International cooperation for the utilization of earth observational data in an integrated manner

— Development of *de jure* standardization of the common infrastructure for the global earth observation system of systems —

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While each country separately obtains, processes, and utilizes earth observation data, there is a pressing need for a common infrastructure to facilitate integrated use of these resources. At an intergovernmental meeting, an international agreement was reached to construct a common infrastructure for the global earth observation system. Several organizations have submitted components for this infrastructure. These submissions were fairly evaluated, and the most suitable components were recommended for inclusion into the infrastructure system, at the intergovernmental meeting. Recommendation of specific infrastructure components establishes *de jure* standards for the global earth observation system. Since Japan has not offered its own components, it has been able to take a neutral stance on formulating *de jure* standards. Consequently, the standards widely used as *de facto* in Japan have been selected as *de jure* standards. This experience could be a model case for the development of a strategy for international standardization activity.

Keywords : International standard, *de jure*, *de facto*, global earth observation system of systems, intergovernmental group on earth observations, GEOSS common infrastructure

1 Introduction

Several lessons were learned on the position of science and technology in the field of earth observation in the Great East Japan Earthquake. First is the importance of the worldwide collaboration for earth observation. Japan's Advanced Land-Observing Satellite (ALOS) stopped operation on April 22, 2011, only about a month after the earthquake. Japan lost one of its "eyes" from outer space. However, other countries conducted intensive observation of the earthquake area using their satellites, supplemented the missing data, and effective data sharing was done.[1] Through such international cooperation and data sharing for earth observation, the reliability of the scientific data increased. On the other hand, there are criticisms that the scientific findings from such earth observations were not utilized fully in the earthquake countermeasure policy.[2] The importance of a mechanism to reflect the findings of the earth observation data in policy-making became apparent.

2 Current situation of earth observation data use

In earth observation, various measurement devices including the observation network on land and sea, aircraft, and weather satellites are used. Based on the data obtained from the observations, prediction model, climate change scenario, and various information services are provided. The objective of earth observation is to gather regional data to address biodiversity, energy, and health issues, as well as for global problem solving. Ultimately, the observations may be reflected in the decision-making process for environment and energy policies.

In the conventional earth observation, collaborations were conducted using land data and satellites for each subject observed such as land, ocean, and atmosphere. For example, the World Meteorological Organization built a global observation system and is trying to link the geostationary meteorological satellites, polar orbit satellites, and ground meteorological observation network.[3] Also, the UN Food and Agriculture Organization constructed the global land observation system.[4] Moreover, collaborations and adjustments were done among the global observation system and aerospace organizations that develop and operate the observation satellites under the Integrated Global Observing Strategy Partnership (IGOS-P).[5] Collaborations progressed among individual fields or satellites observation systems.

However, at the scene of decision-making, there are many instances where various observation data must be combined. For example, when planning the construction of an offshore wind power plant, the oceanographic data is necessary as well as the atmospheric data. In conventional decision-making, such observations were often duplicated for different purposes.

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To accomplish international collaboration for integrated use of earth observation data that may contribute to policy and decision-making, it is necessary to establish an infrastructure that enables the common use of observation data and services that are conducted by various organizations for individual purposes. This is called the Global Earth Observation System of Systems (GEOSS) Common Infrastructure (GCI). Figure 1 shows the conceptual diagram for GCI.

The following three basic elemental technologies are needed for the common infrastructure (CI) system for earth observation data. One is the global earth observation web portal (GWP or WP). WP provides the web interface function that allows the user to use the data and services provided by various organizations. Second is the GEOSS clearing house (CL). CL provides the function that allows global search and utilization of the data and services that are dispersion-managed on the Internet. Third is the component service registry (CSR). CSR is the database to register the earth observation data and services. The system of earth observation information is configured by combining these three components. Figure 2 shows the overall configuration of the use system of earth observation data.

As of 2009, the WP and CL that are CI components were separately operated by three organizations including private companies respectively, and the registry was operated by the George Mason University under subcontract of the US Geological Survey (USGS). The users of the world combined the components provided by these organizations and accessed the earth observation data and services.

The multiplicity of the WP and CL is desirable from the perspective of system redundancy. However, for WP, there were problems of poor usability such as differences in maneuver and compatible operating systems or browsers, demand for unique plug-ins when using a certain browser, or operational instability unless extremely high spec PC is used. For CL, there were problems of comprehensibility where the existing data may not be reflected in the search result due to difference in search method, or that the data not in the registry may be reflected in the search result. To solve these problems, it was necessary to establish a scheme of international collaboration where the earth observation data would be shared and reflected in various policies. Such a scheme would be composed of both the provider of systems and the decision makers of various fields who are the users.

3 Scenario for the integrated use of earth observation data

To realize the integrated use of earth observation data, the most important issue was to create a common infrastructure (CI) that allowed the integrated use of various data and services provided by various earth observation organizations around the world.

