resources and to be actively notified when problems occurred. In particular, a new tool for the *Service Availability Monitoring* was developed, which ensures the availability of the base gCube services functionalities, e.g. the Information System and the Search subsystem.

An accounting tool was also put in production providing relevant statistics about the users' exploitation of the infrastructure.

In order to reduce the impact of upgrades on the production environment, a *pre-production environment* was set up during the second year to validate the new developments and upgrades coming from the integration, testing and distribution team.

In order to increase the quality of service, it was decided to maintain two instances of the web portal acting as a point of access to the D4Science-II infrastructure: one offering the service to the User Community and one (called "*newportal*"[3], Figure 3) dedicated to host the next version of the services including the new technologies released by the technical work packages. This strategy helped in reducing the downtime experienced by the user communities.

Suitable documentation of the gCube software through a public web distribution site was produced and continuously updated.

[3] https://newportal.d4science.research-infrastructures.eu/

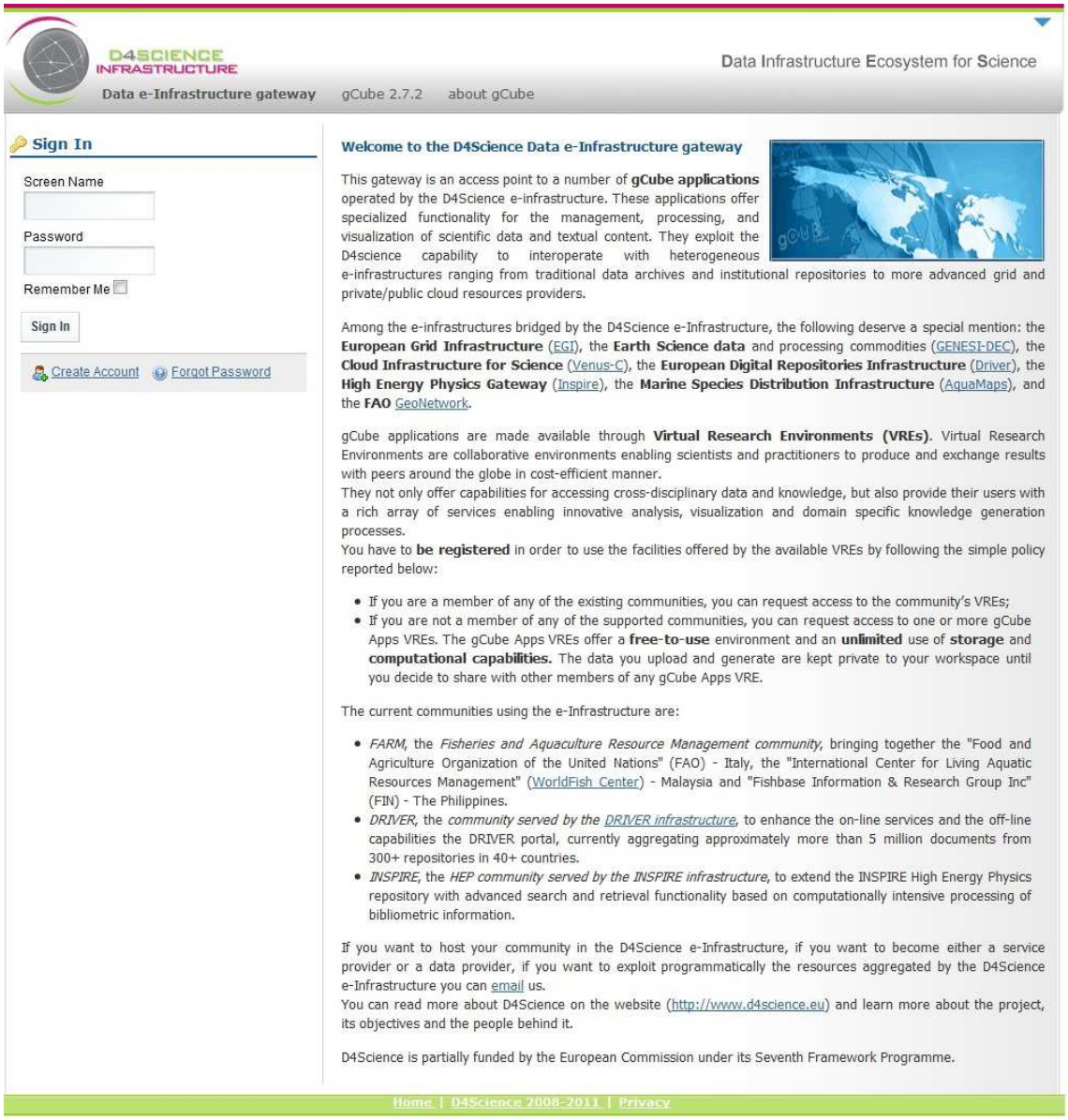


Figure 3: D4Science gateway

iii. Virtual Research Environments Development and Enrichment Activities

This area aimed at realising and operating Virtual Research Environments serving very different application scenarios. These scenarios exploit resources that are provided by the different e-Infrastructures participating in the ecosystem. Some of these VREs were expected to be consumed through end-user interfaces, while others were expected to be consumed programmatically by third-party services through APIs.

Main achievements

These VREs played a key role in the project since they enabled to validate the effectiveness of the support offered by the infrastructure and to convey to the community concrete examples of possible innovative exploitations.

In particular:

- *INSPIRE VRE*: This VRE was created to offer to the INSPIRE High Energy Physics Information System, through APIs, a set of specific functionalities which require large scale processing capabilities. The development around this VRE focused on three algorithmically stable areas: *metadata extraction*, *OCR-ing* and *full text indexing*. Despite solutions were addressing requirement related to the INSPIRE system, the project aimed at developing more general components that could also have been reused to serve the needs of other infrastructure customers. After an experimentation and pilot development performed in the first year extensive developments and tests were performed in order to achieve high scalability. JDL and grid resources were used for OCR and metadata extraction. In particular, full text indexing was performed by exploiting the Hadoop based parallel processing. Tests with the Hadoop cluster allowed parallel processing of up to 23 thousand documents in 2h time.
- *DRIVER VRE*: This VRE was set up to provide functionality to the DRIVER and other D-Net[4] empowered infrastructures. It offers back-end facilities to this infrastructures by making available D4Science accessible content through the OAI-PMH standard protocol and by providing typical library functionality that requires large processing capabilities. Examples of this functionality are *thumbnailing* with custom thumbnailers and extraction of text from PDF documents maintained in distributed repositories through *OCR-ing* so to enable multidimensional search capabilities. The latter facility required the implementation of a Resource Discovery component to search for documents through the web (following the link indicated in the aggregated metadata records), starting from a given set of resources up to a given search depth. The PDF documents so retrieved can now be processed by applying the OCR services developed in the context of the INSPIRE scenario to provide the necessary information to the D-Net indexing service. A series of experiments for the tuning of this facility were performed considering a limited number of DRIVER collections. These experiments highlighted the need for greater exploitation of the D4Science computational back-end and for access to context-free processing over grid and cloud computing, to be offered through the Process Execution Engine of gCube.
- *AquaMaps VRE*: This VRE offers a comprehensive working environment supporting the production of *species distribution maps* via predictive algorithms matching species characteristics with environmental data (Figure 4). It was deployed in the production infrastructure at the beginning of the project and since then it was constantly updated by acting on both user-oriented and systemic functionalities. Examples of the former are the integration of a richer set of algorithms for computing the species distributions, the provision of capabilities for selecting the version of the dataset to be processed in order to produce the distribution maps, and the implementation of a *Transect chart framework*, which includes tools for charts visualization and labelling usable to analyse the species distributions over a special area. Examples of the latter are the integration of a number of processing platforms, including Cloud ones, for improving the performance of calculations, the implementation of an HTTP-based interface for programmatically exposing the AquaMaps objects produced through the suite, and the production of GIS maps that can be disseminated through *GeoServer*. Because of the effectiveness of the release environment, the AquaMaps community raised pretty soon the need to sync the gCube AquaMaps environment with the official AquaMaps service (www.aquamaps.org).
- *FCCPS VRE*: The Fishery Country Profiles Production System VRE is focused on the production of country reports in the context of fisheries management. This VRE has been operated since the beginning of the D4Science production infrastructure. In the course of the project it has been improved to better support the collaborative activities. A *Business Document Workflow Suite*, i.e., a comprehensive working environment supporting the

