Acknowledgments

The AIP-2 Summary ER provides just an overview of the efforts of scores of GEOSS Members and Participating Organizations. Hundreds of individuals from those organizations have contributed to the development of the GÉOSS Architecture Implementation Pilot. Our collective contributions are making it possible to create GEOSS.

Revision History

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AIP-2 Summary Engineering Report

1. ER introduction

This Engineering Report (ER) provides an overall summary of Architecture Implementation Pilot, Phase 2 (AIP-2) including description of the development process, an overview of the architecture, summary of the achievements and a discussion of lessons learned. This AIP-2 Summary ER describes the process of implementing GEOSS Societal Benefit Areas (SBA) scenarios through reusable Service oriented Architecture (SoA) Use Cases. A definition for “persistent exemplar” services was developed and applied during AIP-2. Elements of other AIP-2 ERs are included along with short summaries of the all of the ERs.

2. Summary of AIP-2

GEO Members and Participating Organizations conducted AIP-2 from June 2008 to August 2009. AIP is a task of the GEOSS Architecture and Data Committee. During its duration, two GEO Tasks defined AIP-2:

- AIP-2 began as GEO Task AR-07-02 to lead the incorporation of contributed components consistent with the GEOSS Architecture using a GEO Web Portal and a Clearinghouse search facility to access services through GEOSS Interoperability Arrangements in support of the GEOSS Societal Benefit Areas.
- AIP-2 concluded as GEOS Task AR-09-01b to develop and pilot new process and infrastructure components for the GCI and the broader GEOSS architecture through continuation of existing efforts and new activities solicited through AIP Calls for Participation and other means; including continuation of the Interoperability Process Pilot Project (IP3)

AIP supports the elaboration of the GEOSS Architecture (See Figure 1). The requirements for AIP are based on meeting user needs and community scenario requirements as recommended by tasks of GEO and the User Interface Committee (UIC). One of the main outcomes of the pilot is to augment the operational capability of the GEOSS Common Infrastructure, which in turn supports the operational needs of the users. The Results of the AIP are transitioned to GEO Task AR-09-01a and the GEOSS Common Infrastructure.

![Figure 1 – Elaboration of GEOSS Architecture](image)
From inception, the main themes of AIP-2 were:

- Implement SBA scenarios identified through UIC/ADC collaboration
- Augment the GEOSS Common Infrastructure (GCI) Initial Operating Capability
- Develop and promote the concept of "persistent exemplar" components to improve availability and performance of GEOSS services
- Elaborate the GEOSS Architecture
  - Scenarios and Use Cases: a reusable process for SBA groups to use the GEOSS Architecture.
  - Service and Component types: refinement and extension of the types in GEOSS Architecture
  - Interoperability Arrangements: refinement and extension of the registered Interoperability Arrangements.

The main achievements of AIP-2 include:

- Developed and demonstrated six SBA scenarios in close collaboration with other GEO Tasks. The SBAs were identified through consultation with the ADC and UIC.
- Defined and refined a reusable process to implement SBA scenarios in a Service oriented Architecture (SoA) tailored to GEOSS based upon international standards for software development including UML and RM-ODP. The process can be used in the future by any SBA Community of Interest with or without AIP involvement.
- Defined ten general use cases for the GEOSS Service oriented Architecture (SoA) that transversely support all SBAs. Several of the general use cases were specialized to meet the specific needs of SBAs.
- In conjunction with the SIF, further advanced GEOSS Interoperability Arrangements by implementing many international standards and special arrangements for the use cases.
- Augmented the GCI through identification of Engineering Components contributed by GEO Members and Participating Organizations.
- Increased the number of registered components and services in the Components and Services Registry (CSR)
- Contributed to furthering the establishment of GEOSS components that provide a persistent capability. These “persistent exemplar services” are committed to providing relevant services for an extended duration, with high availability through GEOSS Interoperability Arrangements.
- Service testing components were used to test contributed components during the registration process and are now available for testing during operations to assess operational availability and performance.
- AIP-2 used an evolutionary development process tailored to the technology of GEOSS and considering the globally distributed nature of the GEO participants.
- Results of AIP-2 are documented in 12 Engineering Reports and 10 Demonstration Videos (See Section 4)
AIP employs an “evolutionary development process” whereby the architecture, the delivered systems, and the stakeholders co-evolve. This approach is well suited to the GEOSS information system development. The AIP Development process consists of a series of phases, including the recent completion of phase 2 (AIP-2). Each phase consists of a series of steps shown in detail in Section 5. Major milestones of AIP-2 are listed in Table 1. A phase of AIP is completed with the delivery of demonstrations, engineering reports, and the transition of new functionality to persistent operations.

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIP-2 CFP announced by GEO Secretariat</td>
<td>30 June 2008</td>
</tr>
<tr>
<td>CFP Responses requested to support Kickoff Workshop</td>
<td>1 September 2008</td>
</tr>
<tr>
<td>Kickoff Workshop at NCAR, Boulder Colorado, USA.</td>
<td>25-26 September 2008</td>
</tr>
<tr>
<td>Interim Design Review, Barcelona, Spain</td>
<td>December 2008</td>
</tr>
<tr>
<td>Scenarios and Use Cases defined</td>
<td>January 2009</td>
</tr>
<tr>
<td>Demo Capture Workshop, Stresa, Italy</td>
<td>4-5 May 2009</td>
</tr>
<tr>
<td>Finalize AIP-2 deliverables</td>
<td>September 2009</td>
</tr>
<tr>
<td>AIP-2 results transition to operations</td>
<td>2nd Half of 2009</td>
</tr>
</tbody>
</table>
3. SoA architecture for GEOSS

3.1 GEO community objective

As a “system of systems”, GEOSS is composed of contributed Earth Observation systems, ranging from primary data collection systems to systems concerned with the creation and distribution of information products. Although all GEOSS systems continue to operate within their own mandates, GEOSS systems can leverage each other so that the overall GEOSS becomes much more than the sum of its component systems. This synergy develops as each contributor supports common arrangements designed to make shared observations and products more accessible, comparable, and understandable.¹

For elaboration of the objectives of the GEO Community refer to the GEOSS 10 Year Plan; the GEOSS 10 Year Plan Reference Document; and to GEOSS Interoperability Strategic Guidance Document.

![Figure 2 – A Global Earth Observation System of Systems: GEOSS](image)

3.2 Reusable SBA to SoA process

3.2.1 Introduction

An objective for GEOSS is to provide decision-support tools to a wide variety of users. As with the Internet, GEOSS will be a global and flexible network of content providers allowing decision makers to access an extraordinary range of information at their desk. To achieve this goal, the GEOSS Architecture must provide an easy process to integrate the GEOSS components in support of many SBA communities. This section describes a process for implementing the needs of an SBA community into the GEOSS architecture. The process is reusable for the various SBAs and it reuses the GEOSS architecture across the SBAs.

¹ GEOSS Strategic Guidance Document, GEO Task Team AR-06-02, 14 Dec. 2006
The core of the reusable process are community *Scenarios* and transverse *Use Cases.* Scenarios are narrative description of the activities of the SBA communities with minimal discussion of the implementation architecture. Scenarios provide an end user view of the value of GEOSS. Scenarios are implemented in the GEOSS architecture by use cases. Use cases describe reusable functionality of the GEOSS service oriented architecture implemented through Interoperability Arrangements. This process builds on these core concepts using a system modeling process based on international standards tailored to the GEOSS environment.

Development of architecture models is a step towards a mature GEOSS: “Creating explicit models of a system’s design is the step leading from art to practice.” AIP begins with the typical architecture practice of describing a system from multiple viewpoints. The AIP process tailors international standards for system architecture by considering the environment of GEOSS, in particular: 1) GEOSS is a system-of-system development that does not begin with a “blank sheet” but rather requires iteration of design synthesis with existing implementations, and 2) Contributions are made by GEO Members with no central procurement authority.

It is recommended by AIP that the GCI provide support to SBA Communities to use the GEOSS Architecture.

- Use of the GEOSS Architecture by SBA Communities is supported by the GCI components informed by expert advice about GCI and the broader GEOSS architecture. The experts are available to support SBA-focused individuals and groups that seek to employ the GEOSS architecture to meet their EO information and processing needs.

- A reusable process is defined and refined that is available to for GCI experts to work with SBA community experts to apply the GEOSS Service oriented Architecture to SBA scenarios. Here the GEOSS SoA is the GCI along with the contributed components of GEOSS members and participating organizations. Interactions of GEOSS SoA components are accomplished using Interoperability Arrangements.