There are currently enormous quantities and volumes of earth observation data and model results. For example, AIST has an archive of data gathered by an earth observation device called the advanced spaceborne thermal emission and reflection radiometer (ASTER), and the number and volume

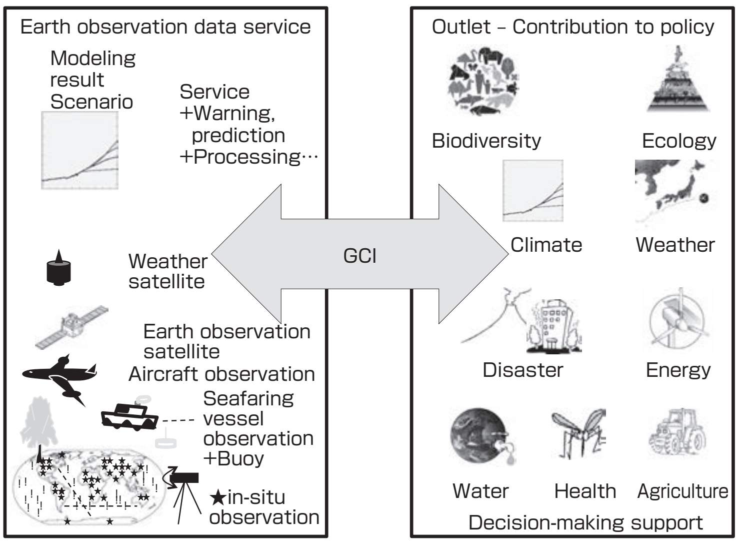

Fig. 1 Role of GCI in the integrated use of information and services
A system that supports the utilization of scientific findings in the policy-making of various fields, through the international collaboration of earth observation information and services

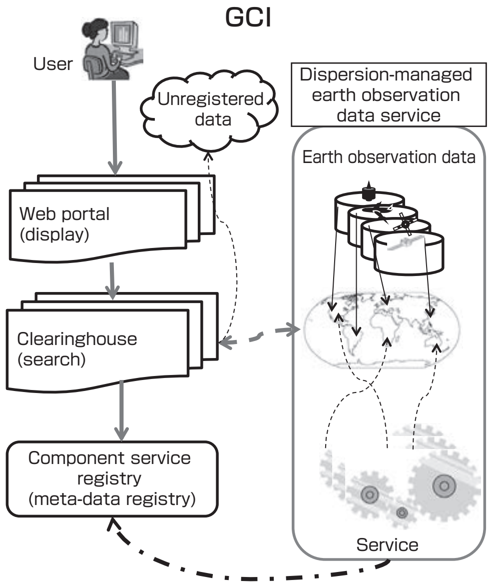

Fig. 2 Configuration of standardized CI and access to data service
The main components of the CI are web portal, clearinghouse, and component service registry. The actual component (data) and services are dispersion-managed and operated by individual institutes.

Table 1. History of international discussions on the collaboration for earth observation

Year held	Meeting (place)	Accomplishments
2002	World Summit on Sustainable Development RIO+10 (Johannesburg)	Emphasized the importance for the framework of international cooperation for earth observation in its action plan.
2003	G8 Evian Summit (Evian)	Former PM Koizumi proposed the "Global Earth Observation System."
2003	First Earth Observation Summit (Washington)	Adopted the declaration that emphasized the importance of stance commitment at political level, to initiate the action to develop the earth observation system composed of multiple, sustainable systems. Temporary earth observation work group was established, with EU, Japan, South Africa, and USA as joint chairman.
2004	Second Earth Observation Summit (Tokyo)	Adopted the framework document that defined the range and intent of the GEOSS.
2005	Third Earth Observation Summit (Brussels)	10-Year Implementation Plan for GEOSS was deployed. Intergovernmental Group on Earth Observations (GEO) and its secretariat were established.

of data from 2000 to February 2012 are about 2.5 million scenes and 150 terabyte, respectively. It is estimated that the number of earth observation satellites in the world may reach 200 in 2012.[6] Multiple earth observation devices are installed on a satellite, and for example, there are five types of earth observation devices onboard the TERRA satellite on which ASTER is installed. Therefore, it is not realistic to aggregate and manage such voluminous earth observation data in one place. Such data and services are most reasonably dispersion-managed by the organization that collected and processed them. Instead, the information on the data and services offered by the organizations can be registered in one place, and the user can access the data and services of the individual organizations based on the registered information. By building a common infrastructure that allows access to the data and services that are already dispersion-managed by the individual organizations, it is not necessary to request updating the existing data and services to new specifications. Also, for the managerial and policy reasons, including the consideration for different policies for copyright and data management of the earth observation data, dispersion management is desirable.