[4] D-Net is the DRIVER supporting system

definition and execution of workflows governing the collaborative production of rich documents, was finalised. Other activities were performed to better meet and integrate the on-going practices of the community working at the production of the Country Reports. Examples of such activities are the customization of the D4Science report model to accommodate the features needed to support the Fishery Country Sector branch of the FiMES schema, and the enhancement of the Report and Template Portlets to create an online version of the Fishery and Aquaculture Country Profile Word template and make the export possible by exploiting the FAO converter tool.

- *ICIS VRE*: This VRE supports fisheries statisticians by providing them with a set of tools to *curate and manage catch statistics and related data*. It has been operated since the beginning of the D4Science production infrastructure. Pretty soon in the course of the project it emerged that the application operated by this VRE might benefit from the bunch of facilities offered by the *SDMX* (Statistical Data and Metadata eXchange) standard, e.g. for code list linking and time series publishing. Requirements on this innovative feature were analysed and web services supporting its provision were developed. Moreover, the capabilities of this VRE were largely expanded by integrating the existing application with *R* and with other VREs, such as VTI, and by making it interoperable with *FLOD* and *GeoServer*. It was also enhanced with graphing facilities and with the provision of a more friendly User Interface.

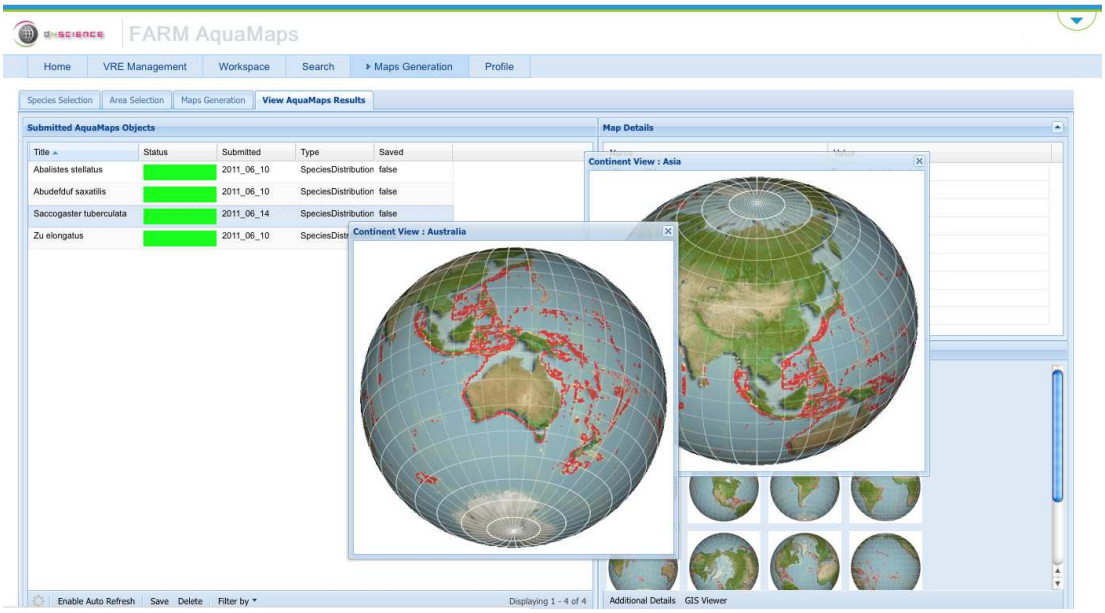


Figure 4: Maps Generation in the AquaMaps portal

The more in depth analysis of the five application scenarios, the availability of new infrastructural resources and the development of new capabilities, stimulated a number of additional activities originally unplanned. Major results produced by these activities are:

- *VTI VRE:* this VRE, named Vessel Transmitted Information, is a spin-off of the ICIS VRE. It was created to specifically target the *management of Vessel Position Records* to extract monthly fishing effort per unit area (Figure 5). The scenario requires that statistical data can be merged with environmental data, e.g. bathymetry extracted from GENESI-DEC. This was proven feasible. The specific position of VTI, at the exact intersection between the spatial and statistical communities, offers real and valuable services to a potentially very large community. As part of the development related to this VRE, new software artefacts were implemented, e.g. software libraries crunching vessel records for guessing fishing activity.

- *OpenSDMX environment*: this environment, exploited in the ICIS VRE, aims to leverage the power of D4Science technologies for the international statistical data collection community. It addresses the provision of mechanisms facilitating the management of code lists and mechanisms aiming at reinforcing the management of time series objects by relying on the SDMX standard. In particular, it comprises an SDMX Publisher offering a RESTFul interface serving FAO Codelists. It also supports an SDMX DSD's for the Fisheries and Aquaculture domains, currently used by e.g. FAO and Eurostat. Collaboration agreements at the level of software development are being drafted with other organisations to join forces on continuing its developments also after the end of the D4Science-II project.
- *FLOD: Fisheries Linked Open Data Knowledge Base* is a knowledge base dedicated to capture semantic knowledge on entities ranging from species to geospatial entities. At the end of the project it consists of more than 20 rdf linked datasets in the fisheries domain, each equipped with a set of services to maintain and consume the contents. FLOD data cross the spatial, statistics and marine legislation domains. The integration was achieved using semantic technologies.
- *SPREAD*: 'Spatial REAllocation of Data' is a demonstrator built by exploiting D4Science capabilities. It deals with the process of transforming data from one spatial resolution to another one. By relying on a number of facilities and repositories offering geospatial and other kind of data hosted in the Ecosystem, this demonstrator offers functionality for distinguishing catches in the High Seas from catches within the EEZs (one of the UN General Assembly recommendations). In the context of this demonstrator, a number of requirements related to quantity and quality of catch and related data to be managed to serve these scenarios were fulfilled.
- *TimeSeries suite:* This is a comprehensive working environment supporting the management and curation of time series objects. It was developed during the reporting period as part of the ICIS VREs. Among the others, it makes available facilities for dealing with errors in data during the curation phase, supporting the management of code lists, producing a rich array of graphs from time series; and transforming time series data to a set of GIS layers.