### 3.2.2 The Reusable Process

The reusable process for deploying SBA Scenarios into the GEOSS Architecture is shown in Figure 3 and described in Table 2. This process is iterative with the main flow of activities as shown in the Figure, but the process is not accomplished in one pass. It is important that the SBA communities are considering the SoA technology when conceiving of their objectives as SoA provides capabilities that not previously available.

---

2 Definitions for terms in *italic* typeface are listed in Section 3.2.3


Table 2 – SBA to SoA Process Steps

<table>
<thead>
<tr>
<th>Step</th>
<th>Activities</th>
<th>Artifacts</th>
</tr>
</thead>
</table>
| 1. Scenarios          | SBA community experts develop narrative descriptions of *processes* for the desired behavior of decision makers using Earth Observations in the context of GEOSS Scenario development occurs with a general understanding of GEOSS. The SBA community experts develop the narrative with an understanding of the basic GEOSS architecture, e.g. the generalized use cases. | • Objectives  
• Scenarios  
• Processes                                                                 |
| 2. Enterprise Models  | AIP system engineers - working with SBA community experts - elaborate and specify the scenarios into enterprise models. Steps in the *processes* are detailed in *activity* actions.                      | • Activity diagram  
• Enterprise objects  
• Context diagram                                                                 |
| 3. Engineering Design | AIP architects - working with the SBA Community experts and AIP system engineers - develop optimized designs for the enterprise models by applying and refining SoA use cases, *information objects*, and *component types*. Each activity action is assigned to a pre-existing generalized use case or a specialized use case is developed. | • Refinement of Generalized use cases  
• Specialized use cases  
• Information objects  
• Component Types  
• Interoperability Arrangements                                                                 |
| 4. Deployment         | Component providers – working with AIP architects and Community Moderators – identify, develop (as necessary) and register a set of *component instances* based upon the engineering design. Components include those provided by the community and discovered in the wider GEOSS. Deployment includes testing that the components meet the community objectives. Demonstrations are developed to communicate the system operation to users. | • Component Instances  
• Persistent Exemplars  
• Demonstrations                                                                 |
3.2.3 Modeling Terminology

This section lists terminology used in the AIP Modeling process. The terms are taken from several standards. Some terms are unique to the AIP process. Figure 4 shows relationships between some of the terms.

The following references are used in this section. The references in order of precedence:
1. UML4ODP (ISO 19793)
2. RM-ODP (ISO 10746-2):
3. UML (OMG 07-02-05, UML 2.1.1))

Scenario (as used in AIP-2, scenario can be best understood considering the term Process from [UML4ODP])
- The modelling of behaviour may be structured into one or more processes, each of which is a graph of steps taking place in a prescribed manner and which contributes to the fulfillment of an objective. In this approach, a step is an abstraction of an action in which the enterprise objects that participate in that action may be unspecified. [UML4ODP])
- Scenario defines the “business” objectives of the Community in using the GEOSS architecture.
- A template for SBA Scenarios was developed early in AIP-2 process implicitly defining concepts. Refinement of the template based upon the preceding paragraph results in these concepts: A scenario may contain one or more processes. A process is defined in narrative form as a set of steps in a table.

Activity (Diagram):
- An activity is a single-headed directed acyclic graph of actions, where occurrence of each action in the graph is made possible by the occurrence of all immediately preceding actions (i.e. by all adjacent actions which are closer to the head). [RM-ODP]
- The notation for an activity is a combination of the notations of the nodes and edges it contains, plus a border and name displayed in the upper left corner. [UML]
- Activity replaces ActivityGraph in UML 1.5. Activities are redesigned to use a Petri-like semantics instead of state machines. [UML]

Enterprise object
Community object
- Each enterprise object models some entity (abstract or concrete thing of interest) in the Universe of Discourse. A particular kind of enterprise object is a community object, which models, as a single object, an entity that is elsewhere in the model refined as a community. [UML4ODP]

Role: Identifies a specific behaviour of an enterprise object in a community. [UML4ODP]

Action: Something that happens [RM-ODP]

Use Cases:
Generalized Use Case
Specialized Use Case
- A use case is the specification of a set of actions performed by a system, which yields an observable result that is, typically, of value for one or more actors or other stakeholders of the system. [UML]
- Each use case specifies a unit of useful functionality that the subject provides to its users (i.e., a specific way of interacting with the subject). [UML]
- AIP defines both generalized use cases and specialized use cases. A generalized use case specifies actions of value to GEOSS in general. A specialized use case refines a generalized use case as needed for a specific SBA community’s requirements.

Use cases for AIP focus on services and interoperability arrangements.

Actor
- An actor specifies a role played by a user or any other system that interacts with the subject. (The term “role” is used informally here and does not necessarily imply the technical definition of that term found elsewhere in this specification.) [UML]
- Actors may represent roles played by human users, external hardware, or other subjects. [UML]
• *Actors* are external to the subject of the use case. [UML paraphrased]

**Service:**

• A *service* is a distinct part of the functionality that is provided by an entity through *interfaces* [ISO 19119:2005]
• In AIP-2, *services* are types of computational objects as defined in [RM-ODP].

**Interface**

• An *interface* is an abstraction of the behaviour of an object that consists of a subset of the interactions of that object together with a set of constraints on when they can occur.
• RM-ODP defines three types of *interfaces*: 1) A signal interface is an interface in which all the interactions are signals; 2) An operation interface is an interface in which all the interactions are operations; 3) A stream interface is an interface in which all the interactions are flows.
• For SoA: an *interface* is a named set of operations that characterize the behaviour of an entity [ISO 19119]
• In GEOSS, agreements about interfaces are termed *interoperability arrangements*.

**Interoperability arrangements**

• GEOSS interoperability arrangements are to be based on the view of complex systems as assemblies of components that interoperate primarily by passing structured messages over network communication services. [GEOSS Strategic Guidance Document, October 2007]
• By expressing interface interoperability specifications as standard service definitions, GEOSS system interfaces assure verifiable and scaleable interoperability, whether among components within a complex system or among discrete systems. [GEOSS Strategic Guidance Document, October 2007]

**Information object**

Information held by the ODP system about entities in the real world, including the ODP system itself, is modelled in an information specification in terms of *information objects*, and their relationships and behaviour. [UML4ODP]

**Component type**

**Component instance**

A *component* represents a modular part of a system that encapsulates its contents and whose manifestation is replaceable within its environment. [UML]

A *component* is modeled throughout the development life cycle and successively refined into deployment and run-time. [UML]

For AIP-2, *component types* are design concepts that encapsulate *information objects* and provides *services* on the information through *interfaces*. *Component instances* are developments that have been deployed and are accessible at a network address. *Component instances* are registered in the GEOSS CSR.

---

5 As modeling of the Information Viewpoint during AIP-2 has been minimal, the single term “Information Object” is used as general concept that will be detailed in future AIP activities.
Figure 4 – Modeling Terminology
3.3 SBA scenarios

GEOSS is simultaneously addressing nine areas of critical importance to people and society (as shown in the top of Figure 2). It aims to empower the international community to protect itself against natural and human-induced disasters, understand the environmental sources of health hazards, manage energy resources, respond to climate change and its impacts, safeguard water resources, improve weather forecasts, manage ecosystems, promote sustainable agriculture and conserve biodiversity. GEOSS coordinates a multitude of complex and interrelated issues simultaneously. This crosscutting approach avoids unnecessary duplication, encourages synergies between systems and ensures substantial economic, societal and environmental benefits.

Development in AIP-2 focused within four SBAs:

- **Energy SBA**: AIP-2 participants developed an end-to-end scenario between a data provider on the one hand and a consulting company looking for the best place to sit a solar power plant on the other hand. Both benefit from GEOSS as a centralized point of access. The needs of the data providers looking for an efficient dissemination of his databases are expressed.

- **Health SBA**: AIP-2 participants focused on Air Quality with a scenario entitled, "Southern California Smoke" which describes how air quality event managers would use data available through GEOSS to predict and analyze the effect of smoke plumes on air.

- **Biodiversity SBA**: AIP-2 participants developed three biodiversity scenarios. 1) GEOSS was used to predict how the distribution of Pika will change with climate change in the Great Basin of North America. 2) GEOSS was used to assess the impact of climate change on the species of a simple food chain in the Arctic region. 3) GEOSS was used to identify the extent and degree of vegetation changes in response to climate change in arctic ecosystems, and in particular, the boreal-tundra ecotone.

- **Disaster Management SBA**: AIP-2 participants used GEOSS components and standard services to supply forecasts, a stream of satellite and in-situ observations, and derived maps integrated with local and regional data sets to support all phases of the disaster cycle. The scenario is applied to flooding disasters caused by tropical storms, hurricanes, cyclones, and tsunamis in particular, but can be easily re-cast to cover other disaster types such as earthquakes, wildfires, landslides, volcanoes, tornadoes, and many more.

