The Cybercartographic Atlas of Antarctica: Towards Implementation

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Abstract

This paper provides an overview of progress to date and future directions for implementation of the Cybercartographic Atlas of Antarctica (The Atlas). The Atlas project was formally adopted as an official WG-GGI project at a meeting of project coordinators in Sienna in July, 2001. The goal of the project is to develop an on-line atlas, covering a broad range of issues and using content that takes advantage of existing sources of data, particularly those created by SCAR programs. This approach presents challenges with respect to data discovery, sharing, interoperability of systems and data representation. An essential model that aims to establish links between real-world issues and proposed Atlas systems is presented. The essential model is extended to form an initial abstract model outlining requisite standards and services. The paper presents a discussion of implementation based on progress to date. The work concludes with a discussion of future work and an invitation for comment by interested stakeholders.

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1 INTRODUCTION

This paper has 4 objectives as follows:

1. Provide background to and update on the Cybercartographic Atlas of Antarctica (The Atlas)
2. Present a high level essential (real-world) model for The Atlas
3. Outline a preliminary abstract model for The Atlas
4. Indicate directions for The Atlas in terms of implementation technologies

1.1 Background

The term "cybercartography" was first introduced in 1997 at the International Cartographic Association (ICA) meeting in Stockholm (Taylor, 1997). Cybercartography is a theoretical construct that aims to capture recent developments in cartography and related disciplines. The idea for a cybercartographic atlas of Antarctica was first put forward by Dr. Daniel Vergani

Presented at the 2nd International Antarctic GIS Workshop (SCAR GI Technical Experts Meeting). Institut f. Physische Geographie Universität Freiburg, Freiburg, Germany, April 7th -11th, 2003.

(Argentina) following work on a cybercartographic atlas of Latin America (http://www.atlaslatinoamerica.org). In collaboration with Dr. Vergani, development of The Atlas has been led by The Geomatics and Cartographic Research Centre (GCRC) at Carleton University, Ottawa, Canada.

The Canadian Committee for Antarctic Research discussed and approved the project in 1999. The work was then presented to the Scientific Committee on Antarctic Research's Working Group on Geodesy and Geographic Information (SCAR WG-GGI) meeting in Tokyo, in July 2000. The project was formally adopted by SCAR WG-GGI at its meeting in Siena, Italy in July 2001. A development workshop in Puerto Madryn, Argentina in December 2001 brought together a number of key stakeholders to discuss the conceptualization and initial design phases of the project. A second workshop in Ottawa (May, 2002) further developed The Atlas concept and design by identifying specific atlas elements.

Partnerships have been, and will continue to be, critical to the success of the project. Currently, there are a number of formal partner nations involved. These include: Argentina Australia, Belgium, Canada, Chile, China, Germany, Poland, United Kingdom and the United States.

A number of new partnerships are currently being developed. Representatives from Gateway Antarctica (New Zealand) have voiced interest in participating with details to be determined during the summer of 2003. Recently, The Atlas staff have been collaborating with members of an Ottawa-based group of educators named Students on Ice (SOI) (http://www.studentsonice.com/). We expect that SOI and the students with whom they work will be key participants during the user needs analysis and user testing phases of the project. The development of partnerships and relevant collaborative relationships is ongoing.

1.2 Cybercartography and the New Economy

The concept of cybercartography is covered in detail by Taylor (2003). The concept sees a cybercartographic product as:

- Multisensory
- Multimedia
- Interactive
- Comprising an information package
- Developed by interdisciplinary teams
- Forming new partnerships
- Applicable to a wide variety of subjects

These elements guide research in cybercartographic theory and methods.

A key development challenge, and the focus of efforts to date, has been to secure a stable source of funding for research and development. After a multi-stage application process, GCRC was recently awarded a major collaborative initiatives research grant. The four year project, titled

Cybercartography and the New Economy is being funded by the Social Sciences and Humanities Research Council of Canada under The Initiative on the New Economy (INE) program. The research focuses on Human interaction[1] with geospatial information, a topic which has been recognized but not well addressed by major standards initiatives (OGC, 2003:23). The project includes collaborators from a number of disciplines including Psychology, Cognitive Science, English, Economics, International Studies, Music and Film Studies. A human oriented development approach will be adopted. Central to this approach is the involvement of product users from the outset of development efforts. To maintain consistency with this approach, detailed technical specifications will be developed throughout the user needs analysis process.

The ideas presented in the following sections are based on work carried out during previous workshops and subsequent communications with various stakeholders. Section 2, termed the essential model, provides a brief overview of the objectives of The Atlas, potential uses, proposed themes and SCAR stakeholders. Section 3 presents a preliminary abstract model that identifies a Web services model for addressing challenges of data discovery, sharing and interoperability. Section 4 provides a list of the technologies being considered for use during the implementation phase.

2 ESSENTIAL MODEL

For the purposes of this paper, an essential model aims to describe the real-world considerations related to development of The Atlas. This includes objectives of The Atlas, potential uses, proposed themes and SCAR stakeholders.

2.1 Objectives

The stated objectives of The Atlas are as follows (Taylor and Pulsifer, 2002):

- Create an innovative new product and methodology to compliment discovering, utilizing, presenting and distributing existing information and data about Antarctica to a wide variety of users, including scientists, decision makers and the general public
- Facilitate increased cooperation and information exchange between Antarctic stakeholders under the terms of the Antarctic treaty
- Through international cooperation, develop and link National Atlases of Antarctica

As emphasized, the intention is to maximize the utility of existing sources of information on Antarctica. Organizations like SCAR and the Joint Commission on Antarctic Data Management can play a key role in facilitating access to information resources.