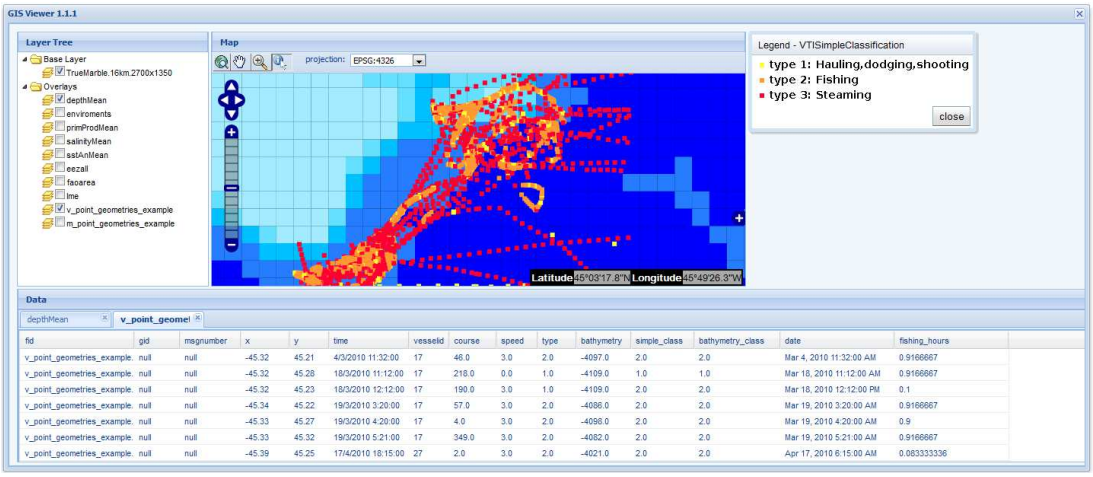


Figure 5: Vessel Transmitted Information VRE

iv. Communication, Dissemination and Training Activities

This area aimed at fostering the growth of a D4Science-II community by disseminating project results and knowledge to raise awareness within interested scientific circles. It also

was in charge of training software engineers, VO and VRE administrators and end-users in the configuration and exploitation of the gCube system and of the D4Science infrastructure facilities.

Main achievements

In order to raise awareness and disseminate project results among the largest pool of potential users and user communities, live D4Science project (Figure 6), and gCube web sites (Figure 2) were maintained to reflect the on-going work of the project and its interaction with scientific communities. Project partners were actively involved in communications at scientific events such as talks, demos, panels, discussions, presentations, tutorials, and poster sections. A range of presentations, brochures and articles in scientific literature were produced to convey the complex technical details of the project in a language that clearly showed the power and reach of the project. Three videos were also produced to effectively communicate relevant information and offer an interactive and engaging experience to the visitors of the D4Science-II website. Finally, scientific papers were published in scholarly, scientific and academic journals in order to increase visibility among research communities and target groups.

D4Science-II collaborated with different projects and R&D programmes striving for similar or complementary objectives. These collaborations contributed both to increase awareness and visibility of the D4Science-II project and to enlarge the planned ecosystem.
Relevant to the establishment of these collaboration was the organization of a number of events, like the D4Science World User Meeting, attended by more than 80 international fisheries and biodiversity delegates, a meeting with ESFRI Environmental projects, and another one, involving digital libraries and repository experts. Stimulated by recommendations received from the project's External Advisory Board, the Project Management Board discussed extensively the sustainability of the several D4Science-II products, e.g. D4Science infrastructure, gCube system, VREs, and various developed tools. A workshop dedicated to discuss this specific aspects with a larger community was organised towards the end of the project. Collaboration activities were also performed with the ERINA+ project, which tested its methodology for socio-economic impact assessment by analysing the exploitable results of the AquaMaps VRE.

As a further contribute to outreach, on-line tools and electronic material for support of events and off-line training were produced. Several training sessions to external and internal to the project audience were held and others were planned to be hold in near future also outside the project lifetime.

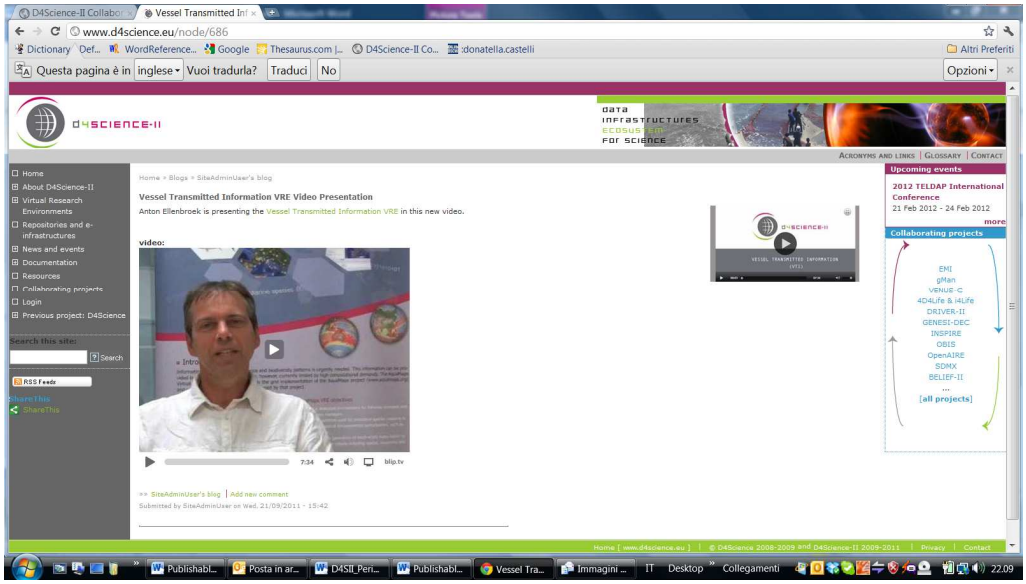


Figure 6: D4Science Website

v. Coordination and Management Activities

This last area was concerned with all the actions dedicated to the overall management of the project in its scientific, technological and administrative aspects. In particular, it included the definition of a detailed work plan, the monitoring and assessment of the progresses of the project with respect to this work plan, the measurement of the quality of the activities performed and the timeliness application of corrective actions. It also included careful monitoring of the resources and financial expenditures and the fulfillment of contractual obligations and reporting.

Main achievements

Activities were continuously supervised from the scientific, technical and financial points of view in order to assure appropriate quality and progresses. To help in this process, a Quality Assurance Task Force, appointed at the beginning of the project, defined a project quality plan and monitored it. The defined procedures concerned a considerable number of project aspects such as Project Governing Bodies, Meeting Procedures, Risk Management, Conflict Resolution, Activity Reporting, Deliverables Management, Software Release, Infrastructure Operation, etc. These procedures were made available in a wiki website open to all the project partners that also contained an up-to-dated progress status of the project deliverables.

The Scientific and technical directors operated to achieve the completion of the activities according to the established plans. Particular attention was dedicated to assure the proper level of interaction between the technologists and the representatives of both other e-Infrastructures participating in the ecosystem and scientific communities exploiting the VREs. These and other project activities were coordinated through periodic physical meetings and phone conferences.

Many co-operations agreements with other EU projects and initiatives were established, often as a result of networking events organised by the project. For example, as an outcome of the meeting organized with the ESFRI Environmental projects and of the ESFRI ENV Thematic working group the D4Science infrastructure was selected as underlying platform in the context of two new 7th Framework projects: ENVRI and EUBrazilOpenBio. The former, which will start on November 2011, aims at developing mechanisms for the integration and harmonisation of resources from environmental infrastructures by supporting the definition of unifying views over heterogeneous information spaces. The latter, which will start on October 2011, aims at deploying an open-access platform supporting the needs and requirements of the biodiversity scientific community by federating and integrating existing European and Brazilian infrastructures and resources.

An intense activity was initiated towards the end of the project to identify solutions for the sustainability of the D4Science Infrastructure. In particular, a collaboration activity was established with a team of experts of the ERINA+ Project to develop a preliminary "socio-economic impact assessment", through the analysis of one of the project's exploitable results: the AquaMaps Virtual Research Environment. Moreover, a 2.5 day workshop dedicated to address the unique sustainability issues confronted by the infrastructure was organized in near Nice, France, on September 2011. The outcome of this workshop has been reported into the public deliverable "DNA1.5 *Action Plan for Exploitation and Sustainability."*

2. Use and dissemination of foreground

2.1. Section A - Dissemination measures

In order to raise awareness and disseminate project results among the largest pool of potential users and user communities, the following dissemination measures were performed:

- Creation of a set of graphic materials:
  One triptych brochure and six inserts with an A5 size, to be stored within it. The inserts address these topics: gCube, AquaMaps, ICIS, FCCPS, DRIVER, INSPIRE. These materials were prepared to be used on different external events where D4Science-II team members participated aiming to transmit a clear overall picture of the project.