The scenario that aims for the integrated use of earth observation data is explained using Fig. 3. As presented in chapter 2, the access to earth observation data and services that are dispersion-managed by individual organizations is enabled through the GCI. GCI is composed of three components. As requirements to build the CI, the operational robustness must be guaranteed for each component. In a case where one of the components fall into operational difficulty due to financial trouble, the GCI may cease to function. The requirements for the components include the technological requirements such as ease of access and comprehensibility of data, as well as being a system that is highly friendly to users who may have various purposes.

4 International collaboration activities

4.1 History of international collaboration

The importance of collaborations in earth observation and the discussions on reflecting the scientific findings in policies has been raised since the beginning of 2000s. Table 1 is the brief history of the international agreement on common earth observation network building. Mr. Koizumi (Prime Minister of Japan at that time) declared the need for the Global Earth Observation System of Systems (GEOSS) at the 2003 Evian Summit,[7] and this kicked off the international collaboration movement for earth observation.

4.2 Global Earth Observation System of Systems (GEOSS)

The GEOSS proposed by former Prime Minister Koizumi aimed to build the "system of systems" or the global earth observation collaboration where all satellite, aircraft, and in-situ observations of earth, which were individually gathered

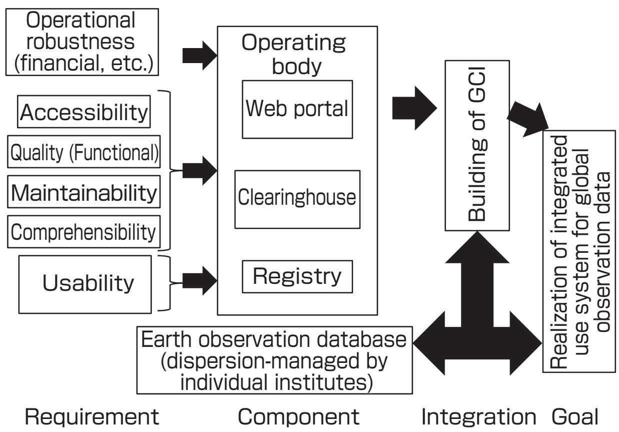

Fig. 3 Scenario for integrated use of the earth observation data

The components for building the GEOSS common infrastructure that aims to be the integrated system for using earth observation data and the requirements were summarized as a scenario.

by countries, and all observation systems, earth datasets, prediction models, and services for earth are combined. The *GEOSS 10-year Implementation Plan*[8] was drafted in Brussels in 2005, and its ultimate goal was to reflect the scientific findings obtained through earth observation collaboration in policies. Specifically, nine societal benefit areas including disaster, health, energy, climate, weather, water, ecology, biodiversity, and agriculture were selected, and immediate issues that must be solved within 10 years were extracted.

4.3 Intergovernmental Group on Earth Observations (GEO)

To realize the GEOSS, the Intergovernmental Group on Earth Observations (GEO) was established under the international agreement in 2005. As its management body, the GEO Secretariat was established in Geneva, Switzerland. The mission of the Secretariat was to draft the *GEO Work Plan*,[9] manage its progress, adjust the international investments in earth observation projects, and others.

Unlike the permanent United Nation organizations, GEO was set as a fixed-term organization to solve the issues by 2015. While the UN has certain binding force in its resolution, the resolution of GEO is not binding but is taken as recommendations. The GEO is operated by volunteers from the governments of 87 countries and 61 international organizations and institutions including the UN organizations, as of October 2011. The member countries of the GEO at present are shown in Fig. 4.

The member countries and participating organizations of GEO are represented by principals. For the government of Japan, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) is in charge, and the deputy director-general of the Research Promotion Bureau acts as the principal for the Japanese government in 2012. Although GEO is a voluntary organization with no binding force, the member countries and organizations participate actively and contribute financial and human resources. One reason is because the GEO is positioned as an international function for the management and coordination of earth observation activities. The progresses on the issues are reported at the Plenary meeting of GEO held once a year, and at the ministerial level meeting held every three years. The resolutions at such meetings are reflected directly in the earth observation policies of the countries. In Japan, the Minister of MEXT attends the ministerial-level meeting. The other reason for the active participation by many countries, is while the methods used in each member country and organization are used as the *de facto* standard in various fields, the GEO may be the place to set the unified *de jure* standard. Therefore, the private companies as well as the government and public institutes may provide technological support to the GEO activities. However, private companies do not have membership. The public institutions for earth observation of various countries contribute as part of the member countries' participation to GEO. The organization of GEO is shown in Fig. 5.

The author participated in the activities of the GEO Secretariat as a scientific and technical officer from AIST for two years, from April 2009 to March 2011, through the Japanese government as part of human resource contribution to GEO. The Secretariat is located in the building of the World Meteorological Organization and the employees are equivalent to that of UN officers. During the author's appointment period, personnel were dispatched from the USGS and National Oceanic and Atmospheric Administration of the USA, European Space

Fig. 4 Distribution of member countries of GEO (as of October 2011)

The darkened countries are current members and grey ones are non-members. Of the 193 countries that are members of UN (as of 2011), 87 countries, or about half, are participating. While there is participation by Switzerland that is not a UN member, the number of participating African countries is particularly low.