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[1] see (ISO, 2003: 19100 series). Human interaction deals with services for managing user interfaces, graphics, multimedia, and presenting compound documents.

2.2 Potential Uses

The potential uses for cybercartographic atlas products are numerous (Carwright and Peterson, 1999; Taylor, 2003). Applications will vary depending on the user audience. The current research will study three user groups as identified in the objectives section (scientists, policy makers and general public). Application requirements for each of the identified groups are expected to vary considerably.

In the case of scientific users, initial interest has been in the use of The Atlas to acquire, integrate and analyze geographic information. In particular, the ability to visualize and analyze spatio-temporal datasets is an area in need of further research (Prentice, M.: pers. comm.). Some possible scientific applications include:

- 4D cartographic visualization (3D animation) using data from distributed databases
- Composite map construction using distributed databases while integrating sensors on the ground in near real-time
- Use of a cartographic interface to locate research texts and dynamically link geographic references in the text to other geographic information

Initial perceptions are that policy makers will use The Atlas to integrate and analyze geographic information to support policy decisions. Cordonnery (1999) identifies benefits in using GIS to support policy development in an Antarctic context. Research carried out as part of The Atlas project aims to contribute to applied research of this sort. Some possible policy applications include:

- Obtain relevant geographic information for a topic of interest to policy making i.e. decisions related to the Commission on Environmental Protection
- Dynamically link textual data (i.e. Antarctic treaty) to geographic information. This may include an historical scale temporal component comparing older maps with the recent maps and geographic information
- Through links to other Atlas modules, identify science programs that may inform decisions.

For a general public audience, the desire for a teaching focus has been identified. The Atlas may be used as a teaching tool that provides thematically based synthesis of information. Some specific uses may include:

- Obtain geospatial and textual information on a particular topic of interest
- Find data for general purpose research i.e. a school project, personal interest
- Link popular textual data sources (i.e. travel diaries) to geographic information

The relationship with Students on Ice previously stated will be important in identifying the needs of high-school aged students in a Canadian context.

For all user groups, the potential exists to include cartographic visualization to support information discovery and knowledge generation (MacEachren et al., 1999). This method would make use of metadata repositories and catalog services to provide users with a cartographic representation of an information domain. The private sector has developed a number of operational implementations that use this approach (see for example http://antarctica.net/ ; http://www.kartoo.com/). While these products are now available, there is no consensus on the effectiveness of visualizing knowledge domains (Rosenfield and Morville, 2002:129). This uncertainty presents a research opportunity for the project.

2.3 Proposed Themes

Various themes have been proposed during previous workshops. The reader is directed to the SCAR Geoscience Standing Group Website for more detail (http://www.geoscience.scar.org/meetings/index.htm). Some themes of note include: Ice (characteristics, processes and effects); historical exploration of the Antarctic; Declining seal population; Geodesy in Antarctica; Antarctica and Global Climate Change.

2.4 SCAR Stakeholders

The importance of partnerships for The Atlas has already been stated. Figure 1 provides a graphic representation of some of the SCAR stakeholders who may benefit from or contribute to The Atlas.