- Following the same visual identity, three posters were created on the following topics:

  i. Generic poster about D4Science-II, its objectives and components
  ii. Poster on the ICIS VRE
  iii. Poster on gCube PE2ng

  These posters were used in different conferences and adapted to each event necessity.

- A high-level explanation of the D4Science-II project was developed for reaching a wide audience and encouraging understanding of the project by a large community, bearing in mind that people who come for the first time to the project and can be potential users of it, do not necessarily have an accurate knowledge about the more technical parts.

- A project website was created and maintained. During the whole project period, 90 blog entries were published in the D4Science-II blog. They reported on project activities, highlight events, presentations, deliverables, milestones and promoted website's novelties. With different metrics, the project members have been able to monitor and evaluate the effectiveness of the communication activities. Figures were extracted from Google Analytics, a service offered by Google that generates detailed statistics about the visitors to a website. These statistics show that the regularly updated D4Science-II block page was the most frequented. The site reflected the ongoing work of the project and its interaction with scientific communities.

- A gCube website, describing the system technology and reporting its advances, was also created and maintained operational. Thanks to the lively web presence the number of visitors was fairly stable during the full period with visits from 82 countries. At the time of preparation of this report (Oct. 2011) this site has recorded 2353 software component downloads.

- Project partners participation to events, listed in the dynamic web calendar, was reported in the form of blog stories with attachments to the presented material. There were 41 selected dissemination events where D4Science-II was present and actively involved in communications such as talks, demos, panels, discussions, presentations, tutorials, poster sections. A range of presentations, brochures and articles in scientific literature were produced to convey the complex technical details of the project in a language that clearly showed the power and reach of the project. All materials prepared for conferences and

meetings were accessible - depending on their nature - either on the D4Science-II project website or on the internal project CMS.

- Free WEB 2.0 tools, such as social media sites, were used to create a powerful media project presence. Blip TV and YouTube (as a secondary channel) were used to add D4Science-II project videos. 3 videos were filmed and edited:
  - D4Science-II video about GRDI 2020 meets the D4Science Project;
  - D4Science-II video about Fishery Country Profiles Production System;
  - D4Science-II video about Vessel Transmitted Information.

  With these videos the project effectively communicated relevant and complex information to the visitors of the D4Science-II website. The videos offered a more interactive and engaging experience, keeping visitors on the site longer.

- A monthly news digest was also introduced. It summarized the news published on the D4Science-II blog and was sent to all project contacts collected in the course of the different D4Science-II events.

- A long-standing technique for generating an image of authority, excellence and professionalism in scientific circles is through the publishing of papers in scholarly, scientific and academic journals. During the full period of the project the D4Science-II team worked on publishing papers with the objective of increasing visibility among research communities and target groups. 14 scientific publications were disseminated and are available in print and online.

2.2. Section B - Exploitable foreground and plans for exploitation

At the end of the D4Science II project, two distinct scientific communities are involved in exploiting and testing the D4Science infrastructure:

- FARM collect and analyze data on fisheries, biodiversity and ocean observation;

- INSPIRE and DRIVER develop computationally demanding e-library functions such as processing documents and computing bibliometrics.

The current exploitation by these communities can be grouped into two major areas:

- Distributed Open Source software development, pooled into one single infrastructure, fostering the adoption of standards, with tools/systems such as OpenSDMX and FLOD;

- Development and usage of Virtual Research Environments, with the aim of building resources for Communities of Practice, developing convincing demonstrations for other potential users, and fostering wider engagement of the community, through products such as Aquamaps, FCPPS, ICIS for potential use with visualisation tools such as maps or dynamic charts (e.g. Gapminder) and analytical tools (e.g R).

These exploitation areas would be developed to further address and resolve an interlinking set of issues for the science/user community, including overcoming data collection and sharing problems, better meeting the need to generate reliable harmonized quality structured data sets, opening access to closed data repositories, and overcoming the lack of computing power amongst researcher, data users and resource managers. The practical aspects of these aims can be further defined to meet specific demands by the science/user community, including:

- The development of code list management and dissemination services;
- Archival services;
- Production and access to a library of on-demand Oceans observation satellite images;
- The availability of harmonized, qualified, and timely shared Time series of key data sets;
- Improved cross-domain analytical capacities, including interactive mapping capacities and services, and streamlined flow among analytical tools such as R and Gapminder;
- Improved and more integrated modeling capacities, including the modeling of species distribution and biodiversity with flexible space and time resolution, of fishing activity from vessel-transmitted Information, and of reallocation of catch statistics across species, stocks, fleets, reporting zones and countries.

These would be developed according to fundamental principles of supporting open access and free use of platforms and systems (with options for various fees/licensing for specific added value services, and for use of system components outside the primary communities – see next section); ensuring access and use of shared data and tools fully meeting users' confidentiality and security requirements; and greatly enhancing access to greater computing power and capacity.

To enable this to be achieved, a longer-term plan for system sustainability is required. While recognising the key role that core funding for D4Science has played in establishing the working elements of the system, if these are to be applied widely and well, the system maintained and updated, features and services developed and improved, and users guaranteed a reliable and 'future-proofed' resource, a pragmatic perspective is required to identify and develop a more diverse strategy for funding and service development. This would recognise the diversity of potential products and services, addressing various audience types, including users of infrastructure assets, software developers, data managers, statisticians, scientists and policy makers.

3. Conclusions

The main results of the D4Science-II project are:

- the gCube software framework release 2.5.1;[5]
- the D4Science Ecosystem, operated through the gCube framework, interoperating with several other infrastructures;
- thirteen Virtual Research Environments supported by the D4Science Infrastructure offering services to users through dedicated portals and to other services through specific APIs;
- a number of specific tools for curation, management and processing of data that can be exploited in many different application contexts.

Each of these products has a potential market that ranges from large international organizations willing to create their own infrastructure as well as companies interested in either developing services on top of the infrastructure or offering other infrastructure services (e.g. Cloud services) to D4Science, to groups of scientists interested in innovative and more competitive environments where to perform their experiments and generate new and better quality knowledge.

The D4Science-II project has also largely contributed to produce a considerable know-how on infrastructure interoperability development. Generic interoperability solutions have been introduced whenever possible. Several issues have been addressed and validation activities have been performed. Also, interoperability issues that are not usually known in the literature have been highlighted through concrete development and experimentation activities

The D4Science products have also acted as catalysts for other communities/organizations that have shown interest in them and have decided to join with the D4Science partners in order to move forward the development of these products.

[5] The activity of releasing new gCube versions continued after the project official end. At the time of finalising this deliverable (November 2011) gCube 2.7.0 was available.