Each of the AIP-2 SBAs is described in an Engineering Report.

3.4 GEOSS users

At the beginning of AIP-2, the GEOSS users were minimally characterized into two categories: GEOSS Service Consumers and GEOSS Service Providers. As AIP-2 development progressed, it became clear that a more comprehensive description of the GEOSS users is needed. The AIP-2 Use Case ER provides a further elaboration of the actors in the use cases based upon examining the use cases. Further description of the GEOSS Users will be required in AIP-3 based upon the AIP-2 results along with definitions from the GCI Task Force and the User Interface Committee.

The GCI Concept of Operations document provides definitions of users:

- **Publisher** – Individual(s) authorized by Member and Participating Organizations to commit GEOSS Components and/or Services
- **Operator** – The agency/organization responsible for the operation and maintenance of a committed service and related data
- **Approver** – Acts to approve or disapprove an entry or update in one of the GEOSS Registries and the GEO Web Portals.
- **Software and services integrator (Integrator)** – A class of user typically engaged in support of one or more application areas who is able to use GEOSS to locate suitable services, data, and related resources, and to develop and deploy integrating software solutions that cater to a specific context or subject area.
• GEOSS-Experienced users – Users who understand the concepts of GEOSS and seek registered resources through the GEO Web Portal interface or desktop applications.

• Issue-Oriented Users - Researchers and science-to-policy analysts who work on specific issues that fall within one or more Societal Benefit Areas.

During the UIC and ADC meetings in May 2009, there was much discussion of GEOSS users, in part due to the presentation of the AIP-2 Demonstration Videos to the committees and due to comments coming from the GCI Usability Testing conducted concurrently with the committee meetings.

AIP Participants suggested that based upon discussions in the UIC additional user types should be defined that are complementary to those already mentioned.

• Man in the street: politicians, certain level of decision makers, public at large from which we want a recognition of the benefits of GEO…

• Possibly, some specializations of the Issue-Oriented users, in order to more precisely cope with the GEO SBAs and the targeted GEO outcomes…

3.5 SoA use cases

To coordinate development across the SBA Scenarios a set of generalized use cases (Figure 5 and Table 3) were developed. The generalized use cases show the reuse of GEOSS service oriented architecture for a narrow action, e.g., discovery, data access. (The use cases were also titled transverse technology use cases.) Use cases are specific to interoperability arrangements. A use case template for was provided early in AIP-2 enabling consistent development of AIP-2 use cases. Each of the steps in a scenario process are implemented through a use case. For some steps, the use case needs to be tailored to the SBA thereby creating a specialized use case.

The AIP-2 Use Cases Engineering Report\(^6\) describes the use cases in detail. The report contains the generalized use cases that were specialized to implement the specific SBA scenarios. The SBA Scenarios and specialized use cases are defined in separate AIP-2 ERs. The Use Case ER contains a mapping of the use cases to the GEOSS AIP Components Types.

\[\text{Figure 5 – Use Cases for the AIP Service-Oriented Architecture} \]

\(^{6}\) http://www.ogcnetwork.net/AIP2ERs#UseCases
<table>
<thead>
<tr>
<th>Use Case</th>
<th>Title</th>
<th>Actors and Interfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Registration and Harvesting Use Cases</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Register Resources</td>
<td>Register resources in GEOSS Components and Services Registry (CSR) or Community Catalog</td>
<td># Service Provider # Components and Services Registry # Community Catalog Provider</td>
</tr>
<tr>
<td>10. Register New Interoperability Arrangements</td>
<td>Register, in the GEOSS Standards and Interoperability Registry (SIR), new and recommended interoperability arrangements) as well as utilized standards.</td>
<td># Service Provider # Components and Services Registry # Standards &amp; Interoperability Registry # SIF Moderator</td>
</tr>
<tr>
<td>3. Harvest &amp; Query via Clearinghouse</td>
<td>This use case describes the steps for harvesting and/or querying service or content metadata from community catalogs or services via a GEOSS Clearinghouse</td>
<td># Service Provider # GCI Registry # GEOSS Clearinghouse # Client Application</td>
</tr>
<tr>
<td><strong>Clients and Portals Use Cases</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Search for Resources</td>
<td>Steps for portals and application clients to support the GEOSS user in searching for resources of interest via the GEOSS Clearinghouse or Community Catalogs</td>
<td># GEOSS User # Portals and Client Applications # GEOSS Clearinghouse # Community Catalog</td>
</tr>
<tr>
<td>5. Present Services and Alerts</td>
<td>Present GEOSS User with services and alerts as returned per the user’s search criteria</td>
<td># GEOSS User # Portals and Client Applications # GEOSS Service Providers</td>
</tr>
<tr>
<td>7. Exploit Data Visually and Analytically</td>
<td>Steps for exploitation in Client Applications of datasets served through Web Services and online protocols as used within GEOSS.</td>
<td># GEOSS User # Components and Services Registry # GEOSS Service Providers # Portals and Client Applications</td>
</tr>
<tr>
<td><strong>Deployment and Access Use Cases</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Deploy Resources</td>
<td>Deploy Resources for use in GEOSS</td>
<td># Service Provider # Components and Services Registry</td>
</tr>
<tr>
<td>6. Interact with Services</td>
<td>Interact with Services</td>
<td># Service Provider # Portals and Client Applications</td>
</tr>
<tr>
<td><strong>Service Testing Use Cases</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Test Services</td>
<td>Service Provider tests its service using a proper Test tool discovered in the GEOSS CSR.</td>
<td># Service Provider # Components and Services Registry # Test Facility/Tool # Relevant Standards Authority</td>
</tr>
<tr>
<td><strong>Workflow Use Cases</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Construct and Deploy Workflow</td>
<td>Design, deploy and execute a workflow. described in Business Execution Language (BPEL) or any other script language.</td>
<td># GEOSS Integrator # Client Application # Service Provider</td>
</tr>
</tbody>
</table>
3.6 Engineering components

3.6.1 Augmenting the GEOSS Common Infrastructure (GCI)

The systems and components that comprise GEOSS are contributed by GEO members and participating organizations. As a result of AIP-1 and several other GEO tasks, a set of engineering components were established in May 2008 as the GEOSS Common Infrastructure (GCI) Initial Operating Capability (IOC). One objective of AIP-2 is to augment the GCI beyond the level of IOC. AIP-2 defined several types of components beyond the GCI components that are needed to accomplish the SBA scenarios. Figure 6 shows the GCI augmented by a set of additional GEOSS-relevant engineering components.

From an SoA point of view, a component represents a modular part of a system that encapsulates its contents and whose manifestation is replaceable within its environment. A component is modeled throughout the development life cycle and successively refined into deployment and run-time. For AIP-2, component types are design concepts that encapsulate information objects and provide services on the information through interfaces. Component instances are developments that have been deployed and are accessible at a network address. Component instances are registered in the GEOSS CSR. Business functions are offered for use by other components as services.

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7 The term “components” is has several different meanings across the GEO activities. In AIP the term used is “engineering component to indicate that the term is used with in the context of the RM-ODP engineering viewpoint.

8 AIP-3 development may consider use of the “OASIS Service Component Architecture Assembly Model Specification”, 
http://docs.oasis-open.org/opencsa/sca-assembly/sca-assembly-1.1-spec.pdf
The components shown in Figure 6 are organized using a three-tier model that is typical in SoA. The tiers help to categorize the components but it does not constrain the component interactions, e.g., client tier components need not go only to the middle tier, they may directly access the bottom tier.

- The top tier is the only one with which people deal directly. The Clients in this layer provide access to the other components;
- The middle tier embodies business processes to aid clients in achieving tasks in the SoA. The services in general embody everything from discovery to complex geoprocessing on sets of data from various repositories and from generation of map views to statistical charts that the client gets back at the end of the process;
- The lower tier provides read and/or write access to data, whether its geospatial data, accounting records, or sensor data.