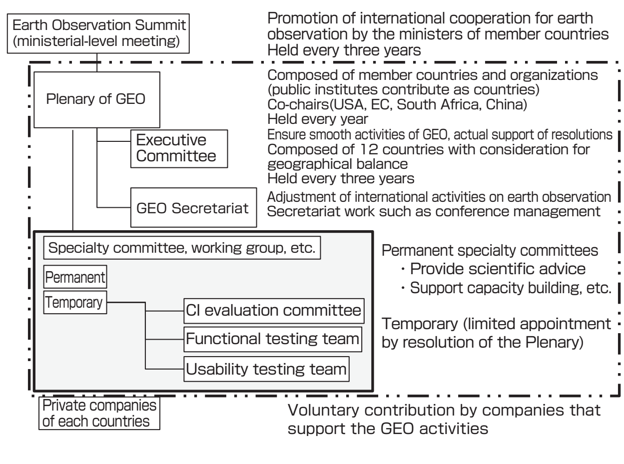

Fig. 5 Organization of GEO

The GEO promotes the international cooperation of earth observation in the annual Plenary in which all member countries and participating organizations, and in the ministerial-level meeting held once in three years. To ensure smooth operation, the Secretariat is established under the Plenary, to act as the coordinator. Permanent specialty committees that provide scientific advice and temporary committees that conduct evaluation and selection, as described in this paper, may be also set under the Plenary.

Association, Instituto Nacional de Pesquisas Espaciais of Brazil, Government of South Africa, China Meteorological Administration, Korea Meteorological Administration, and Japan Aerospace Exploration Agency. The Secretariat was composed of the personnel dispatched by the governments, as well as a few directly employed personnel including the chief secretary.

4.4 Common infrastructure (CI)

To realize the "system of systems" for global earth observation, the most important issue for the GEO was to construct the common infrastructure (CI) that enables the use of various observation data and services that are provided by the earth observation institutes around the world. In building the CI, the assumption was the dispersion management of earth observation data and services by the individual organizations as it has been done in the past. The information pertaining to the data and services provided by the organizations are registered to the CI, and one could access the data and services of the various organizations through the CI. The basic principle of GEOSS that does not require the integration of observation systems or information systems operated by individual organizations was enforced.[10]

The CI was configured by three basic components along the scenario explained in chapter 3. The three components are web portal, clearinghouse, and service registry. By combining the components, the whole CI was realized as shown in Fig. 3.

4.5 Problems in building the CI

Ideally, the user should be able to use the same information and service no matter which combinations of WP and CL are used. However, in reality, there were many cases where the search result and the usable services differed according to the combination of the existing WP and CL, and there were some confusion among the users.

In response to such a situation, in the Plenary of GEO held in 2009, it was resolved that the cause of confusion must be clarified, and the organizations described in chapter 2 providing the existing WP and CL offered would be evaluated, and to recommend the WP and CL for the common infrastructure.[11] The period allotted for the selection task was short, and it was to be done by the ministerial-level meeting of GEO in 2010.

In this paper, the cause of user confusion, the evaluation method employed to build the CI, and the results will be described. Also, the relationship between the building of the CI and *de jure* standard established for the earth observation field will be explained.

By building the CI, it is expected that the integrated management of earth observation data will become easy, the comprehensive search will become possible, and the user confusion will be resolved. Moreover, the experience of establishing the *de jure* standard will provide a model case for Japan in establishing the international standard in the future.

5 Requirements and synthesis method

5.1 Requirements for evaluation and selection of the components of CI

In evaluating and selecting the components of CI, the following requirements were considered. First was to guarantee the fairness of the evaluation result. To conduct the evaluation and selection of the organizations that developed and operated the WP and CL on a voluntary basis, it was necessary to obtain an international agreement for fair and equal evaluations and results. Second was time limit. The evaluation report had to be submitted to the member countries and organizations before the GEO ministerial-level meeting. Therefore, the cause of confusion and the evaluation of components had to be investigated in a period less than one year. Third was the establishment of the standard used for evaluations. In the traditional system evaluation, technological evaluation standard such as response time required for displaying the search result would be set. The technological evaluation standards were set for this evaluation also.

