Open Geospatial Consortium Interoperability Institute Inc.

Date: 2007-06-30

Version: 1.0.0

Editor: David Arctur

PAMAP Reference Architecture Workshop
Volume 1: Summary Report

Warning

This document is an OGCII/OGC Workshop Report.
It is not an OpenGIS® specification or standard.

Document type: OGCII Workshop Report
Document subtype: Reference Architecture Report
Document stage: Proposed
Document language: English

Contents

Page

Figures

Page

i. Preface

This document is an overview of the reference architecture for the Pennsylvania State Map (PAMAP).

Numbers appearing in brackets, such as [1], [2-3], etc., represent citations in the References section at the end of each volume of the report. For consistency, all volumes have identical References sections.

ii. Document contributor contact points

All questions regarding this document should be directed to the editor or the contributors:

Name	Organization
David Arctur	OGCII
Carl Reed	OGC

iii. Revision history

Date	Release	Editor	Primary clauses modified	Description

iv. Changes to OGC Specifications

Previously approved OGC® Specifications do not need changes to accommodate the technical contents of this document.

v. Acknowledgment

The authors of this Reference Architecture document express grateful credit to Dr. Robert Starling and Michael Wilson of OGC-Australasia, and Dr. Renate Mason, the authors of SIDP Notional Architecture, Vol. 1 [19], from which this document has been adapted with much of their text and figures intact. That material has been reused for this document under the guidelines of the copyright notice which accompanied the SIDP Notional Architecture, and which is part of this document as well.

Foreword

> *Across all sectors of … society, it is becoming increasingly recognized that basic geographic information serves as a direct input to informed decision-making in a wide variety of activities, including logistics, investment, public policy, citizen mobility and awareness, health research, resource management and emergency preparedness. The rapid development and widespread proliferation of distributed computing and the Internet over the last decade have only increased the demand for access to a variety of geographic data. However, the data dissemination and licensing frameworks used to promote, extend and support the use of government geographic data generally have not kept pace with developments in technical capacity and growing user demand.* Source: GeoConnections Canada [28]

For the very same reasons in the quote above, development of the National Spatial Data Infrastructure (NSDI, see http://www.fgdc.gov/nsdi/nsdi.html) and the National Map (http://nationalmap.gov/) have been high priorities in the United States. Pennsylvania and other states have also recognized the importance of shared geographic information at the local, regional, and state level. Besides bringing the benefits of shared data for local and state use, the Pennsylvania State Map (PAMAP) contributes directly to the US National Map, which cannot be done without the states' help. PAMAP, in turn, cannot be successful without the cooperation and help of local governments.

PAMAP emerged out of plans begun in 2002, which have so far resulted in specifications and a framework for compilation of (essential) geospatial data layers across the Commonwealth. But PAMAP has a broad vision that goes beyond just managing the framework data layers. ***The vision is to enable other communities in the Commonwealth (government, academia, commercial entities, citizen groups, and even individual citizens in some cases) to not only access, but to actively contribute data for use in conjunction with the framework layers and other hosted data. PAMAP will facilitate and demonstrate the benefits of linking business processes and sharing spatial and other information resources across organizational lines.***

The PAMAP team recognizes that engaging the public (including commercial and industrial entities) in a federated network of data sources – both internal and external to the state government's control – can bring about the level of broad-based participation and cost sharing needed to fund the data collection at the local level. For this vision to be realized, that is, integrating diverse local-level data into a coherent, statewide product, as well as integrating the state-level data into a coherent US National Map, it is necessary that PAMAP's design includes a well defined, long term strategy and plan for a ***Service-Oriented Reference Architecture***. By "Service-Oriented" we mean that the architecture is "web enabled" – that all data access and workflow is understood to occur by means of Web Services developed according to industry standards and practices. By "Reference Architecture" we mean a set of policies that guide the development, usage, and evolution of the spatial data infrastructure (SDI) of which PAMAP is a part. The reference architecture is not a wiring diagram of hardware and software components, but a conceptual model of the data sources, types of users and applications, and their associated roles and relationships to meet the long-term requirements for the Commonwealth's SDI. Once developed, this architecture will serve as a guide for making decisions in the growth of PAMAP and other data sources and processes in the Commonwealth, such as the choice between federation or centralization of specific datasets, or the manner in which updates from data providers will be integrated into the statewide framework on an ongoing basis, or how data rights issues will be handled.

PAMAP stands at the threshold of the future. Without an overarching reference architecture to guide future decisions in the evolution of Pennsylvania's geospatial data and data related policies, it is almost certain that different data developers and custodians will choose data structures and processes without consideration for the public good in terms of interoperability across the Commonwealth. The public good is particularly served by interoperability at times of emergencies such as hurricanes, flooding, wildfires, toxic spills, and acts of terrorism, when diverse government agencies, jurisdictions, citizen groups, and commercial entities are all called to share data and services with utmost cooperation and efficiency. Even in the absence of such emergencies, interoperability serves the public good by enabling more integrative and interdisciplinary academic and public research, and by stimulating software entrepreneurship to develop web-enabled geoprocessing and other workflow services that can be more widely used.