A description of each component type and some example interoperability arrangements are listed in Table 4.
<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
<th>Example Interoperability Arrangements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main GEO Web Site</td>
<td>Earthobservations.org</td>
<td>http</td>
</tr>
<tr>
<td>GEO Web Portals</td>
<td>A single point of access to information, internal or external to GEOSS, relevant to all SBAs and is of interest to various types of users</td>
<td>http, CSW, WMS, KML</td>
</tr>
<tr>
<td>GEOSS Registries</td>
<td>Component and Service Registry (CSR) Standards and Interoperability Registry (SIR) GEOSS Best Practices Wiki GEOSS User Requirements Registry</td>
<td></td>
</tr>
<tr>
<td>GEOSS Clearinghouse</td>
<td>Provides search access to high-level metadata from all catalogs registered in the CSR through remote harvest of metadata or provision of distributed search. Indexes all CSR entries.</td>
<td>CSW, ISO 23950</td>
</tr>
<tr>
<td>Community Portals</td>
<td>A community-focused portal (website) that provides a human user interface to identified content</td>
<td>CSW, ISO23950, KML, WMS</td>
</tr>
<tr>
<td>Client Applications</td>
<td>Application hosted on users computer to access remote services and provide manipulation of the data in the client application. Clients may be specific to a user community or may be more generic geospatial data applications.</td>
<td>CSW, ISO23950, WMS, WFS, WCS, SOS, SPS, WPS, CAP, KML, RSS, GeoRSS</td>
</tr>
<tr>
<td>Community Catalogues</td>
<td>Collection of community-organized information descriptions (metadata) exposed through standard catalog service interfaces</td>
<td>CSW, ISO 23950</td>
</tr>
<tr>
<td>Mediation Servers</td>
<td>Federates several catalogue services with differing vocabulary and offers results through a catalogue service.</td>
<td>CSW, ISO 23950</td>
</tr>
<tr>
<td>Alert Servers</td>
<td>Component provides feeds of alerts.</td>
<td>CAP, RSS, GeoRSS</td>
</tr>
<tr>
<td>Workflow Management</td>
<td>Encapsulates an engine capable of managing workflows, services, activities, and workflow execution instances.</td>
<td>BPEL</td>
</tr>
<tr>
<td>Processing Servers</td>
<td>Components that accepts requests to process data using an algorithm hosted in the component. The data is accessed from a remote service.</td>
<td>WPS</td>
</tr>
<tr>
<td>Test Facility</td>
<td>Provides persistent services to support the service registration and operational monitoring of services.</td>
<td>WMS, WFS, WCS, CSW</td>
</tr>
<tr>
<td>Product Access Servers</td>
<td>Services to access Earth Observation data. Typically hosted by a facility that provides redundant resources for both high availability and high performance.</td>
<td>WMS, WFS, WCS, ftp, OpenDAP,</td>
</tr>
<tr>
<td>Sensor Web Servers</td>
<td>Services to access sensors and sensors networks: e.g.; ground station and associated satellites; and in-situ networks of sensors.</td>
<td>SOS, SPS, SAS</td>
</tr>
<tr>
<td>Model Access Servers</td>
<td>Services to access outputs of predictive models of geospatial information, hosted by a simulation and modeling center.</td>
<td>WMS, WCS, WFS, SOS</td>
</tr>
<tr>
<td>GEONETCast</td>
<td>Global network of satellite-based data dissemination systems to distribute data via broadcast.</td>
<td>DVB-S</td>
</tr>
</tbody>
</table>
3.6.2 Test Facility

The Testing Services Facility was created in the frame of the GEOSS AIP-2 activities to provide a persistent testbed able to support the service contribution process to GEOSS. This facility is mainly based on contributed tools from ESA and FGDC.

The Service Test Facility is intended to ensure proper and interoperable use of GEOSS components and services in applications and interfaces. The Test Facility is intended to promote predictable and reliable access to services registered with the GEOSS Service Registry. The facility will support service providers, service operators, technology providers, integrators, and other users. It will provide a means for service operators and technology providers to get feedback on the efficacy of their interfaces and applications in implementing and using GEOSS Interoperability Arrangements. The Test Facility should enable web services developers to test their data and model prototypes for GEOSS SBA scenarios and demonstrations. In this way, the facility can foster improved collaboration for interoperability. It will allow service operators to test their service interfaces at the operation level to determine nominal conformance/compliance with published interface specifications, where they exist. This will promote interoperability between compatible client and service instances of the same version and allow integration of diverse resources across GEOSS. The facility will also enable periodic checking as to the availability and reliability of registered components and services, encourage cross-community implementations, and shorten prototyping cycles. To these ends, the Test Facility needs to be a permanent, sustainable resource.

3.6.3 Data Broker

During AIP-2 there was development of “data broker” components to provide access to data that is behind firewalls, is not to be made fully available, or for other reasons where the primary data holder does not offer the access service to GEOSS but rather relies on a data broker to provide the function. As shown in Figure 7, the broker provides access to a select portion of an institutional data provider in a machine outside of the institution. The Data broker handles the registration of the datasets into GEOSS. The client, e.g., a GEOSS Web Portal, then discovers and access the data that is associated with the institution. A data broker was used to make data available in the AIP-2 Disaster Response Scenario.

The use of data broker components is demonstrated in the video on Disaster Management\(^9\)

\(\text{Figure 7} – \text{Data Broker}\)

\(^9\) http://www.ogcnetwork.net/pub/ogcnetwork/GEOSS/AIP2/index.html/
3.6.4 Portlets

A variation in the approach to Interoperability was defined in AIP-2 using “portlets”. GEOSS interoperability is based on a SoA where the interfaces are defined using non-proprietary standards, with preference to formal international standards.” In development of the AIP-2 Renewable Energy Scenario an alternative to client/server interaction by achieved by reuse of portlets, i.e., code sharing. By using portlets that adhere to JSR168, a client framework is able to download a portlet codeset and then access remote services by invoking the portlet. The agreement in this case is about reuse of the portlet and not about the client service interface standard.

The use of portlets is demonstrated in the video on the Renewable Energy scenario.\(^\text{10}\)

3.7 RM-ODP viewpoints

The preceding sections describe elements of an architecture for open distributed processing. The AIP-2 CFP uses the ISO standard “RM-ODP” to describe the GEOSS architecture. A key element of RM-ODP is the organization of an architecture into a set of viewpoints. The table below shows how the preceding sections are organized in an RM-ODP architecture.

<table>
<thead>
<tr>
<th>Table 5 – Mapping AIP-2 Artifacts to RM-ODP Viewpoints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enterprise Viewpoint</td>
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<tr>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>Information Viewpoint</td>
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<tr>
<td>Computational Viewpoint</td>
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<tr>
<td></td>
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<tr>
<td>Engineering Viewpoint</td>
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<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>Technology Viewpoint</td>
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<tr>
<td></td>
</tr>
</tbody>
</table>

\(^\text{10}\) http://www.ogcnetwork.net/pub/ogcnetwork/GEOSS/AIP2/index.html?movie=10
4. AIP-2 Deliverables

4.1 Demonstration videos

In order to communicate the results of AIP-2, several demonstrations were captured and made available online.\(^1\)

The SBA Community Working Groups developed demonstrations of the scenarios for specific events in various geographic locations. The demonstrations are listed followed by the lead producers of the demos:

- Disaster Management: Stuart Frye, Didier Giacobbo, Hervé Caumont
- AQ & Health – Smoke Event: Rudy Husar, David McCabe, Erin Robinson
- Biodiversity: Pika Distribution: Stefano Nativi, Mattia Santoro
- Biodiversity: Arctic Food Chain: Stefano Nativi, Mattia Santoro
- Biodiversity: Polar Ecosystems: Doug Nebert, Yuqi Bai
- Renewable Energy - Facility Planner: Lionel Menard

The Transverse Technology Working Groups developed demonstrations on technology topics that support multiple communities. The demonstrations are listed followed by the lead producers of the demos:

- Publish, test, register, and monitor: Hervé Caumont
- Geo-Processing with WPS: Brian Falk, Greg Yetman
- GEO Web Portal to Clearinghouses
  - Compusult - Robert Thomas
  - ESA/FAO – Gianni Sotis, Jolyon Martin
  - ESRI – Marten Hogeweg

AIP has developed some practices for capturing the scenarios and publishing them as videos on the web. The process involves the Scenario developers capturing video of variety of clients involved in the scenarios. Demo capture involves several technical issues associated with video production and editing. The client screen captures along with PowerPoint viewgraphs and other graphics are edited using video editing software. A voice over narration is added to the video to create the final product. The demonstration videos are then posted on-line as part of a web page and other videos that tell a coherent story about AIP.

Storytelling about the development of technology is key to the transition of the technology to an operational capability in support of GEOSS users.

4.2 Engineering reports

One of the major deliverables of AIP-2 is a set of Engineering Reports (ERs).\(^2\) Listed below is the set of coordinated ERs that describe the requirements, design, and implementation conducted during AIP-2. Figure 8 shows the relationship of the ERs to each other and to other GEOSS documents. Several ERs will be offered for consideration by the GEOSS Best Practice Registry. It is also anticipated that several ERs will be considered by bodies external to GEO, e.g., the OGC Technical Committee and SBA-related organizations.