On the other hand, the users of the nine societal benefit areas would be actually using the CI. The purpose is diverse, and the combination of technological evaluation does not necessarily enhance the usability for the users. It was expected that the usability of CI would differ between the users of countries with well-established Internet and the users of developing countries where the speed of the Internet connection was limited. In ordinary Internet search, only the search result of the text would be obtained, but in the CI, satellite images and maps would be handled. Particularly in a case where some special function was added to the image display, the smoothness until the search result was displayed would differ by WPs. Also, in WPs that required installation of special plug-ins, different usability and smoothness were expected depending on the performance spec of the PC used. Therefore, it was necessary to set up the evaluation standard for the usability of the users of nine societal benefit areas, including the users of developing countries with limited work environment such as Internet availability. Moreover, the CI has to run stably during the active period of the GEO, or at least up to 2015. Since the CI will not function even if one function such as the WP or CL becomes short, it was necessary to establish an evaluation standard that guaranteed a stable long-term operation.

5.2 Synthetic method to build the CI

To build the CI, a CI evaluation committee was set, officiated by the GEO Secretariat. To guarantee the fairness of the evaluation result, the participation to the evaluation committee by specialists from all member countries and organizations of GEO was requested. In obtaining the international agreement, importance was placed on geographical balance. The provision of the components was solicited from the institutes and organizations of Europe and the USA. The request for participation to the evaluation committee from regions with high interest in the diffusion and standardization of their original technology was expected from the inception. Meanwhile, there was no organization that offered the components from Asia, Oceania, or Africa. Moreover, in the developing countries, it was expected that troubles will occur in using a system that was decided mainly by Europe and US, since there might be speed limit of Internet connection or lack of spec of the PC used. To ensure wide diffusion of the recommended system to all member countries, active participation was solicited from the developing countries in particular, to guarantee international agreement. However, the evaluation committee members were limited to the members officially recommended by the principals. This was done to ensure the results would reflect the representatives of the member countries and organizations of the GEO. The committee members were composed of the members recommended by the following countries and organizations. The number in the parenthesis shows the number of personnel, and there is no parenthesis when there was only one person.

Member countries: Australia, Austria, Brazil, China, Finland, Germany, Italy (2), Japan (3), Madagascar (3), Pakistan (2), USA (5), and EU (2).

Member organizations: Committee of Earth Observation Satellites, European Space Agency, The Federation of Earth Science Information Partners, European Organization for the Exploitation of Meteorological Satellites, The Institute of Electrical and Electronics Engineers, Inc., US Environment Protection Agency, EU Joint Research Center, Open GIS Consortium, Inc., and World Meteorological Organization.

In addition to the 30 committee members, two members of the GEO Secretariat, including the author, joined the evaluation committee. The functinality and usability testing teams that included the committee members were established under the GEO Plenary. These two teams conducted actual investigation based on the evaluation items for technology and usability created by the evaluation committee. The functionality testing team was composed of the staff from Brazil and the Joint Research Center, while the usability investigation team was composed mainly of people from the EPA. For example, the evaluation committee set the search response time as a technological evaluation item, and the functionality testing team considered the conditions and methods for measuring the response time and conducted the actual evaluation. The fairness of evaluation result was enhanced by reporting the results to the evaluation committee.

When the evaluation committee members were solicited, there were applications from organizations with conflict of interests, namely the European Space Agency that provided the WP that is the component of the CI and the USGS that provided the CL. Since the GEO assumed voluntary participation, they could not be completely eliminated, but in a case where the organization itself would be the subject of investigation, the committee member belonging to that organization was eliminated from the discussions. On the other hand, Japan did not provide any components for the CI, and was expected to have increased say due to its fair standpoint. Therefore, additional three specialists were dispatched from AIST, and discussions could be held with the cooperation of the AIST specialists, with the author acting as a coordinator.

About two months were required from the GEO Plenary in late November 2009 to the official selection of the committee members. When the committee members were determined and preliminary exchanges were done by telephone conference and e-mails, the first meeting of the evaluation committee was held in February 2010 at the GEO Secretariat. At this meeting the “Terms of Reference” of the committee was drafted, and the three items, functionality, usability, and long-term operability were set as the target of evaluation. Also, as shown in Fig. 6, the overall flow was set toward the creation of a report of the evaluation result.

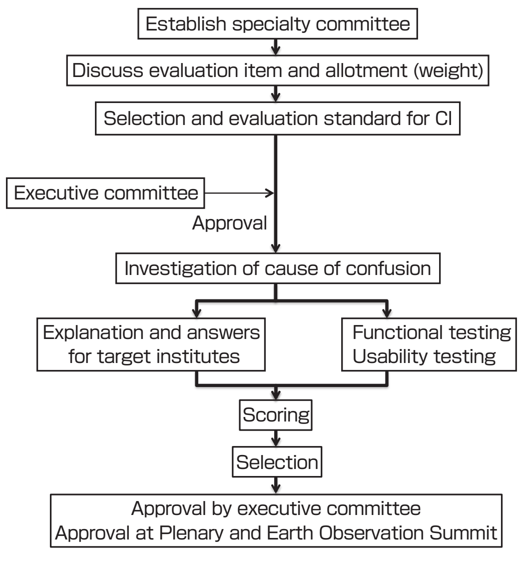

Fig. 6 Flow to the CI selection
The flow of evaluation and approval conducted by the evaluation committee is shown.