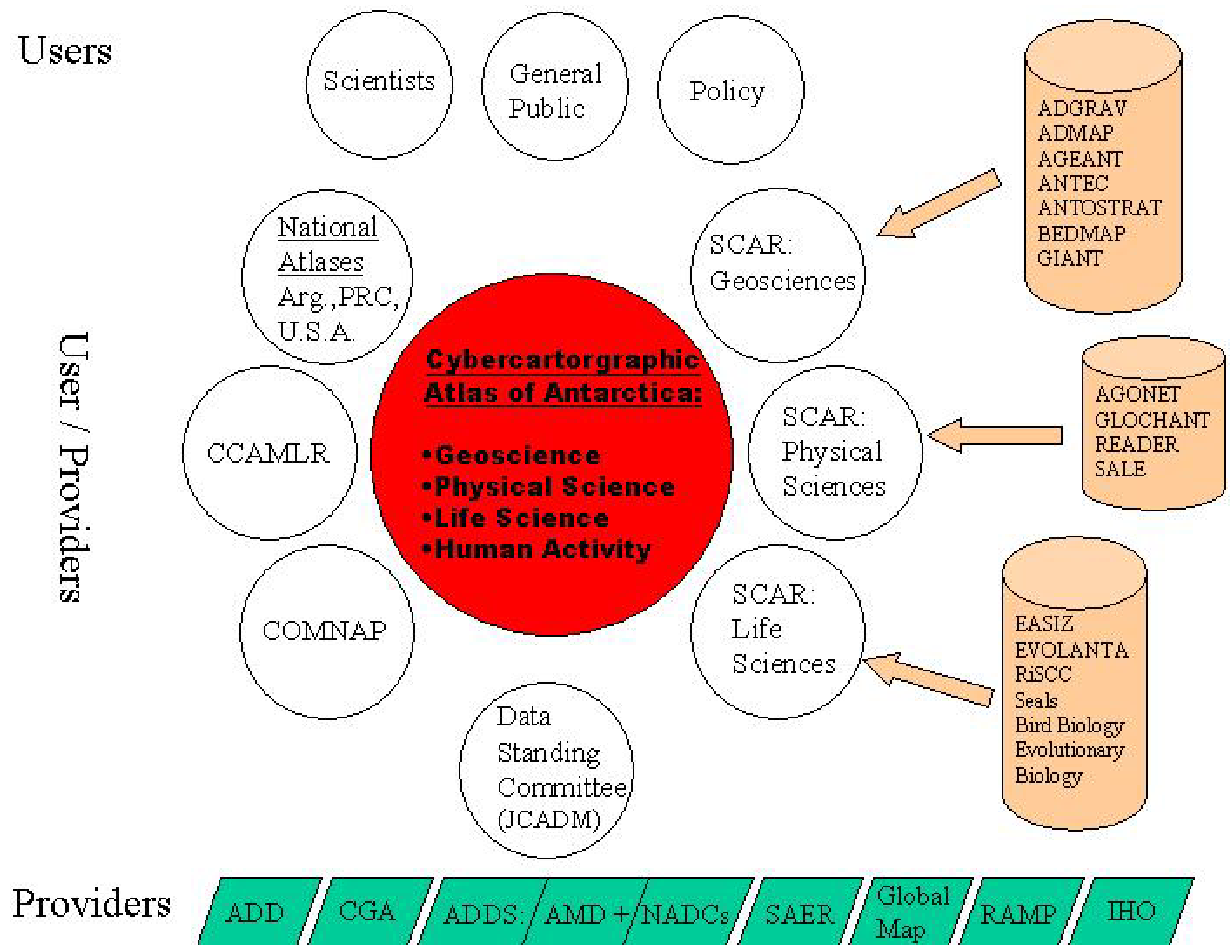

Figure 1. Potential Atlas stakeholders. Stakeholders are identified based on their role as user, provider or user/provider. These roles may change over time (after Taylor and Pulsifer, 2002).

The essential model will be further developed through the user needs analysis process beginning in May of 2003.

3 PRELIMINARY ABSTRACT MODEL

During the Ottawa workshop there was agreement on the adoption of a standards based approach for the development of The Atlas (SCAR, 2002). Key standards to be observed during production are International Organization for Standardization's 191xx series developed by technical committee 211 (TC211) – Geographic Information and Geomatics (ISO, 2003) and the OpenGIS consortium's OpenGIS Reference Model (ORM) and implementation specifications (OGC, 2003).

GCRC works closely with Natural Resources Canada, the lead federal agency for the Canadian Geospatial Data Infrastructure. Concepts from their architecture model are also being considered (CGDI, 2001). CGDI has been closely associated with ISO efforts and observing OGC developments. Thus the CGDI architecture is consistent with ISO/OGC visions and standards (CGDI, 2001:15).

The abstract model subsequently presented attempts to observe and incorporate work previously done through SCAR initiatives such as the SCAR Feature Type Catalog, The Composite Gazetteer of Antarctica and various national Antarctic atlases. During the course of this workshop, further efforts will be made to promote consistency between SCAR geographic information initiatives and The Atlas.

For reasons previously stated[2], the ideas put forward here are not an abstract model in the true sense in that they cannot be directly used to establish implementation specifications. The intention is to present an initial framework that goes beyond concepts and towards implementation.

Following Brolsma and Ryan (2002) the data and information acquisition strategy for The Atlas is based an a distributed systems approach. In keeping with the project principle to use existing data resources, the creation of hub specific databases will be minimal. We see the hub as a container object that will aggregate data provided by partner systems. The value added by the hub will be in the transformation of data and information into an integrated source of geographic information that addresses user-defined themes or issues.

To support a distributed systems method, a Web services architecture is proposed.

3.1 Web Service Architecture

The proposed architecture for The Atlas is one based on Web services. A service is defined as a collection of operations, accessible through an interface, that allows a user to evoke a behaviour of value to the user (ISO, 2003: 19119).

Antarctic science is carried out across a broad range of disciplines and is executed through a large number of organizations. To maximize access to data and minimize effort in terms of database conversion, development and maintenance, an architecture that utilizes relatively ubiquitous resources is needed. A Web services architecture is based on the use of the Internet Protocol and common transport mechanism such as HyperText Transer Protocol (HTTP) and Extensible Markup Lanaguage (XML) to allow communication between distributed systems. Services within this architecture are seen as functional units or components in which implementation details are hidden from the user and operations accessed through a well-defined interface. In the context of providing geospatial data services, this architectural model also assumes the use of standard geospatial data reference models and associated encodings to facilitate information sharing. This type of architecture is implied by Brolsma and Ryan's

[2] user centred design has been adopted which dictates that design details are established in consultation with users. refer to introduction section

“Component Model” for a SCAR distributed data network (Brolsma and Ryan, 2002) and thus should allow for integration of The Atlas into the network.

For simplicity, the Web Service Architecture proposed for The Atlas will be referred to as the WSA. The WSA adopts a computational viewpoint that is concerned with the functional decomposition of the system into a set of services that interact at interfaces. As a means of organizing the discussion, the WSA uses the OpenGIS Service Framework (OSF - OGC, 2003:33) to categorize the services needed for The Atlas. The OSF is a profile of the OGC/ISO –19119 service taxonomy and organizes services into five categories as follows:

- Application services
- Portrayal services
- Processing Services
- Data Services
- Registry Services

The OSF has been designed to meet a number of purposes including the enabling of interoperable services through standard interfaces and encodings. This meets The Atlas requirement previously identified. In addition, a publish, find and bind pattern is supported whereby a service provider publishes services to a broker (registry service). Service requestors then use the broker to find the appropriate service and subsequently bind to the service (OGC, 2003:30). This pattern is illustrated in Figure 2. Table 1 establishes the relationship between the OSF categories presented and the ISO 19119 service categories. The ISO categories provide a higher level description of services that are less useful for this discussion.