\(^1\) [http://www.ogcnetwork.net/pub/ogcnetwork/GEOSS/AIP2/index.html](http://www.ogcnetwork.net/pub/ogcnetwork/GEOSS/AIP2/index.html)

\(^2\) The AIP-2 ERs are available here: [http://www.ogcnetwork.net/AIP2ERs](http://www.ogcnetwork.net/AIP2ERs)
The SBA Scenarios ERs are:

- Renewable Energy SBA ER
- Air Quality and Health SBA ER
- Pika Distribution Biodiversity SBA ER
- Arctic Food Chain Biodiversity SBA ER
- Polar Ecosystems Biodiversity SBA ER
- Disaster Management SBA ER

Each of the ERs are described in the following scope statements and are posted on-line.¹³

**GEOSS AIP-2 Renewable Energy SBA Engineering Report**

Scope: This AIP-2 ER illustrates an end-to-end scenario between a data provider on the one hand and a consulting company looking for the best place to sit a solar power plant on the other hand. Both benefit from GEOSS as a centralized point of access. The needs of the data providers looking for an efficient dissemination of his databases are expressed. The necessary concepts, steps, tools and actions needed on the data providers side to ensure that resources cope with the various GEOSS use cases allowing a full search, discovery and bind mechanisms are described. From W3C Web Service deployment, building INSPIRE ISO 19119 Metadata for WAF (Web Accessible Folder) catalogue, registering components and services in the GEOSS Service Registry, all the necessary steps towards data and catalogue interoperability are detailed. A dedicated Community Portal for Renewable Energy (www.webservice-energy.org) is currently hosting numerous Web Services for the goods of the community. A dedicated client specially build for the scenario as a JSR-168 Portlet is presented. This client allows Web Services chaining from remote interoperable map resources of GEOSS data providers. Based on a real business use case, the needs of the consulting company are also expressed within the scenario and illustrate the usefulness of GEOSS.

Point of Contact Editor: Lionel Menard, Mines ParisTech. Contributing Editors: Mines ParisTech and Team

¹³ http://www.ogcnetwork.net/AIP2ERs
<table>
<thead>
<tr>
<th>GEOSS Architecture Implementation Pilot, Phase 2</th>
<th>Version: 1.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIP-2 Summary Engineering Report</td>
<td>Date: 23 September 2009</td>
</tr>
</tbody>
</table>

### GEOSS AIP-2 Air Quality and Health SBA Engineering Report

**Scope:** This Engineering Report describes how the Air Quality Workgroup used and tested the GEOSS Common Infrastructure (GCI) in order to register, discover, and access datasets relevant to air quality management. The AQ Workgroup adopted the convention that all AQ data must be accessible as an OGC WMS or WCS and developed a process to create ISO 19115 metadata records for the AQ Community Catalog from WMS/WCS GetCapabilities documents. Using a service oriented architecture approach, data and metadata flows from the data providers through the GCI to the users. This methodology and infrastructure was demonstrated using a scenario entitled, "Southern California Smoke" which describes how air quality event managers would use data available through GEOSS to predict and analyze the effect of smoke plumes on air quality during and after the Southern California Wildfire of October 2007. This demonstration is just one example of the broad capabilities of the infrastructure, which allows a single dataset to be reused for multiple decision support activities and supports a single decision support activity that needs multiple datasets.

Point of Contact Editor: Erin Robinson, Washington University - St. Louis. Contributing Editors: David McCabe, EPA; Rudy Husar, Washington University - St. Louis; Stefan Falke, Northrop Grumman;

### GEOSS AIP-2 Pika Biodiversity SBA Engineering Report

**Scope:** This AIP-2 ER will briefly describe the use scenario entitled "Pika Distribution" of the Climate Change and Biodiversity WG. The ER describes how the GEOSS-based system was tested to predict how biodiversity will change with climate, for Pikas distribution in the Great Basin (North America). The architecture of the developed system is described, focusing on the GEOSS standard components and services utilized by the demonstration. Persistent Exemplars services identified are listed.


### GEOSS AIP-2 Arctic Food Chain Biodiversity SBA Engineering Report

**Scope:** This AIP-2 ER will briefly describe the use scenario entitled "Climate Change and Biodiversity Arctic Food Chain" of the Climate Change and Biodiversity WG. The ER describes how the GEOSS-based system was tested to assess the impact of climate change on the species of a simple food chain in the Arctic region. The architecture of the developed system is described, focusing on the GEOSS standard components and services utilized by the demonstration. Persistent Exemplars services identified are listed.


### GEOSS AIP-2 Polar Ecosystems Biodiversity SBA Engineering Report

**Scope:** This AIP-2 ER will describe the user scenario entitled "Polar Ecosystem Vegetation Changes Scenario". The ER describes how the GEOSS-based system was tested to identify the extent and degree of vegetation changes in response to climate change in arctic ecosystems, and in particular, the boreal-tundra ecotone. The architecture, workflow of the developed system is presented, the standards-based GEOSS components and services are highlighted.

Point of Contact Editor: Doug Nebert, USGS. Contributing Editors: Yuqi Bai, GMU;
**GEOSS AIP-2 Disaster Management SBA Engineering Report**

Scope: The GEOSS AIP-2 Disaster Management Scenario describes the integration and utilization of GEOSS standard components and services to supply forecasts, a stream of satellite and in-situ observations, and derived maps integrated with local and regional data sets to support all phases of the disaster cycle. The scenario is applied to flooding disasters caused by tropical storms, hurricanes, cyclones, and tsunamis in particular, but can be easily re-cast to cover other disaster types such as earthquakes, wildfires, landslides, volcanoes, tornadoes, and many more. The user roles and their contributions to the scenario are defined at the several levels of the GEOSS architecture. The components and services implemented as part of this scenario are in on-going use supporting disaster management activities on a global scale. For example, evaluation of the utilization by local and regional disaster, meteorology, and hydrology agencies in Africa and the Caribbean will be developed in Nov-Dec 2009 and plans for 2010 refined accordingly.

Point of Contact Editor: Didier Giacobbo, SpotImage. Contributing Editors: Stuart Frye, NASA; Hervé Caumont, ERDAS/OGC: Ron Lowther, Northrop Grumman

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**GEOSS AIP-2 Unified Modeling Engineering Report**

Scope: The GEOSS Unified Modeling team engineering report provides the depiction expresses the Reference Model of the Open Distributed Processing (RM-ODP) viewpoint using the Unified Modeling Language as the syntax. This is done by expressing each scenario of each GEOSS Societal Benefit Area in five viewpoints as described in ISO/IEC 10746:1996 Part 3 Reference Model ODP Architecture and description of the UML concepts and extensions provided in ISO/IEC 19793:2007

Point of Contact Editor: Larry McGovern, INCOSE and Northrop Grumman. Contributing Editors: INCOSE GEO Team

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**GEOSS AIP-2 Use Cases Engineering Report**

Scope: This AIP-2 ER describes a set of transverse technology Use Cases developed and used in AIP-2. The Use Cases define reusable activities of a service-oriented architecture tailored for GEOSS. This report will contain the general Use Cases that were specialized to implement the specific SBA Scenarios. The SBA Scenarios and specialized use cases are defined in separate AIP-2 ERs. The Use Case ER will contain a mapping of the use cases to the GEOSS AIP Components Types. This AIP-2 ER will be offered for consideration by the GEOSS Best Practice Registry editors and to OGC Technical Committee for consideration as a Best Practice.

Point of Contact Editor: Nadine Alameh, Mobilaps and OGC. Contributing Editors: George Percivall, OGC; Josh Lieberman, Traverse/OGC; Hervé Caumont, ERDAS/OGC

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**GEOSS AIP-2 End-to-End Discovery and Access Engineering Report**

Scope: This AIP-2 ER describes the practice of publishing, documenting, and registering contributed resources from the point of view of classes of GEOSS users who wish to discover and access those resources. It emphasizes two roles for the GEOSS Common Infrastructure: 1) Service-oriented structure for service-based application development by technically advanced users; and 2) Content-oriented search and linking for users with a less technical Web portal approach. "End-to-end" here refers to the connection between desired user discovery practices and queries on the one end; and the provided resource interfaces and documentation on the other.

Point of Contact Editor: Josh Lieberman, OGC and Traverse, Inc. Contributing Editors:Hervé Caumont, Nadine Alameh, Doug Nebert, Ted Habermann, Marten Hogeweg
GEOSS AIP-2 Workflow and Processing Engineering Report

Scope: This AIP-2 ER describes the workflow and processing group experience in implementing two use cases: authoring workflows and publishing workflows. Extracts from a detailed use case developed for registering workflows within the GEOSS registry are included, and issues related to the limits of the registry related to workflow and processing interoperability are discussed. Technical issues in processing services within GEOSS are presented.