Appendix A - Dissemination (public)

A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers (if available)	Is/Will open access[6] provided to this publication?
1	D4Science-II - An e-Infrastructure Ecosystem for Science	Donatella Castelli, Marc Taconet and Virginie Viollier	ERCIM News 79 Special theme: Towards Green ICT	October 2009	ERCIM	Europe	2009	P.9	**Link**	Yes
2	Functional Adaptivity for Digital Library Services in e-Infrastructures: The gCube Approach in proceedings of the Research and Advanced Technology for Digital Libraries,	Simeoni F., Candela L., Lievens D., Pagano P. and Simi M.	13th European Conference, ECDL 2009	October 2, 2009		Europe	2009	P51-62	**Link**	Yes
3	On-demand virtual research environments and the changing roles	Candela L., Castelli D., Pagano P	Library Hi Tech, vol. 27 (2)	2009	Emerald Group Publishing	Europe	2009	P 239 - 251	**Link**	Yes

5[6] Open Access is defined as free of charge access for anyone via the internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you i6ntend to establish open access afterwards.

	of librarians				Limited					
4	Building an e-Infrastructure for Capture Statistics and Species Distribution Modeling: the D4Science Approach	Candela L., Castelli D., Ellenbroek A., Pagano P., and Taconet M.	International Conference on Marine Data and Information Systems (IMDIS 2010)	March 2010		Europe	2010		**Link**	Yes
5	Making Virtual Research Environments in the Cloud a Reality: the gCube Approach	Leonardo Candela, Donatella Castelli and Pasquale Pagano	ERCIM News 83 Special theme: Cloud Computing	October 2010	ERCIM	Europe	2010	P46	**Link**	Yes
6	A count in the dark	Pauly, D. and R. Froese	Nature Geoscience 3	2010		Europe	2010	P662-663	**Link**	Yes
7	Deploying general-purpose virtual research environments for humanities research	Blanke T., Candela L., Hedges M., Priddy M., Simeoni F	Philosophical Transactions of the Royal Society of London Series A-Mathematical Physical and Engineering Sciences, vol. 368	2010	Royal Society Publishing	Europe	2010	P 3813 - 3828	**Link**	Yes
8	The gCube interoperability framework. In: 2nd DL.org Workshop - Making Digital Libraries Interoperable	Candela L., Kakaletris G., Pagano P., Papanikos G., Simeoni F.	2nd DL.org Workshop - Making Digital Libraries Interoperable	9-10 September 2010		Europe	2010	Proceedings : P35 - 42		Yes
9	An event-centric	Castelli D.,	Digital	2010		Europe	2010	P79 -	**Link**	Yes

	provenance model for digital libraries	Candela L., Manghi P., Pagano P., Tang C., Thanos C.	Libraries - 6th Italian Research Conference. Communications in Computer and Information Science, vol. 91 - Part 3					88		
10	D4Science: An e-Infrastructure for Facilitating Fisheries and Aquaculture Resource Management	Donatella Castelli, Anton Ellenbroek, Pasquale Pagano and Marc Taconet.	Abstract, presented at 22nd International CODATA Conference	24-27 October, 2010		CapeTown, South Africa.	2010		**Link**	Yes
11	An Event-Centric Provenance Model for Digital Libraries	Castelli, Leonardo Candela, Paolo Manghi, Pasquale Pagano, Cristina Tang, Costantino Thanos	Digital Libraries - 6th Italian Research Conference	28-29 January 2010		Europe	2010	P 91, 79-88	**Link**	Yes
12	Building Scientific Workflows for the Fisheries and Aquaculture Management Community	Pagano P., Candela L., and Andrade P.	5th EGEE User Forum	April 2010		Europe	2010		**Link**	Yes
13	Potential contribution of the Internet to a global community of practice for	Serge M. Garcia	ICES Journal of Marine Science	January 2011		Europe	2011		**Link**	Yes

	fishery management, Internet to a global community of practice for fishery management.									
14	The D4Science Approach toward Grid Resource Sharing: The Species Occurrence Maps Generation Case.	Candela L., Pagano P.	Data Driven e-Science - Use Cases and Successful Applications of Distributed Computing Infrastructures (ISGC 2010)	January, 2011		Europe	2011	P. 225-238	**Link**	Yes

A2: LIST OF DISSEMINATION ACTIVITIES

NO.	Title	Date	Place
1	World User Meeting	25-26 November 2009	Rome, Italy
2	Italian Research Conference on Digital Libraries	28-29 January 2010	Padua, Italy
3	2nd meeting of the Italian Working Group on Digital Cultural Heritage E-Infrastructure	01 March 2010	Pisa,Italy
4	International Conference on Marine Data and Information Systems (IMDIS)	29-31 March 2010	Paris, France
5	International Symposium on Grid Computing	5-12 March 2010	Taipei, Taiwan
6	6th European Conference on Research Infrastructures (ECRI2010)	23-24 March 2010	Barcelona, Spain
7	D4Science meets ESFRI & RI Projects: Workshop	17 Mar 2010	Brussels, Belgium
8	Second Meeting of the Italian Working Group on Digital Cultural Heritage e-Infrastructure	1st April, 2010	Pisa, Italy
9	HASTAC 2010: Grand Challenges and Global Innovations Conference	15-17 April, 2010	London, UK
10	5th EGEE User Forum,	12-16 April- 2010	Uppsala, Sweden
11	The 5th international conference on Open Repositories (OR2010)	6-9 July 2010	Madrid, Spain
12	DH2010	7-10 July 2010	London, UK
13	ICES Symposium on the Collection and Interpretation of Fishery Dependent Data	23-26 August 2010	Galway, Ireland
14	The 2nd DL.org workshop (ECDL2010)	9-10 September 2010	Glasgow, Scotland, UK
15	The FOSS4G conference for Open Source Geospatial Software	6– 9 September 2010	Barcelona, Spain
16	EGI Technical Forum 2010	4-17 September 2010	Amsterdam, The Netherlands
17	ICT 2010	27-29 September 2010	Brussels, Belgium
18	Workshop with the Environmental projects	30 September 2010	Brussels, Belgium
19	DL.org Autumn School on Digital Libraries and Digital Repositories: Modelling, Best Practices, and Interoperability	03-08 October 2010	Athens, Greece
20	D4Science Demonstration at Theory and Practice in Digital Libraries: A European Approach (DL.org Workshop)	13 October 2010	Athens, Greece
21	22nd CODATA International Conference, Scientific Data and Sustainable Development	24-27 October 2010	Cape Town, South Africa
22	Workshop on Theory and Practice in Digital Libraries: A European Approach	12-13 December 2010	Athens, Greece

23	Workshop on Digital Repositories – Linked Open Data – the possible Role of D4Science	16-17 December 2010	Rome, Italy
24	5th Session of the IODE Group of Experts on Biological and Chemical Data Management and Exchange Practices	17-20 January 2011	Oostende, Belgium
25	Information Systems Architecture Forum – Cloud Computing and FAO	25 January 2011	Rome, Italy
26	29th Session of Committee on Fisheries (COFI)	31 January – 4 February 2011	Rome, Italy
27	Third Meeting of Regional Fishery Body Secretariats Network (RSN 3)	07-08 February 2011	Rome, Italy
28	Metafor Project Workshop: Using the Metafor Common Information Model (CIM) to store, discover and locate climate modelling data	14 Mar 2011	Abingdon, United Kingdom
29	TELDAP International Conference	16-19 March 2011	Taipei, Taiwan
30	International Symposium on Grids and Clouds (ISGC 2011)	21-25 March 2011	Taipei, Taiwan
31	European Grid Infrastructure (EGI) User Forum	11-14 April 2011	Vilnius, Lithuania
32	Presentation of D4S results in the Erina Workshop at Egi forum	12 April 2011	Vilnius, Lithuania
33	SDMX Global Conference 2011	2-4 May 2011	Washington DC, United States
34	Presentation of ICIS, the Integrated Catch Information System Virtual Research Environment (VRE) and the D4Science Supporting Technology for FAO staff	17 May 2011	Rome, Italy
35	Extreme Large Database Workshop	9-10 June 2011	Edinburgh, United Kingdom
36	Presentation of gCube system evolution and its architecture	11 June 2011	Athens, Greece
37	Sustainability Workshop	12-14 September 2011	Cagnes-sur-Mer, France
38	**EGI Technical Forum 2011**	19-23 Sept 2011	Lyon, France
39	Presentation of the paper “An approach to Virtual Research Environment user interfaces dynamic construction” by Massimiliano Assante, Pasquale Pagano, Leonardo Candela, Federico De Faveri and Lucio Lelii TPDL 2011 Conference	26-29 Sept 2011	Berlin, Germany
40	Presentation “Taming Data Sharing and Re-using in the e-Infrastructures realm” by Pasquale Pagano at “Global Research Data Infrastructures: The Big Data Challenge'	18-19 Oct 2011	Brussels, Belgium
41	Presentation “e-Infrastructures for the Future Ocean” by Donatella Castelli, at “Workshop on Scientific Data Infrastructures in the European Parliament”	20 Oct 2011	Brussels, Belgium