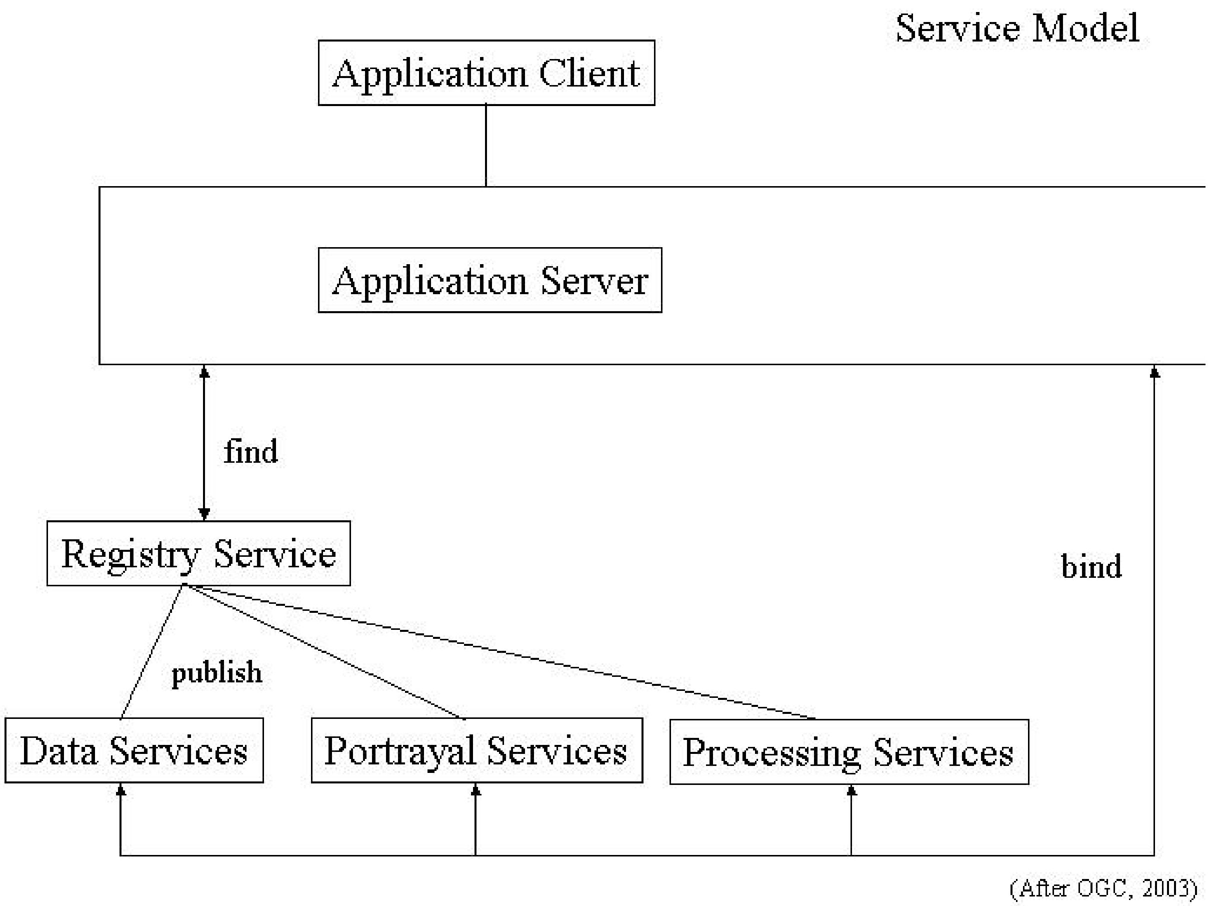

Figure 2. The OpenGIS Services Framework.. Services operate within a publish, find, bind pattern.

OSF Service Category	**ISO 19119 Service Taxonomy Categories**
Application Services	Geographic Human Interaction
Portrayal Services	Geographic Human Interaction
Processing Services	Geographic Information Management
Data Services	Geographic Information Management
Registry Services	Geographic Information Management

Table 1. Relationship between the OSF categories and ISO 19119 service categories

Figure 3 illustrates how the OSF categories may be implemented in the WSA. Data are provided to The Atlas by existing services maintained by partners. From this viewpoint, potential partners (i.e. U.S.G.S. Atlas of Antarctic Research, KGIS) act as *data services* that respond to data requests from The Atlas hub. The hub then acts as a *processing service* that performs necessary query, transformation or integration operations. The results of these processes are then acted upon by the *portrayal service* with the result being the generation of maps, visualizations or other cartographic products. The *portrayal service* results are delivered to the *application service*. The *application service* integrates the cartographic products with other types of information to produce a specific product to serve the needs of a particular user group.

It is important to note that The Atlas can also act as a *data service* providing other systems access to data using standard interfaces and encodings. A second point of elaboration is that the *portrayal service* is seen as separate from the *application service*. Maps and cartographic visualization products are only one element of a cybercartographic system. Thus, a service that simply produces maps is not seen as an *application service*. In a real-world implementation scenario, detection of this separation may be difficult.