Point of Contact Editor: Greg Yetman, CIESIN. Contributing Editors: Genong (Eugene) Yu, GMU; Brian Falk, CIESIN;

GEOSS AIP-2 Testing Services Engineering Report

Scope: This document aims to provide a clear picture of the Test facility setup during GEO Architecture Implementation Pilot #2 (AIP-2). The Test Facility is an augmentation of the AIP-2 with respect AIP-1 of GEO. Main contributors to the Test Facility have been the European Space Agency (ESA) and the U.S. Geological Survey (USGS). Contributors have provided testing services that can be used by developer of GEOSS service and components to verify their implementation of protocols and standards. Test services have also been used during AIP-2 activities to test components against the Transverse Technology Use Cases and to support the Scenario demonstrations through the test of services used in the scenarios. Examples of performed tests are provided in the document.

Point of Contact Editor: Gianni Sotis, ESA. Contributing Editors: Michelle Anthony, USGS
4.3 Persistent exemplar services

An objective of AIP-2 was to increase the operational capability of GEOSS by focusing on components and services that provide a high availability and performance. These components are termed “persistent exemplars.” Persistent exemplars are the subset of CSR registered components that meet these criteria:

1. Registered in CSR: Component is registered in the GEOSS CSR with the Resource Availability field set to be “Continuously Operational”.
2. Standards-accessible services: The services associated with the “continuously operational components” are accessible through a GEOSS Interoperability Arrangements that is an international standard.
3. Level of service: Services are expected to be available at least 99% of the time, except when otherwise required by the nature of the service. This allows for approximately 7 hours of down time a month. Adequate network service must be provided in order to provide this level of availability.

It is planned that this definition will be entered into the GEOSS Best Practices Wiki for discussion.

As of 13 July 2009, the CSR lists 269 services associated with 231 components that meet criteria 1; and 192 services that meet criteria 1 and 2. AIP-2 has contributed to the establishment of this set of servers but not all of the persistent services were the result of AIP-2.

<table>
<thead>
<tr>
<th>Service Type</th>
<th>Number of Services meeting criteria 1 and 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catalog/Registry Service</td>
<td>21 services</td>
</tr>
<tr>
<td>Data Access</td>
<td>36 services</td>
</tr>
<tr>
<td>Portrayal and Display Service</td>
<td>131 (102 are WMS)</td>
</tr>
<tr>
<td>(Processing Services)</td>
<td>2 (both are WPS)</td>
</tr>
<tr>
<td>(Alerting)</td>
<td>2 (one CAP, one RSS)</td>
</tr>
<tr>
<td>Total</td>
<td>192</td>
</tr>
</tbody>
</table>

Criteria 1 and 2 are rather easy to assess. Criterion 3 is more difficult to assess and has not been attempted for this report. The emphasis in the future should be on assessing the operational status of the services that meet criteria 1 and 2 using the Service Test Facility created in AIP-2. By monitoring the operational status of the registered services, the overall availability and performance of GEOSS can be increased.

4.4 Lessons learned and recommendations

The following items are areas where AIP can continue to optimize the process and results towards meeting the objectives of GEOSS:

4.4.1 User involvement

Although user involvement has been a key since inception of AIP, it is important to continue increase engagement of the UIC and GEOSS users generally in the definition and elaboration of the GEOSS Architecture. As the Air Quality ER says, the ultimate goal of GEOSS is to improve the availability and usefulness of data and information for decision makers. The next phase of AIP should bring in more users into the process for evaluating the ability to make better use of data through the GCI and community infrastructures.

Prior to the start of AIP-2 there was consultation with the UIC about which SBAs on which to focus. Such a consultation should be done prior to the beginning of AIP-3. Coordination with UIC should also be accomplished
prior to the start of AIP-3 regarding a GEOSS User Typology. AIP-3 may consider coordination with the respondents to the UIC/CBC Decision Support CFP.

4.4.2 Stability of services

As the Disaster Management ER notes: Many components and services utilized in this AIP-2 scenario are prototypes of persistent exemplar data services, but most of them are pulled together on budgets gleaned by the individual AIP-2 participants who write proposal after proposal to granting agencies for competed funds to support the scenario. Funding needs to be allocated to support data delivery infrastructure capacity for integration of satellite data and value added services for local use in addition to funding the local utilization and capacity building activities.

4.4.3 Test Facility and Compliance

The Test Facility needs to be a permanent, sustainable resource. The Service Test Facility is intended to ensure proper and interoperable use of GEOSS components and services in applications and interfaces. The Test Facility is intended to promote predictable and reliable access to services registered with the GEOSS Service Registry. The facility will also enable periodic checking as to the availability and reliability of registered components and services, encourage cross-community implementations, and shorten prototyping cycles. The Air Quality ER suggests that the services used in GEOSS be compliant to the standards they implement. This compliance testing should be as determined by the standards body for the relevant service and encoding standard.

4.4.4 Data and Information

As noted in this ER and others, data and information are lesser-developed areas of the architecture in comparison to services, for example. Development is needed of an information architecture for GEOSS based upon international standards for geospatial information. An emphasis should be placed in AIP-3 in promoting access services that host a key datasets. This should be done in conjunction with the GEO Task DA-09-03 for Global Datasets. Many datasets are available from GEOSS organizations but they are not readily available. As the Air Quality and Polar Ecosystems ERs state, more should be done to engage providers to register data services. The Data Sharing Principles and Quality Assurance must be considered as part of a push for data services in AIP-3. Data Sharing Principles Task Force outcomes may require AIP to focus on the topics of GeoDRM, User Registration and Authentication. Development of information architecture can be aided through coordination with the GIGAS project.

4.4.5 End to End Discovery and Access

The End to End Discovery and Access ER makes several recommendations:

- GEOSS should anticipate heterogeneous metadata but promote minimum documentation for specific purposes, e.g. GEOSSRecord for discovery.
- GEOSS should aim to use existing standards/specifications and work through the proper channels where modifications to these standards/specifications are deemed appropriate.
- GEOSS should perform an analysis of the expected system load on the GCI in terms of numbers of users, numbers of resources. GEOSS should define (realistic) performance requirements based on the usability testing experiences.
- It is suggested that service level agreements be put in place supported by the proper resources to sustain the desired level of performance and availability.
- It is suggested that GEOSS engage in discussions with the appropriate standardization bodies to address the issue of including a globally unique metadata identifier as a mandatory item in the metadata specifications.
- It is suggested that GEOSS investigate the use of common authentication mechanisms or standards (such as OpenID)
4.4.6 Distributed search and metadata.

Further work is needed on the functions of the clearinghouse including coordination with the registries, harvest and searching of community catalogues and refinement of search metadata for GEOSS. The Air Quality ER suggests that a concerted effort is required in order to identify a core set of metadata elements needed for the Clearinghouses so that the metadata contents of community catalogs can fulfill those requirements and so that portals and applications submitting searches to the Clearinghouses have a clear understanding of what is retrievable from the Clearinghouses.

4.4.7 Sensors, Models, Processing and Workflow

AIP-1 deployed GWP and Clearinghouse with Registry. AIP-2 emphasized service deployment with an emphasis on access services. Future activities should consider additional service types. For example access to Sensor Web services including request for tasking of sensors and registries for sensor measurables. Access to predictive models should be addressed in some cases with the existing access services and in cases where the user is allowed to initiate the model, other services interfaces may be used such as processing services. Processing services in general should be considered. The Processing and Workflow demonstration video provides an excellent example using the OGC Web Processing Service. Use of services for semantic mediation should be increased building on the IP3 mediation services such as used in the Pikas Distribution ER. Workflow can be a general infrastructure capability to support chaining of the GEOSS services.

4.4.8 Reusable Community Process

The Use Case ER notes that as with the Internet, GEOSS is envisioned as a global and flexible network of content and service providers enabling decision makers to discover, access and integrate an extraordinary range of earth observing related information within their applications. To achieve this vision, the GEOSS architecture must provide an easy and reusable process to leverage the GEOSS Common Infrastructure (GCI) and components in support of many SBA communities. The AIP defined and piloted such a process for using and augmenting the GEOSS Common Infrastructure to meet SBA community needs. The process applies a system modeling methodology based on international standards tailored specifically to the GEOSS environment. This process should be used in AIP-3 and by other GEO tasks outside of AIP.

4.4.9 System Modeling

Each of the SBA WGs – with assistance from the INCOSE team – developed scenarios and associated UML models. The UML team has developed the UML RM-ODP Architecture for each of the scenarios using three views of the ISO/IEC 19793 modeling concepts and structuring rules. These views are Enterprise, Information and Computational. The remaining two views – Engineering and Technology – will be completed in AIP 3.