Dissemination material

D4Science logo

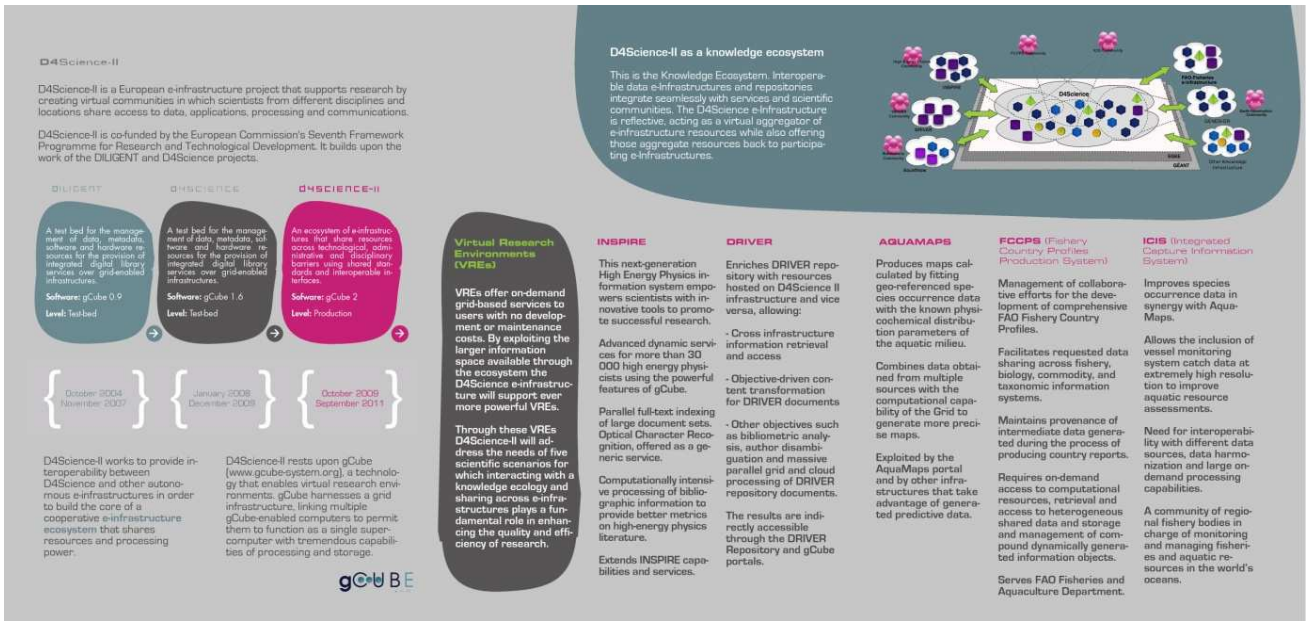
General information

- D4Science-II brochure
- AquaMaps Insert
- FCCPS Insert
- ICIS Insert
- Driver Insert
- Inspire Insert
- gCube Insert

FLYERS: communications team has produced a D4Science-II flyer and five inserts during the M1-M12 period. As the project developed there was a need to rewrite and redesign these previously prepared materials. This revision has been undertaken during the M15-16 period. The flyer gives an overview of the project together with its objectives and context. The flyer and the inserts are distributed during workshops and events. The new versions[1] are also directly available on the D4Science-II website.