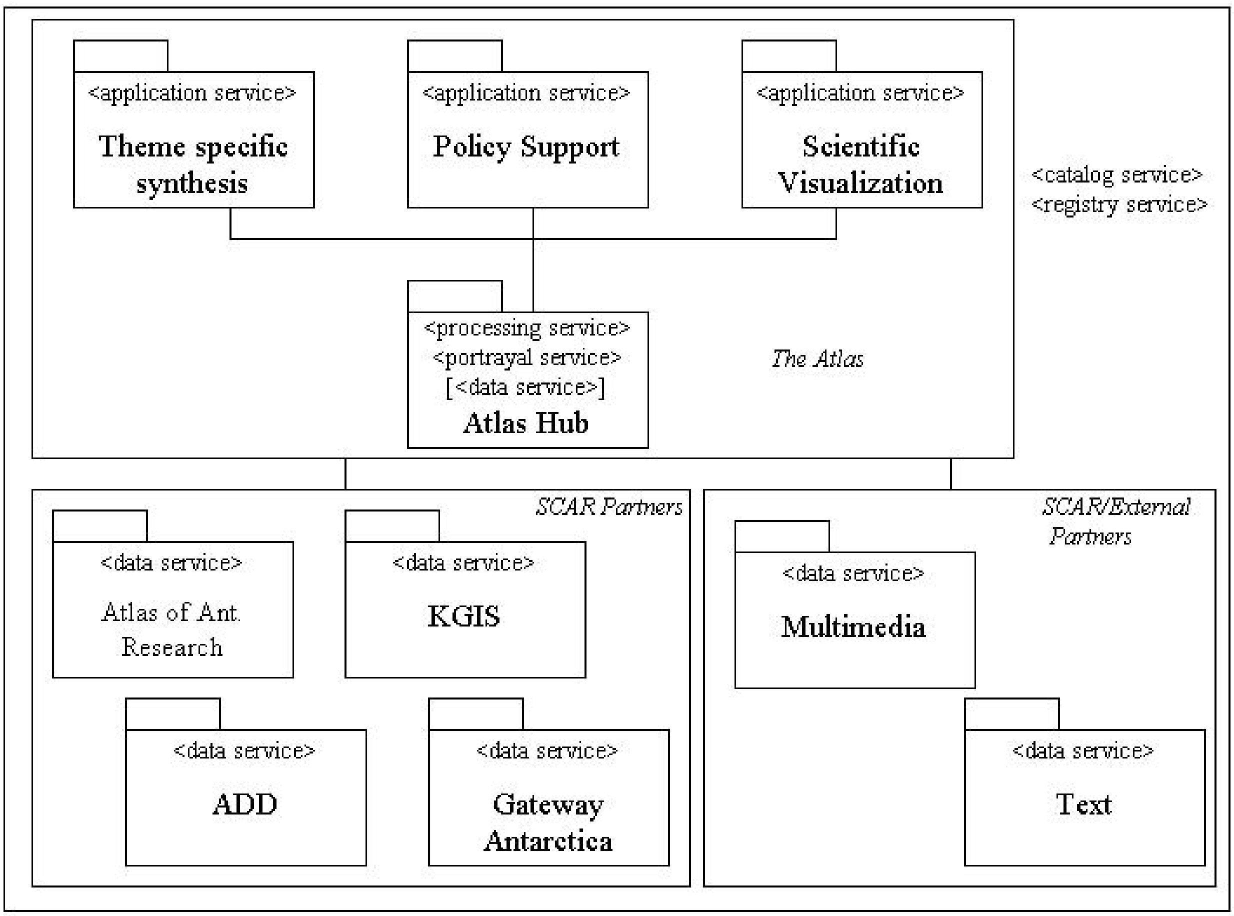

Figure 3. Possible implementation of the a Web Services Architecture for The Atlas. Partners maintain data services that support other services. For purposes of clarity, specifics services are displayed. These values are arbitrary.

3.2 Atlas Services

The services ultimately incorporated into The Atlas will be defined during the user needs analysis process. However, based on a review of the essential model presented in section 2, the following section identifies services that may be required. They are listed by service category.

3.2.1 Application services

A variety of application services may be needed to serve user needs. Some of the applications will be as simple as a Map Viewer, while others may include a number of application types, aggregating services and combining them for delivery to a user agent.

- Map\Terrain\Image viewer (including tactile)
- Cartographic visualization data discovery application
- Geocoded text viewer (text dynamically linked to geographic information)
- Picture display
- Sonic\haptic\[olfactory] display
- Video\animation playback

3.2.2 Portrayal services

Investigation of new ways for portraying geographic information will be a central element in The Atlas research. Some of the services involved may include:

- Map portrayal service
- Coverage portrayal service (i.e. Satellite imagery, shaded relief etc.)
- Terrain portrayal service (i.e. 3D visualizations)
- Mobile presentation services (i.e. for cellular phones)

3.2.3 Processing services

While many of the processing services needed are expected to exist outside of the hub system, the first two listed may be incorporated into the atlas.

- Geofusion
- Semantic translation
- Geocoding/ Gazetteer
- Coordinate transformation
- Image classification
- Advanced modelling

Geofusion refers to the creation of explicit relationships between geographic features that are somehow the "same" but described differently in different sources, and that may also be presented in different media (OGC, 2001b). Figure 4 illustrates the relationship between services in a Geofusion system. Geofusion will be described further in section 4.