AIP-2 involved both “development through prototyping scenarios” along with development of “UML system engineering models”. The prototyping approach tends to discount the value of abstract, requirements-oriented modeling of UML. The UML process is typical of a system development process focused on robust definition of requirements prior to synthesis and implementation. A balance of the two activities was the focus of AIP-2: the software development was accomplished in parallel with modeling and so they are not in direct alignment. Continued refinement during iteration of AIP-3 will progress to a mature architecture.

4.4.10 Global Participation.

GEOSS is a global system. GEO has members and participating organizations from around the world. AIP had participation from many European and Northern American organizations. AIP-3 should establish methods to allow more global participation. For example, the AIP-2 Plenary telecons were typically held at 1200 UTC. We might consider alternating the starting time of the plenary between 1200 UTC and 2400 UTC.
4.4.11 AIP Connection with other Activities

Other GEO Tasks. AIP serves as an integration task for GEOSS with the result being consistent architecture and practices that can be used across SBAs. The validity of the architectures depends critically on coordination with the SBA tasks. Each of the SBA scenarios have a strong connection to the science of the topic of the SBA as seen through the references in the ERs. The coordination between AIP and SBA tasks should continue.

Coordination with GIGAS. The GEOSS, INSPIRE and GMES an Action in Support (GIGAS) promotes the coherent and interoperable development of the GMES, INSPIRE and GEOSS initiatives through their concerted adoption of standards, protocols, and open architectures. The results of AIP-2 will be made available to the GIGAS project. Interaction with GIGAS may increase inputs from INSPIRE and GMES into AIP-3, e.g., information architecture.

Coordination with CEOS. The CEOS Systems Engineering group is developing a set of observables definitions that is relevant to AIP-3. The WGISS Cal/Val group is leading a Quality Assurance activity – QA4EO – that can be considered in AIP-3.
5. AIP Development Process

5.1 Evolutionary development process overview

The AIP Task employs an “evolutionary development process”\(^\text{14}\) whereby the architecture, the delivered systems, and the stakeholders co-evolve. Stakeholder needs are reassessed with each iteration of the architecture; the architecture is used to guide each system as it moves through development, and appropriate versions are used to evaluate each system on delivery. Architectures developed under this approach emphasize flexibility and adaptability. This approach is well suited to software system development where it is impossible to postulate all of the requirements and the system development can proceed iteratively.

The AIP Development process consists of a series of phases, including the recent completion of phase 2 (AIP-2). Figure 9 shows the steps for a single phase. The main result of the Concept Development phase is a Call for Participation (CFP) that is released to the GEO Community. Organizations that respond to the CFP then gather for a Kickoff workshop for the phase that begins the development process. The Development Phase includes design development, design review and testing activities. A phase of AIP is completed with the delivery of demonstrations, Engineering Reports, and the transition of new functionality to persistent operations. The AIP evolutionary develop process is an application of the process defined and used in the OGC Interoperability Program. The OGC process has been used and refined in 35 testbeds and pilot initiatives, mostly notably for the development of the OGC Web Services Standards (OWS) baseline.

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Organizations participate in AIP in one or more of the roles listed in Table 7.

Table 7 – AIP Organizational Roles

<table>
<thead>
<tr>
<th>Role</th>
<th>Description of Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants</td>
<td>Participants are organizations that contribute to the definition of interfaces, prototypical implementations, scenario development and other support for the Pilot. Participants are defined as organizations that have committed to contribute in a &quot;substantial&quot; amount. Participants are represented in an Initiative by business and technical representatives.</td>
</tr>
<tr>
<td>IP team</td>
<td>The Interoperability Program (IP) Team is an engineering and management team to oversee and coordinate an Interoperability Initiative. The IP Team facilitates architectural discussions, synopsizes technology threads, and supports the specification editorial process. The AIP-2 IP Team was comprised of OGC staff, representatives from organizations, and OGC consultants.</td>
</tr>
<tr>
<td>Observers</td>
<td>Observers are organizations that have been granted access to the initiative communication tools but are not contributing as participants. Observers are given full access to email lists, initiative web sites and regularly scheduled initiative wide teleconferences. Observers may make recommendations and comments to the participants via any of these fora.</td>
</tr>
</tbody>
</table>

OGC would like to thank the organizations that sponsored the OGC efforts in AIP-2: The US Geological Survey, European Space Agency, European Commission (GIGAS), ERDAS and Northrop Grumman. OGC would like to also thank the members of the AIP-2 IP Team: Hervé Caumont, Nadine Alameh, and Josh Lieberman.

5.2 Concept development

Three main activities supported development of the concepts for AIP-2: 1) Results of AIP-1, 2) Interactions of the GEO User Interface Committee (UIC) and the Architecture and Data Committee (ADC), and 3) an AIP Architecture Workshop.

A summary of AIP-1 is documented in the “GEOSS Core Architecture Implementation Report.” The report provides an evaluation of the initial AIP results with a particular focus on pilot-level versions of several GEO Web Portals, Clearinghouses and Registries. The report provides descriptions of the implementations that have been achieved to date as well providing recommendations on how the implementations should continue.

In preparing for the definition of AIP-2, members of the ADC and UIC met at various times to discuss in particular which SBAs should be the focus of AIP-2. It was decided during a joint ADC/UIC meeting in November 2009 in Capetown, South Africa that AIP-2 should focus on 5 SBAs – Air Quality and Health, Biodiversity, Solar Energy, Disaster Response, Water/Drought Monitoring – and 2 new technical topics InterCalibration and Sensor Webs. This list was refined and narrowed in later activities.

A GEO ADC Architecture Workshop was held at the JRC in Ispra, Italy on February 4th and 5th, 2008 just prior to the ADC-6 meeting. The Architecture Workshop was an interactive event to develop requirements and design for AIP-2. Participants participated in the refinement of the architecture that became part of the AIP-2 Call for Participation. The workshop consisted of several plenary and breakout sessions. Breakout sessions were conducted on the topics of SBA scenarios, operational core components, sensor information infrastructure, and test facility to

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5.3 Call for participation

The Call for Participation (CFP) sought participants in the GEOSS Architecture Implementation Pilot (AIP). The CFP – as developed by the AIP Task Team – was announced by the GEO Secretariat on 30 June 2008. The CFP was composed of four items:

- GEO AIP Phase 2 CFP - Main Body
- GEO AIP Phase 2 CFP - Annex A: Development Process
- GEO AIP Phase 2 CFP - Annex B: Architecture
- Template for responses to AIP-2 CFP

Responses to the CFP received by 1 September 2008 were used to prepare for the Kickoff Workshop. Clarifications to the CFP were posted and discussed during a teleconference call on 18 July 2008.

This Call for Participation invited organizations associated with GEO Members and Participating Organizations to:

- Participate in the collaborative development of SBA scenarios to guide testing, demonstrations and operations of the identified interoperable services. Initial scenarios have been developed, in close coordination with the User Interface Committee, relevant GEO Tasks, and GEO Secretariat Experts.
- Provide services relevant to SBAs; where those services are deployed consistent with the GEOSS architecture based on Interoperability Arrangements. Participate in interoperability testing to confirm the architecture and including use of the GEOSS Core Infrastructure Components; and,
- Contribute to the refinement of the architecture and interoperability arrangements. Including refinement of the CFP architecture and interactions with the GEOSS ADC Standards and Interoperability Forum (SIF)

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16 Complete agenda, descriptions for each session, and links to presentations and positions papers for the Architecture Workshop, February 2009 are posted: http://www.ogcnetwork.net/node/347

17 http://www.ogcnetwork.net/AIPphase2CFP
5.4 Responses to the CFP

Listed below are the 38 responses to the Call for Participation in Phase 2 of the GEOSS Architecture Implementation Pilot. An analysis of the first 33 CFP Responses was developed to support planning for the AIP-2 Kickoff Workshop in September 2008. The remaining five CFP responses were received after the kickoff workshop.

- ACRF
- BKG
- Caribbean Flood Team
- CIESIN
- CNES and ERDAS
- Compusult
- EPA AirNow
- ERDAS Titan
- ESA
- ESIP AQ Cluster
- ESRI
- ESRI Canada
- EuroCryoClim
- GEO-Ukraine
- GEONETCast
- GEOGrid-AIST
- Giovanni
- ICAN
- ICT4EO
- INCOSE
- IP3
- ISPR
- JAXA
- KDDI
- Mines Paris Tech
- NASA World Wind
- NOAA/NASA GOES-R and GMU CSISS
- NOAA IOOS
- NOAA NCDC
- NOAA SNAAP
- Noblis
- Northrop Grumman
- Spot Image
- SURA/NIMSAT/GoMOOS
- USGS
- VIEWS
- Washington Univ. in St. Louis

5.5 Kickoff workshop

A key event in the AIP-2 process was a workshop convened with the AIP Participants to begin the development phase. To be most effective, organizations that responded to the CFP were encouraged to attend the Kickoff Workshop. This allowed the participants to meet in-person to plan the pilot as all subsequent activities are conducted using distributed communication mechanisms.