D4Science-II Flyer

AquaMaps Insert

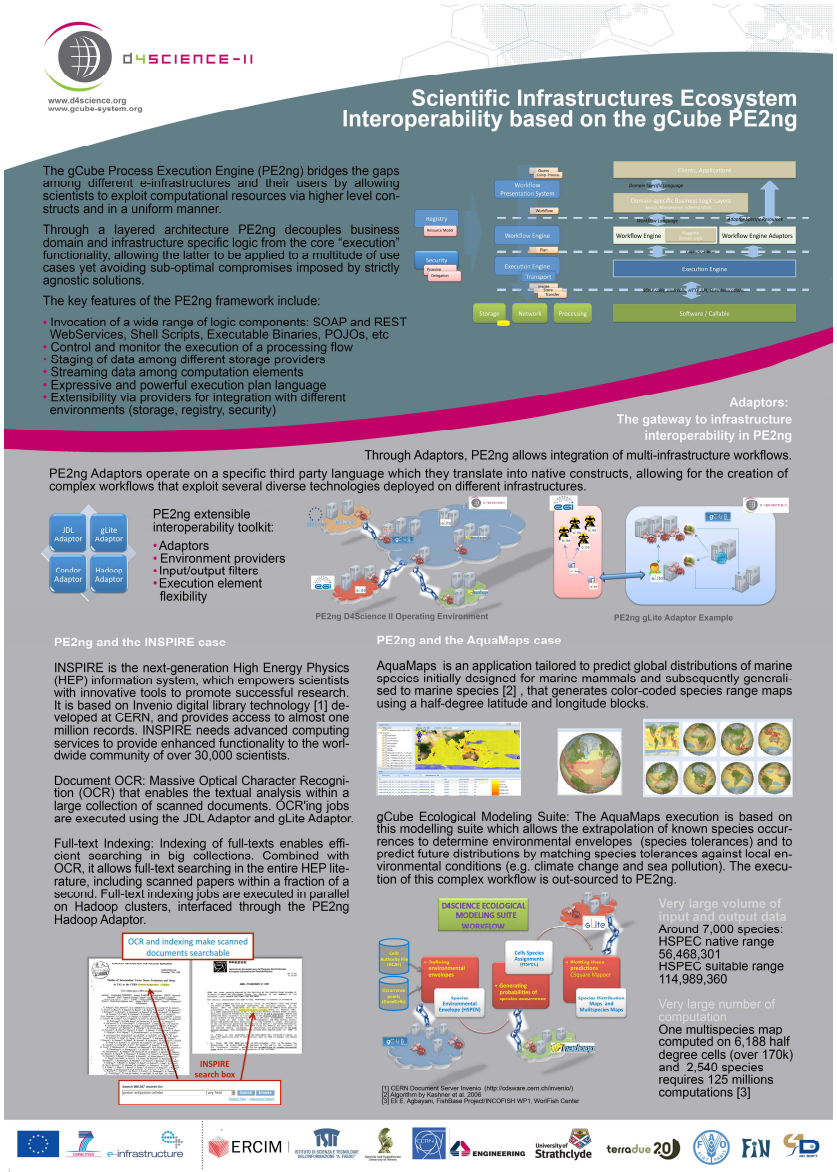


Driver Insert

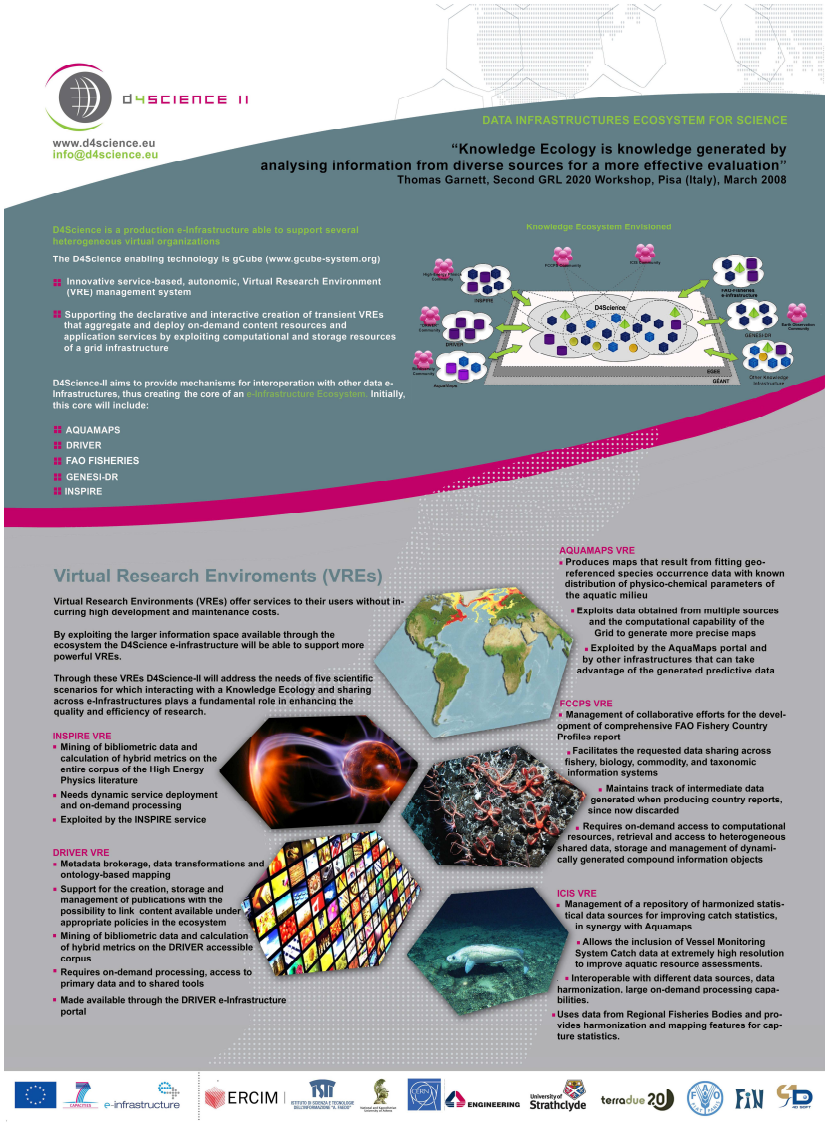
gCube Insert

POSTERS

gCube Posters



D4Science-II Generic Poster



ICES Poster

VIDEOS: an effective means to communicate relevant and complex information to D4Science-II website visitors. During the full project period, there were three videos were filmed:

- Fishery Country Profiles Production System (FCPPS) presented by Marc Taconet highlighted a specific use case for the fisheries community that has been implemented within the project's grid infrastructure;
- Integrated Capture Information System (ICIS) presented by Anton Ellenbroek presented a second use case for the fisheries community that has been implemented within the project's grid infrastructure.
- D4Science-II video about GRDI 2020 meets the D4Science Project;

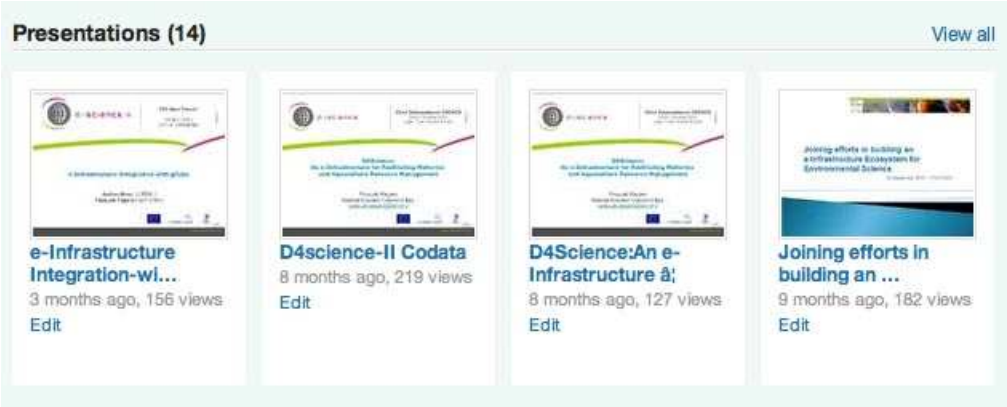
Fishery Country Profiles Production System (FCPPS)

Integrated Capture Information System (ICIS) video

- Blip TV[7] and YouTube (as a secondary channel) are used to add D4Science-II project videos. These videos create a personal, interactive experience between the project and the audience, engaging them and keeping visitors on the site for a longer time.

[7] http://blip.tv/file/1912552

SLIDES: Public PowerPoint files prepared during the reporting period were added to the popular presentation sharing site Slideshare and are linked from the D4Science-II web site



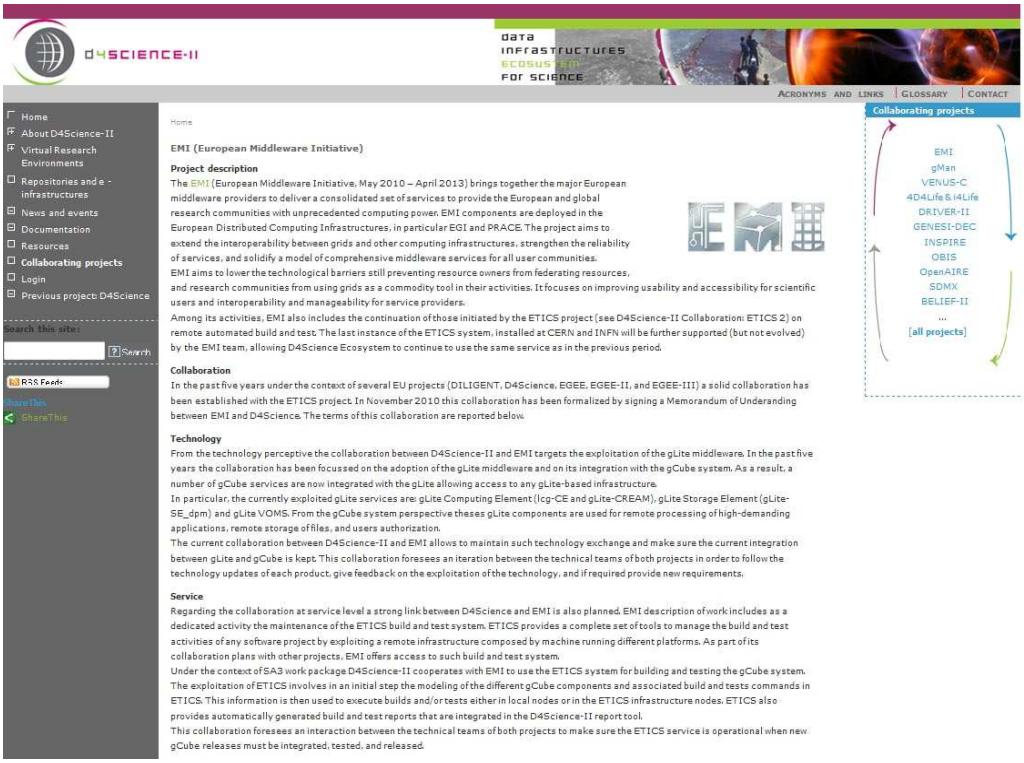
PHOTOS: D4Science–II photos, posted on the D4Science Flickr Gallery4, illustrate project participation at events and meetings. All the pictures are organized using tags enabling search related to particular topics such as event name, subject matter, and place.