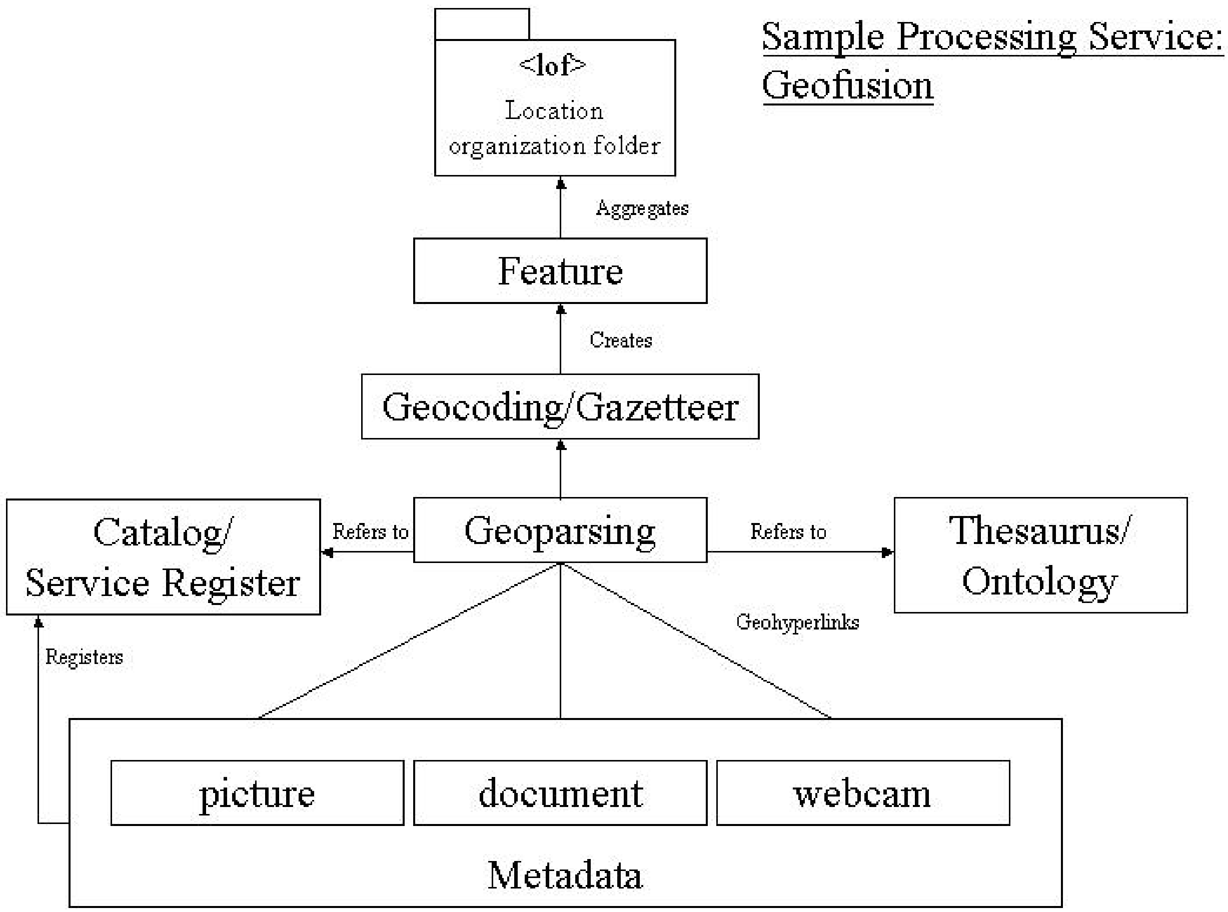

Figure 4. Geofusion: the geoparser service analyzes text and other contextual data to establish a spatial reference for a variety of media types. At the application service level, these relationships are managed in a Location Organization File (see section 4)

If databases are semantically heterogeneous, that is they are use different vocabularies, or are based on different geographic conceptualizations, then some type of semantic translation is required to allow sharing of data. The use of formal ontologies for semantic translation of geospatial data has been an active area of research (Winter, 2001). A detailed discussion of formal ontologies is beyond the scope of this paper, however their application potential will be explored as part of The Atlas research.

3.2.4 Data services

The implementation details of data services will be the responsibility of each partner. If the data service is to be used by The Atlas, then the service must be able to encode requested data in a standard format (i.e. Geographic Markup Language).

3.2.5 Registry services

A registry server will be critical for discovery of data and services required by The Atlas. A catalog will be established at the Atlas hub. This service will need to connect to any other catalog services or metadata databases relevant or of interest to user groups. The basic services required will be:

- Catalog service for dataset metadata
- Service registry for service metadata

4 IMPLEMENTATION

The following section discusses directions for The Atlas in terms of implementation technologies. The discussion is organized by WSA service category.

4.1 Application Services

Application services will use a wide variety of technology. Of particular interest is the use of a Geofusion approach as outlined in section 3. This involves the use of the OGC's GML based Location Organization Folders (LOF) as generated by a Geofusion processing service. LOFs are not yet standardized, however we will work with the standards community to promote standardization. At the application services level, standard application programming and transformation tools such as JAVA and Extensible Stylesheet Transformations (XSLT – see http://www.w3c.org) will be used to process and transform data.

A number of products including the Web Map Composer developed and marketed by the Australian company Social Change Online (http://webmap.socialchange.net.au), the University of Minnesota Mapserver (http://mapserver.gis.umn.edu) and commercial products such as ESRI's ArcIMS are also being considered for use as in developing both application and data services.

4.2 Portrayal Services

Standard portrayal services have not yet been implemented within the geomatics community. In the interim, Web standards developed through the World Wide Web Consortium and de-facto standards will be adopted. Two standards of particular interest are the W3C's Scalable Vector

Graphics (SVG)(http://www.w3c.org/svg). SVG is an XML based graphics standard that supports client-side vector representation including animation. In the short time that it has been available, SVG has generated a great deal of interest in the cartographic research community (i..e. Neumann et al., 2001). Currently, SVG is being proposed as on of the standard graphics format for use in The Atlas.