Table 2. Selection and evaluation standards for CI

Evaluation item		Weight (%)	Outline
Functionality		25	Evaluation result of the technology investigation item list
Usability		25	Evaluation result for usability
Long-term operation	Financial aspect (supporting organization)	10	Promise for financial support as organizations for 2010-2015
	Financial aspect (country or member organization)	20	Endorsement from member countries and organizations for financial support
	Functional aspect	10	Promise for the response to the mandatory requirement items
	Release of rights to the system	10	Release of rights in case of transfer of system to a third-party organization

Prior to the evaluation, the clarification of the cause of confusion was done, the discussion on the investigation standard was continued by weekly telephone conference, and the evaluation items for functionality and usability were listed. The evaluation committee conducted the final scoring based on the results of the investigation items and the general evaluation for long-term operability. The details of the scores of each evaluation item were submitted in the form of advice from the evaluation committee to the GEO, and the work progressed after seeking approvals.

To conduct evaluation of the CI, it is necessary to evaluate the action when the elemental technologies are combined, as well as the evaluation of the individual elemental functionality. Therefore, since there were three organizations respectively that were offering the WP and CL, it was necessary to conduct the tests for nine combinations. However, in conducting the investigation of the problem where the search results were different according to the combination of the WP and CL, it was found that the CI would function only under a certain combination. Therefore, due to time constraints, a two-step process was taken where the CL was evaluated and selected first, and then the WP was evaluated and selected. For the evaluation tests, particularly for the usability, preparations were done quickly to submit the report to the GEO Work Plan Symposium held in May 2010, as there would be attendance of many users participating in the GEO. By conducting the usability test during the symposium, the differences in usability could be clarified, such as use for different purposes under the same conditions of networks and browsers. Also, participation of the users of developing countries who could not regularly attend the meetings was encouraged. Moreover, since the meeting was held in a developing country with limited Internet connection speed, the participants could evaluate the usability of the CI under such conditions. For the usability evaluation, the online evaluation system on the Internet was made available to solicit wide range of users to evaluate from all social beneficiary fields.

For the evaluation standard, it was determined that general evaluation would be done from the three perspectives of functionality, usability, and long-term operability, but it was also necessary to determine the weight of the scores. Table 2 shows the evaluation items determined by the committee and the score weighting. Upon discussion in the committee, functionality and usability were given 25 % each. The remaining 50 % were items for long-term operability.

The functional testing was composed of the mandatory items and optional items. Over 100 evaluation items were listed. For usability evaluation, separate evaluation items were listed to evaluate the usability for all nine societal benefit areas. Four items were set to guarantee the stable, long-term operation. The first item was the promise for the financial support from 2010 to 2015 by the organization that offered the provision of the CI components, and 10 % was allotted. The second item was the endorsement from the GEO member countries or organizations to the organization that offered provision of the CI components, and this was given 20 %. In the case where the components were provided by private companies, it was required that a GEO member country or organization would guarantee the operation (endorsement). The third item was promise for response to the mandatory item by the organization offering the GCI component, and 10 % was allotted. The WP and CL selected by the general evaluation did not necessarily satisfy the mandatory items. Therefore, demand was made to each organization to promise quick compliance to the mandatory items of the WP and CL. The fourth item was the release of license of the system that the organizations developed as the WP and CL, and 10 % was allotted. In a case where the organization providing the WP or CL could no longer manage them for some reason, this ensured the smooth transfer of the system to a third party.

For the item pertaining to the release of license, several requests were made to disclose the whole system as an open source. However, open sourcing was not sought, and the agreement was written to guarantee the situation that allowed transfer in case operation became impossible. This was done to take into account the participation of private companies. On the other hand, the request for the endorsement of financial support from the member countries or participating organizations of GEO in the second item was disadvantageous to the private companies that did not necessarily belong to the member countries or organizations. Ultimately, it was considered important to guarantee the stable operation of the core system of the GEOSS by obtaining the promise for financial support from the member countries or organizations, even if the organization or private company that provided the component lost the financial guarantee. Therefore, this item was given the weight of 20 %.

The result of scoring was not disclosed to the public. However, the scoring results were disclosed by request to the organizations that were screened, including the organizations that were not selected.

6 Evaluation result

When the cause of user confusion was clarified, it was found that the CI functioned only with the combination of certain WP and CL. This was identified as one of the causes of different search results. As individual organizations developed and advanced original systems for search and display, the system linkage with other organizations was not realized. Also, it was found that for the registry that was provided officially by only one organization, some organizations that provided the CL made the search of their own data possible. These two were the reasons that the search result and the usable service differed according to the combination of the WP and CL. It can be said that the universality was lost when the originality and convenience of the function were pursued by adding functions and original data particular to the organization.