D4S-II WEBSITE:

The D4Science-II public web site is an important and versatile tool to communicate project progress and events to existing and potential community members. As the main dissemination vehicle it includes all publications, news, journal articles, presentations at conferences as well as core documents such as project deliverables. Project members are collaborating on the update of the web site by proposing new stories about the project in order to raise awareness among the widest possible audience.
The D4Science-II blog is the most frequently updated part of the website and it is among the most frequented pages of the site (see Table 4). All new information is shared here with project participants and user communities.

New areas were also added. There is now a general page with an explanation regarding the projects collaborating with D4Science-II and links to each of these projects. A new block on the right side of the page has been created in order to easily reach the fifteen sub pages that detail each collaboration. Links are illustrated with logos to increase brand recognition.

Collaborating Projects



Under the Documentation menu a new "Presentations"[8] section has been created providing direct access via an embedded gadget that takes visitors directly to the D4Science-II Slideshare[9] account.

D4Science-II Slideshare presentations

[8] http://www.d4science.eu/presentations
[9] http://www.slideshare.net/d4science

A monthly news digest[10] has also been introduced. It is a summary of the news published on the D4Science-II blog. It is sent to all project contacts collected during different events – the largest set those who attended the D4Science World User Meeting[11] in 2009.

Monthly News Digest

[10] http://www.d4science.eu/node/675
[11] http://www.d4science.eu/worldusermeeting/

PAPERS: 14 D4Science-II papers were published. Their electronic versions2 are also available on a dedicated section of the D4Science-II web site. (See Table A1: List of scientific publications) or the webpage dedicated listing all papers

EGEE JOINT PUBLICATIONS

- Building Scientific Workflows for the Fisheries and Aquaculture Management Community based on Virtual Research Environments 5th EGEE User Forum, April 2010

Appendix C - Report on societal implications

Replies to the following questions will assist the European Commission to obtain statistics and indicators on societal and socio-economic issues addressed by projects. The questions are arranged in a number of key themes. As well as producing certain statistics, the replies will also help identify those projects that have shown a real engagement with wider societal issues, and thereby identify interesting approaches to these issues and best practices. The replies for individual projects will not be made public.

A General Information *(completed automatically when **Grant Agreement number** is entered.*	
Grant Agreement Number:	**239019**
Title of Project:	**D4Science-II**
Name and Title of Coordinator:	Jessica Michel Project Coordinator (ERCIM)

B Ethics		
1. Did your project undergo an Ethics Review (and/or Screening)? If yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project report	**Yes**	**No**
2. Please indicate whether your project involved any of the following issues (tick box) :	***YES***	
RESEARCH ON HUMANS		
• Did the project involve children?		
• Did the project involve patients ?		
• Did the project involve persons not able to give consent?		
• Did the project involve adult healthy volunteers?		
• Did the project involve Human Genetic Material?		
• Did the project involve Human biological samples?		
• Did the project involve Human data collection?		
RESEARCH ON HUMAN EMBRYO/FOETUS		
• Did the project involve Human Embryos?		
• Did the project involve Human Foetal Tissue / Cells?		
• Did the project involve Human Embryonic Stem Cells?		
• Did the project on human Embryonic Stem Cells involve cells in culture?		
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?		
PRIVACY		
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?		
• Did the project involve tracking the location or observation of people?		
RESEARCH ON ANIMALS		
• Did the project involve research on animals?		
• Were those animals transgenic small laboratory animals?		
• Were those animals transgenic farm animals?		
• Were those animals cloned farm animals?		
• Were those animals non-human primates?		
RESEARCH INVOLVING DEVELOPING COUNTRIES		
• Did the project involved the use of local resources (genetic, animal, plant etc)		
• Was the project of benefit to local community (capacity building ie access to healthcare, education etc)		

DUAL USE	
• Research having direct military ude	
• Research having the potential for terrorist abuse	

C Workforce Statistics

3 Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	1	
Work package leader		
Experienced researcher (i.e. PhD holders)	4	26
PhD Students	2	6
Other	13	23
4 How many additional researchers (in companies and universities) were recruited specifically for this project?		**7**
Of which, indicate the number of men:		7

D Gender Aspects

5 Did you carry out specific Gender Equality Actions under the project?

✓ Yes
○ No

6 Which of the following actions did you carry out and how effective were they?

		Not at all effective				Very effective
❑	Design and implement an equal opportunity policy	○	○	○	○	○
❑	Set targets to achieve a gender balance in the workforce	○	○	○	○	○
❑	Organise conferences and workshops on gender	○	○	○	○	○
❑	Actions to improve work-life balance	○	○	○	○	○
✓	Other:	Publication of the D4Science-II Gender statement on the D4Science website http://www.d4science.eu/statement				

7 Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

✓ No

E Synergies with Science Education

8 Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

○ Yes- please specify

✓ No

9 Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

✓ Yes- please specify (Training material, explanatory booklets)

○ No

F Interdisciplinarity

10 Which disciplines (see list below) are involved in your project?

✓ Main discipline[12]:

✓ Associated discipline[12]:

✓ Associated discipline[12]:

[12] Insert number from list below (Frascati Manual)

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*	✓ ○	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

- ○ No
- ✓ Yes- in determining what research should be performed
- ✓ Yes - in implementing the research
- ✓ Yes, in communicating /disseminating / using the results of the project

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	○ ✓	Yes No

12 Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- ✓ Yes- in framing the research agenda
- ✓ Yes - in implementing the research agenda
- ✓ Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ✓ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- ○ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

13b If Yes, in which fields?

Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs		Energy Enlargement Enterprise **Environment** External Relations External Trade **Fisheries and Maritime Affairs** Food Safety Foreign and Security Policy Fraud Humanitarian aid		Human rights **Information Society** Institutional affairs Internal Market Justice, freedom and security Public Health **Regional Policy** **Research and Innovation** Space Taxation Transport	

13c If Yes, at which level?

- ✓ Local / regional levels
- ✓ National level
- ✓ European level
- ✓ International level

H Use and dissemination

14 How many Articles were published/accepted for publication in peer-reviewed journals?		0
To how many of these is open access[13] provided?		-
How many of these are published in open access journals?		-
How many of these are published in open repositories?		-
To how many of these is open access not provided?		-
Please check all applicable reasons for not providing open access:		-
❑ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other: ……		
15 How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*		**0**
16 Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	**0**
	Registered design	**0**
	Other	**0**
17 How many spin-off companies were created / are planned as a direct result of the project?		**0**
Indicate the approximate number of additional jobs in these companies:		

18 Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

❑	Increase in employment, or	❑	In small & medium-sized enterprises
❑	Safeguard employment, or	❑	In large companies
❑	Decrease in employment,	❑	None of the above / not relevant to the project
☒	Difficult to estimate / not possible to quantify	❑	

19 For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:*
1 FTE was made possible through the project	
Difficult to estimate / not possible to quantify	❑

[13] Open Access is defined as free of charge access for anyone via the internet.

I Media and Communication to the general public

20 As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes ✓ No

21 As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes ✓ No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

☒	Press Release	❑	Coverage in specialist press
❑	Media briefing	❑	Coverage in general (non-specialist) press
❑	TV coverage / report	❑	Coverage in national press
❑	Radio coverage / report	❑	Coverage in international press
☒	Brochures /posters / flyers	☒	Website for the general public / internet
☒	DVD /Film /Multimedia	☒	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

❑	Language of the coordinator	✓	English
❑	Other language(s)		

***Question F-10*:** Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, ceanography, vulcanology, palaeoecology, other allied sciences)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY

2.1. Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)

2.2. Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]

2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialized technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)

3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)

3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)

4.2 Veterinary medicine

5. SOCIAL SCIENCES

5.1 Psychology

5.2 Economics

5.3 Educational sciences (education and training and other allied subjects)

5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)

6.2 Languages and literature (ancient and modern)

6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]