To support 3D and 4D visualization, The Atlas will need to adopt a Web enabled technology that supports portrayal of 3D and 4D space-time. The Virtual Reality Modelling Language (VRML) has been used for 3D animation for a number of years. Although VRML was standardized by ISO in 1997, the standard did not explicitly address issues specific to geospatial data i.e. storage and display of very precise coordinates (Rhyne, 1999). In 1998, a working group was formed within the Web3D consortium[3] to deal with the issues. Building on the ISO VRML standard, the working group has produced the GeoVRML specification. This specification aims to enable the viewing of 3D geospatial data using a Web browser and standard VRML technology. GeoVRML is one of the tools being considered for use in The Atlas. Among its advantages is that it can be exported from industry standard GIS software such as ESRI's ArcView. This capability will allow for rapid prototype that may not be possible with more advanced solutions such as JAVA3D. A combination of technologies may be used – simpler technologies like GeoVRML for prototype development and more robust solutions for production.

An advantage provided by both SVG and GeoVRML is that they are not compiled and can be generated, for example, through transformation of an XML document such as a map or terrain model encoded with GML. Dynamic links to other resources and media can be embedded in the map or rendering during the transformation process.

Portraying coverage data such as satellite imagery and cartographically processed DEMs presents a major challenge in a Web environment. Bandwidth constraints coupled with typically large file sizes limits the possibilities for raster representation of coverage data. To try to address this challenge, GCRC has recently partnered with a private sector firm, Innotive Canada. Innotive's iBrowser technology uses various hardware and techniques to effectively deal with very large image databases. In initial trials, GCRC has been effectively working with display and roaming of image databases with dimensions of approximately 10K x 10K pixels (RGB) over a 10Mebabit Per Second Ethernet network. Initial results are very encouraging, however further testing using Internet will be the next step. GCRC will also be assisting Innotive in working towards standards compliance.

4.3 Processing services:

Implementations for processing services developed within The Atlas have yet to be defined, however for standard services such as coordinate transformation and geocoding, various industry standard and public domain applications will be considered (i.e. ESRI, FME, Proj4 etc.). The intention is to, where possible use partners' processing services (i.e. The Composite Gazetteer of Antarctica).

[3] An organization concerned with developing standards for representing 3D space using Web technology

Geofusion, a processing service introduced in section 3.2.3 will be important to The Atlas. To date, there are no existing Geofusion products per se, however a number of companies are developing packages. Experimental Geofusion implementations have made use of a number services to support the creation of a "Location Organization Folder" or LOF. A LOF is an XML file based on the Geographic Markup Language that holds the relationships between features.

In terms of semantic translation, A formal ontology processing service may also be implemented to negotiate semantic differences between database services (See for example Fonseca et al., 2002; Raubal, 2001; Stock and Pullar, 1999). This service could make use of the SCAR Feature Type Catalog and other semantics databases.

4.4 Data Services:

Some data services that may be required to serve the atlas are:

- Web Feature Service
- Web Coverage Service
- Web Terrain Service (OGC, 2001a) (Future)
- Sensor Collection Service using SensorML (OGC, 2003:58)

Implementations of the Web Feature Service are becoming widely available. It is hoped that in the near future, the same will be true for Web Coverage Services. The Web Terrain Service is currently at the (early) discussion paper stage in the standards process. The proposed Sensor Collection Service (OGC, 2003:58), if developed further, may provide a practical method of incorporating data from in-situ sensors.

Figure 5 presents a hypothetical data services node with specific data service examples.