As a result of the general evaluation of functionality, usability, and long-term operability, the WP offered by the European Space Agency and the Food and Agriculture Organization, and the CL offered by the USGS were selected. The combination including the registry offered by the USGS was recommended as the CI of the GEO. The *GCI Coordination Team Report*[12] was accepted at the Earth Observation Summit held in Beijing in 2010. As a result, the European and American organizations that lead the global earth observation were selected.

The evaluation and selection of the elemental functions of the CI resulted in the specification for accessing the earth observation information and services to be selected as *de jure* standards, rather than being left as *de facto* standards. Considering that the principle of GEOSS is not to seek integration of the observation and information systems that are managed by different organizations, it is desirable that the *de facto* standard is implemented as the users actually use the system, and the technology with low universality is eliminated. However, in establishing the standard that may develop into conflict of interest among the countries and organizations, it is believed that the approach of selecting the *de jure* standard was effective.

For the WP, the display method of the geospatial data including the earth observation data was standardized, while for the CL, the definition of the metadata of earth observation data, the method for mutual use of data in various formats, and the data search method were standardized. In the process of the evaluation and selection of the CL, these *de jure* standards were clearly established.

7 Discussion

Looking back at the process by which the *de jure* standard for the earth observation field was established, the points to note in creating the international standard are summarized.

First, care was taken to form a community to promote international agreement in discussing the *de jure* standard. To ensure the wide and international use of the technology, the practitioners and users, including those of the developing countries, were highly influential, as well as the technology specialists representing the countries.

Second, consideration was given to temporal speed. The fact that there was a necessity to set the *de jure* standard indicated that there were diverse original technologies existing in the world, and that might have caused the confusion among the users. To clear up the confusion quickly, a clear timeline was set, the optimal *de jure* standard was decided in the limited time, and this turned out beneficial to the users.

Third, care was taken to ensure fairness in the evaluation process. In this case, the guarantee of fairness of the evaluation result was maintained carefully by establishing a separate investigating team from the evaluation committee, and by conducting the actual evaluation and screening only after the approval of the evaluation index by the GEO executive country committee. The result was widely accepted because of fair processes such as the independency of evaluation and the transparency of individual screening, in the process of selecting the international standard. In fact, the private companies that were not selected this time did not express unfairness in the selection and continues to support the activities of the GEO to present. This is because fairness was maintained in the evaluation process. The evaluation and selection processes could be positioned as the guideline when evaluating the voluntary participation of the private companies. For the private companies, the evaluation result was obtained based on the evaluation by users in various fields around the world, and it provided useful information for reviewing the usability and issues in their products.

From the standpoint of conducting an international technology development, the weight of scores of the evaluation item determined in the process of evaluation and building of the CI presented one guideline in considering the international standard. In the system such as CI that is used widely and internationally, the emphasis is placed on universality rather than technological excellence, and the format is highly likely to become the international standard once it is employed.

The evaluation and building of the CI can also be positioned as a successful case of international agreement for *de jure* building for earth observation recommended by Europe and USA. For example, in the Seventh Framework Programme (FP7), which is the science and technology R&D system of the EU, it is determined politically that all research projects on earth observation must be adopted under the condition that they may contribute to the GEO. The FP7 not only supports the R&D for CI but is active in supporting the R&D for data and services, and as a result, succeeds in producing the *de jure* standard from the technology developed in the FP7. In Japan, it is necessary to build a system for international standardization in which the public R&D support system is involved.

On the other hand, for the specialists who participated from Europe and USA, there were cases where the system offered by the organization to which they belonged would be the direct subject of investigation. Therefore, the voice of Japan which was capable of taking the third-party stance became important. In fact, several technologies were already widely used in Japan and have become the *de facto* standard. In the international standard selection, while the fair and equal evaluation according to the international movement is necessary, the fact that the technology that was widely used in Japan was employed as *de jure* standard could be a guideline for the Japanese activities in the flow of the international standardization led by Europe and the USA. However, it is difficult to follow all of the points among the voluminous conference material while in Japan. Although regular meetings were done over the telephone, they were held late in the evening in Japan, due to regional time differences. International negotiation is not settled in one meeting, and continuation of dialogue is important. This time, it was possible to incorporate the elemental technologies that had become the *de facto* standard in Japan as the *de jure* standard in the international standardization discussions by dispatching personnel to the office that integrated and arranged the entire project, and maintaining a system where appropriate and fair comments could be issued in particularly important meetings. If Japan were to join in the discussion for international standardization, it is necessary to set up such a system.