The AIP-2 Kickoff workshop was held at the National Center for Atmospheric Research (NCAR) Mesa Laboratory in Boulder, Colorado, USA on September 25 and 26, 2008. Eighty five (85) persons attended over the two-day kickoff event. After self-introductions of workshop attendees, the workshop began with a presentation of the analysis of the CFP responses that had been developed by the AIP-2 IP Team. The analysis provided the basis for selecting the topics to be discussed in follow on parallel sessions. Based on CFP Responses, three Plenary Sessions and twelve Parallel Sessions were convened at the kick off event.

Major results of the Kickoff Workshop were the establishment of Working Groups (WGs) and agreement on a Development Plan for the pilot. The WGs that were established along with the volunteers to lead the WG as follows:

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18 Summaries of the CFP responses and links to the responses are provided here: [http://www.ogcnetwork.net/node/395](http://www.ogcnetwork.net/node/395)
Community WGs
- Disaster Response WG: Stuart Frye, NASA; Didier Giacobbo, Spot Image
- Air Quality and Health WG: David McCabe, EPA; Frank Lindsay, NASA; Stefan Falke & Rudy Husar, Washington University – St. Louis.
- Biodiversity and Climate Change WG: Stefano Nativi, CNR; Gary Geller, NASA/JPL
- Energy WG: Thierry Ranchin & Lionel Menard, Mines Paris Tech; Ellsworth LeDrew, Univ Waterloo;

Transverse Technology WGs:
- Catalogues, Clearinghouse, Registries and Metadata WG: Doug Nebert, USGS; Josh Lieberman OGC/Traverse; Ted Haberman, NOAA
- Workflow and Processing WG: Greg Yetman, CIESIN; Eugene Yu, GMU; Satoshi Sekiguchi, AIST;
- Test Facility for service registration WG: Gianni Sotis, Mauro Semerano, ESA
- Portals and application clients WG: Nadine Alameh, OGC/Mobilaps; Herve' Caumont, OGC/ERDAS
- Access Services: products, sensors, models WG: Herve' Caumont, OGC/ERDAS; Glenn Rutledge NOAA; Hans Peter Plag, UNR; Anwar Vahed, ICT4EO; Luis Bermudez SURA;

5.6 Design development and review

The AIP Design Development process focused on development of Scenarios and Use Cases. The Scenarios describe how GEOSS is envisioned to support the SBA Communities of Practice. The Use Cases are reusable transverse technology approaches for implementing the scenarios. For a full description of the process see Section 3.2. The design development began after the kickoff and continued into the testing activities.

An Interim Design Review for the AIP-2 Development was held on 2 December 2008 in Valencia Spain. AIP-2 Working Groups presented their status with a focus on Scenarios and Use Cases. Various changes to the initial design were identified along with actions to correct the direction of the development.

5.7 Testing

A plan for AIP-2 Test and Demonstration was developed and agreed by the AIP-2 Participants. The process was tailored to the specific environment of GEOSS considering that there was not a separate testing team. The testing was done at two levels: 1) unit testing of individual services as defined in use cases, and 2) integrated testing of scenarios. The test plan was organized around two iterations of unit testing followed by a single scenario testing.

The overall phasing of the AIP-2 Test Plan is shown in Figure 10. It should be noted that the testing phase did not fully meet these milestones. Unit Test Period 1 was consumed mainly with organizing a test log and notification mechanism. It also seemed as if there was little emphasis on unit testing by the client and service providers. As the test methods and tools are now better defined it is anticipated that testing could happen more efficiently in AIP-3.
5.8 Demonstration

The demonstrations of AIP-2 development are focused on the SBA Scenarios, the GEO Web Portals and several transverse topics. The AIP-2 Demo Capture workshop was conducted 4-5 May 2009 in Stresa, Italy. The Demo Capture workshop convened the demo developers to coordinate on the production of the demo videos. Each of the videos was developed based upon a template common to all videos and a storyboard specific to each demo. Video of the demo was captured and edited with desktop video tools such as Camtasia and IShowU.

Several of the demonstration videos were presented on 7-8 May to the GEO ADC and UIC meetings also held in Stresa, Italy. The complete set of demonstration videos have been packaged with an overall menu and introduction to AIP and are available on the web\textsuperscript{19} and on DVDs.

5.9 Delivery and transition to operations

The major deliverable items of AIP-2 consist of three types: 1) demonstration videos, 2) engineering reports, and 3) augmentation of the GEOSS Common Infrastructure (GCI). The demonstration videos were described in the preceding section. The engineering reports are described in Section 4.2. The augmentation of GCI will occur over several months following the completion of AIP-2. AIP-2 results will be presented to the several GEO Committees, to GCI Task Force, to various SBA groups external to GEO and to the GEO Plenary in November 2009. These presentations will inform the various groups of the AIP-2 developments and new functionality that has been developed. It is anticipated that the new functionality will contribute to the advance of the GCI beyond the Initial

\textsuperscript{19} URL for Demo videos
Operating Capability. Further it is anticipated that the SBA focus in AIP-2 will be bringing a new level of capability to those SBAs specifically addressed in AIP-2 and to other SBAs through use of the reusable SBA process developed in AIP-2.

5.10 Communication mechanisms

The communications mechanisms of AIP-2 were designed to support development of the Initiative given the geographically distributed locations of the participants. To be effective, the communication mechanisms needed to support the iterative, evolutionary development process.

Telecons were a main means of communication during AIP-2 for communications. An AIP Plenary telecon was held almost every week. Each of the Working Groups held telecons as needed. The Plenary telecon discussions have been posted on a public web site.20

E-mail list-servers were created for the AIP Plenary and for each of the Working Groups. These lists serve to capture a record of the communications. Several were used in AIP-1 and some will be used in AIP-3.21

A major innovation in AIP-2 was the use of Google Sites as a collaborative workspace. Each of the Working Groups had a workspace. Development of the scenarios and the use cases was heavily conducted using the Google Sites pages. The Google Sites provided an excellent dynamic workspace suited to the working groups day-to-day collaboration over the course of the development. Results of the development were captured in the OGC Network website pages, which were less fluid.

5.11 Postscript

The AIP evolutionary development process has been tuned to the GEOSS environment. We realize that in a system as large and complex as contemplated by GEOSS, it is not possible to state in advance the end design. Our approach is to experiment with prototypes that are adapted to the user needs, while simultaneously capturing and increasing our knowledge about GEOSS. Our process can be informed by the approach of Leonardo da Vinci:

“First I shall do some experiments before I proceed farther, because my intention is to cite experience first and then with reasoning show why such experience is bound to operate in such a way. And this is the true rule by which those who speculate about the effects of nature must proceed.”23

20 http://www.ogcnetwork.net/AIPtelecons
21 http://www.ogcnetwork.net/AIPilotLists
22 https://sites.google.com/site/geosspilot2/Home
23 - Leonardo da Vinci, Notebooks, 1513
6. Acronyms

ADC    Architecture and Data Committee (GEOSS)
AIP-2  Architecture Implementation Pilot, Phase 2
BPEL   Business Process Execution Language (OASIS)
CAP    Common Alerting Protocol
CEOS   Committee on Earth Observation Satellites
CFP    Call for Participation
CSR    Component and Service Registry (GEOSS)
CSW    Catalogue Service for the Web (OGC)
ER     Engineering Report
ESA    European Space Agency
ftp    file transfer protocol
GCI    GEOSS Common Infrastructure
GEO    Group on Earth Observations
GeoDRM Geospatial Digital Rights Management
GeoRSS Geospatial RSS
GEOSS  Global Earth Observation System of Systems
GIGAS  The GEOSS, INSPIRE and GMES an Action in Support
http   hyper-text transfer protocol
IOC    Initial Operating Capability
IP Team Interoperability Program Team
KML    formerly “Keyhole Markup Language” (OGC)
OGC    Open Geospatial Consortium
OpenDAP Open Data Access Protocol
OWS    OGC Web Services
RM-ODP Reference Model of the Open Distributed Processing
RSS    Really Simple Syndication
SBA    Societal Benefit Areas
SIR    Standards and Interoperability Registry (GEOSS)
SoA    Service Oriented Architecture
SOS    Sensor Observation Service (SOS)
SPS    Sensor Planning Service (SOS)
UIC    User Interface Committee (GEOSS)
UML    Unified Modeling Language (OMG)
USGS   U.S. Geological Survey
WCS    Web Coverage Service (OGC)
WFS    Web Feature Service (OGC)
WMS    Web Map Service (OGC)
WPS    Web Processing Service (OGC)