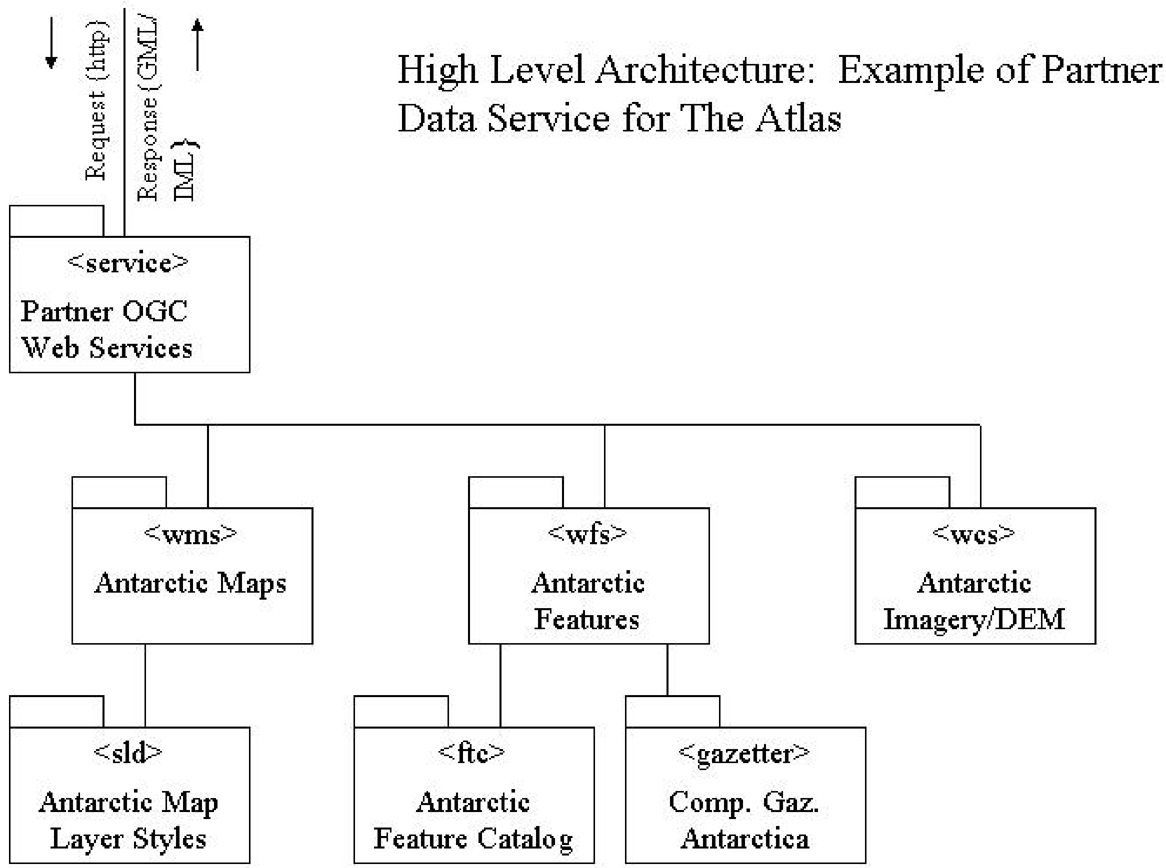

Figure 5. Hypothetical data services configuration. Note that a number of data services are aggregated at a partner node.

4.5 Registry services:

At present, no decisions have been made with respect to registry services. To better inform the research and development, GCRC will consult SCAR stakeholders and our partners, Natural Resources to draw on their extensive experience in this domain. This will include investigating the acquisition or development of visualization based information discovery tools as discussed in section 2.2.

With respect to metadata and cataloging, an issue requiring further research is the use of the DIF standard for describing SCAR databases. This standard will need to be examined in detail to establish how it can be integrated into The Atlas.

4.6 Sample implementation

Figure 6 presents a diagram illustrating how a variety of technologies could be integrated to develop a WAS architecture to support the production of The Atlas or an Atlas partner node. Of importance in this instance is that the technologies listed have free or low-cost licenses (although many require Web/software development skills). A variety of system implementations will be explored to ensure that partners with limited resources will be able to participate in The Atlas project.

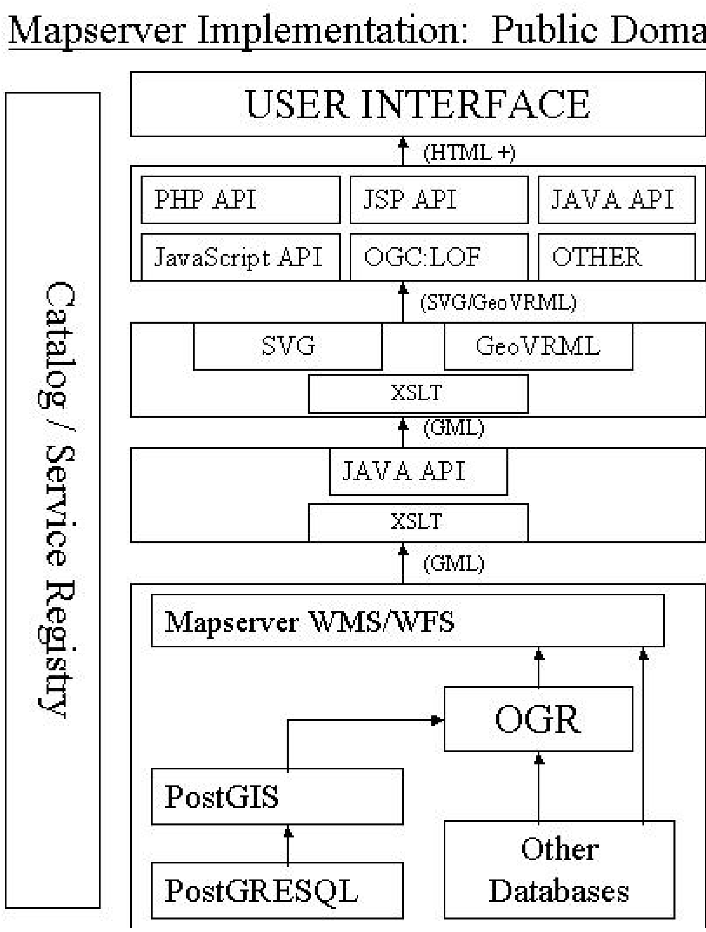

Figure 6. A WAS architecture base on low-cost or public domain software. Although in the public domain, many of these applications (i.e. PostGreSQL and Mapserver) are well tested with a large user base.

4.7 Encoding

The key to transferring and sharing geospatial data between partner Web service nodes will be standardized encoding of the data. At present, the plan is to implement the Geographic Markup

Language (ISO, 2003; OGC, 2003)for encoding feature type data. Discussions with SCAR stakeholder with regards to implementing GML-based encoding have already begun (Steffen Vogt, pers. comm.). Research on establishing a coverage encoding scheme is ongoing.

5 CONCLUSION AND FUTURE WORK

This paper has presented an essential and preliminary abstract model for the Cybercartographic Atlas of Antarctica. At present, no firm decisions have been made. This paper is an attempt to elicit feedback from SCAR stakeholders as to the feasibility of the proposed Web Services Architecture approach. In particular, it is an invitation to interested individuals to participate in the user needs analysis. Doing so will help to insure that The Atlas provides resources that are useful to the scientific community.

In the near future (summer 2003), the user needs analysis process will begin. Concurrently, infrastructure will be developed with the expansion of laboratory space and installation of new equipment having already begun. An Atlas prototype is scheduled for demonstration at the 2004 SCAR general meeting to be held in Bremen, Germany.

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