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List of acronyms

Acronym	Official title
ALOS	Advanced Land Observing Satellite
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CL	GEOSS Clearinghouse
CSR	Component and Service Registry
ESA	European Space Agency
GCI	GEOSS Common Infrastructure
GEO	(Intergovernmental) Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GWP	GEO Web Portal
USGS	US Geological Survey

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Author

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Discussions with Reviewers

1 Overall

Comment (Akira Ono, AIST)

This paper is about building an information system where users can comprehensively make use of various earth observation data gathered and processed individually by different countries and organizations. I think it is an excellent *Product Realization Research*. As the author expresses the completed product "system of systems" the process of which the product is made by integrating various elements, it is suitable for *Synthesiology*.

2 Importance of the integration of earth observation data

Comment (Koh Naito, Center for Service Research, AIST)

Many readers may not sufficiently understand the importance of the integration of earth observation data. Therefore, please explain this point in the "Introduction" at the beginning of the paper. In the Great East Japan Earthquake, many scientific data were not used in policy-making.

Answer (Koki Iwao)

I added the chapter of "Introduction" and mentioned that the scientific data were not fully used in policy-making in relation to the Great East Japan Earthquake.

3 Addition of technological viewpoint

Comment (Koh Naito)

I understand that the efforts explained in "Synthetic method" is the most important point of this paper. While the text contains the explanation of that method, please describe what kind of efforts were made, what were the points including the technological viewpoints, and finally how the international agreement on selection result was reached.

Answer (Koki Iwao)

As you mentioned, the "synthetic method" is the most important point. In working on this project, I summarized the technological requirements, described the work done for the corresponding requirements, and re-synthesized the items that led to the agreement of selection results. In revising the "synthetic method," I also revised the results and discussions so the correspondence will become clear.

4 Description of the scenario

Comment (Akira Ono)

In the text, it is written that the author joined the GEO Secretariat, was given a framework, created scenarios, and then executed them. In *Synthesiology*, the topic is not limited to what the author handled directly. The author can describe a larger scenario from the author's viewpoint, including the accomplishments of the GEO Secretariat and GEO itself. I think the readers of the journal will be able to grasp the whole picture, and that will be beneficial for them.

Answer (Koki Iwao)

I added Fig. 3 to explain the whole scenario, and provided an explanation in the paper.

5 Comparison with the database integration of other fields

Question (Akira Ono)

I understand the main point of this paper is the creation of a system where multiple databases built by various entities with different standards can be used by the users as if using a single database.

The demand for integrated use of multiple databases is also frequently heard in areas other than earth observation. Comparing with other fields, can the author offer some opinion about the issues or solutions that characterize the earth observation field?

Answer (Koki Iwao)

As you indicated, the main point of the paper is to build a common system that links the database managed by multiple institutions, and to realize a system that could be used comprehensively.

Comparing to other fields, taking the example of multiple database integration, I mention the case described in AIST Press Release "Opening of integbio.jp, a joint portal site of bioscience database of four ministries (in Japanese)" (released December 12, 2010: http://www.aist.go.jp/aist_j/press_release/pr2011/pr20111212/pr20111212.html).

In this article, it is explained that the integration of the bioscience database is accomplished in four steps: catalog, cross search, archive, and reconstruction.

In the earth observation field, the aims were catalog and cross search. I think the catalog (list of links by database) corresponds to the registry in our project. The cross search function (keyword search of multiple databases) corresponds to the clearinghouse. Even in different fields, there are similarities in the database integration steps. On the other hand, there is a slight difference in archive (integration of database format and consideration of rights), the third step in database integration of the bioscience field. In the earth observation field, rather than integrating the database format, the differences are absorbed in the CL. In this case, the characteristic of earth observation data is that almost all data contain time and location information, and that allows narrowing down the search condition.

The consideration of the rights of earth observation data is positioned as an important issue. A specialty committee is established under the Plenary to draft the principle of data sharing (promotion of earth observation data sharing). However, currently, there is the thinking that all data should be actively disclosed (free and open), and also the thinking that rights should be respected. The thinking of respecting rights is dominating, and the rights related matter is not sufficiently organized yet. The USA is promoting free and open data. It is actively releasing data, starting with the completely free release of the Landsat earth observation satellite data (LANDSAT DATA DISTRIBUTION POLICY: http://landsat.usgs.gov/documents/Landsat_Data_Policy.pdf). The GEO named the free and openly available data as GEOSS Data-CORE and is asking the member countries and organizations to supply data. Therefore, the rights matter (active free release) is expected to progress further. However, the types and rights of data are diverse, from the local observation data collected by individual researchers to satellite images on a national scale, and more time is required to organize this matter.

In the reconstruction (advanced search) activities in the fourth step, while this was not explained in this paper, we are organizing the ontology and the terminology used in the nine societal benefit areas. I expect there may be effects similar to the reconstruction in the bioscience database integration. Also, in earth observation, we aim for linkage of services, not just data. For example, in the activity called Model Web, multiple models are bound together to be used for some new purpose. (http://www.uncertweb.org/)