The PAMAP program development team has recognized the need at this stage to conduct additional research, workshops, and pilot studies to arrive at a durable, robust architecture for PAMAP that will remain viable and adaptive to still more changes in the technical, political and social milieu in which it evolves. In March 2007, the OGC Interoperability Institute (OGCII) was invited to support development of PAMAP by conducting a technical workshop for the development of the PAMAP Reference Architecture. This workshop was designed to examine the SDI requirements for such an architecture in Pennsylvania from three of the perspectives described in the ISO Reference Model for Open Distributed Processing (RM-ODP, see [13-14]): the Enterprise, Information, and Computational viewpoints. The enterprise viewpoint captures the policy level requirements, while the information viewpoint captures data flow and work flow requirements, and the computational (also called services) viewpoint captures the web-enabled interfaces needed to support the tasks identified in the information viewpoint, subject to the policies identified in the enterprise viewpoint. This is a mature, widely used process for developing an SDI-level reference architecture, and in fact, an excellent example of such a process, drawn from Australia's Spatial Interoperability Demonstration Project (SIDP) [18-23], was the starting point for the workshop discussion. After considering the reference architecture requirements from these viewpoints, workshop participants then explored the relative merits of four types of candidate architectures for integrating multiple data sources over the web, from their own perspectives as users or managers of geospatial data.

The workshop was conducted June 5, 2007 in Middletown PA. This volume of the workshop documentation provides an overview of the resulting, proposed reference architecture. Details of the workshop methodology, discussion, and conclusions are contained in volume 3 of the reference architecture documentation.

One other specific activity of the workshop was to consider use cases and data sources for an Interoperability Pilot Study, in which some portions of this architecture would be implemented and tested. The discussion and results of that activity are reported in volume 2 of this reference architecture documentation.

The References section at the end of each volume contains a bibliography of citations, a list of acronyms with links to web-based source material, and a cross-referenced glossary of terms. These resources provide a quick reference to most of the technical terms and concepts brought up in this report.

PAMAP Reference Architecture, Volume 1: Summary Report

1. Scope

This document defines an open, standards based Reference Architecture for the Pennsylvania State Map (PAMAP) that is vendor-architecture neutral. The reference architecture provides a frame of reference for the description and definition of scenarios encapsulating user requirements and the data access, processing, and display services needed to meet the long-term requirements of the PAMAP.

The architecture is "reference" in that it makes no assumptions either about physical implementation or about commercial entities and institutions other than their acceptance and support of open, non-proprietary standards. It provides an explanatory framework within which distributed services, managed by authoritative custodians, can be implemented to support an expanding set of spatial services for the PAMAP.

The reference architecture is broad based, flexible, extensible, and sets a context which accommodates the diversity of Pennsylvania's growing geospatial resources and users, including those of local governments, state and federal agencies, commercial entities, and potentially even neighbouring states. This architecture specifically accommodates and supports other Pennsylvania initiatives, such as PAMAP's raster and vector conceptual designs [1-5], PGDSS [6], the PA Geospatial Enterprise Server Architecture (GESA), PASDA (www.pasda.psu.edu), and the PA GIS Consortium of local governments for data federation (www.pagis.org).

This document is based on Australia's Spatial Interoperability Demonstration Project (SIDP) Summary Report [19]. The multi-year, multi-million-dollar SIDP study [18-23] represents a "best practice" in the development of a spatial data infrastructure (SDI) reference architecture.

2. Summary

The PAMAP will use existing international standards and best practices to define a platform for technology diffusion, technology transfer and skills development and increasing market awareness of the potential and benefits to be gained from the use of geospatial data and services in business. This will be accomplished by demonstrating the value of innovative spatial data system interoperability to the industry, government and end-users of the Commonwealth of Pennsylvania. As the reference architecture is implemented, instantiations of it will be able to:

- Establish access on demand to spatial information from diverse information sources.
- Enhance management of real-world critical situations in defense, security and emergency services.
- Improve users' access to innovative worldwide research and technologies.

For PAMAP to be successful, it will be important to disseminate the knowledge acquired during development of the reference architecture by facilitating and delivering seminars and training workshops to encourage capacity building, through the uptake of research and technologies by Pennsylvania organizations, especially Small and Medium Enterprises (SMEs) in the spatial industry.

It will also be important to provide awareness training to the marketplace – especially senior policy and decision makers in the private and public sectors - so that a marketplace ready to demonstrate commitment to open standards through their procurement policies and guidelines can be fostered.

This document establishes the PAMAP Reference Architecture that provides the foundation and proof-of-concept of a spatial information solution for tracking, monitoring, identifying and responding to business opportunities and service delivery challenges for sustainable communication with, and planning and protection for, the diverse communities of the Commonwealth.

In the next phase of work, the PAMAP Project Team, together with partners and stakeholders, will design and deliver a pilot implementation that can be used on an on-going basis, as a test bed for further scenario implementation and conformance testing. Participation and access to the PAMAP pilot will be available to the geospatial information industry across the Commonwealth. Both the pilot and lessons learned (best practices) will support skills development and transfer throughout Pennsylvania.

The PAMAP Reference Architecture must allow and provide support for the following:

- Transactions between users and services being conducted by web agents, mediated through the Internet;
- Rules governing the authority of users and agents to access specific content and services. Appropriate authentication rules can be established according to services' access policies, capable of providing an accounting of the amount and type of services that are used;

- Applications providing transactional interfaces to users' agents, whether via 'thin' (browsers) or 'thick' (remote processes such as desktop GIS) clients, to specify required actions and to receive results;
- Descriptions of services and content (metadata) being available for interrogation so as to allow dynamic discovery and in the case of services, provide detailed interface specifications that allow agents to adhere to the described service;
- Means for querying and accessing data stored in repositories;
- Performing a variety of geographic processes including reprojection, sub-sampling, analysis, comparison and amalgamation; and
- Operational data repositories which collectively provide storage, modification and access to spatial data, geo-linked data, metadata descriptions, policy and authority specifications, and user accounts.

The definition and description of the PAMAP Reference Architecture is based on the *ISO Reference Model of Open Distributed Processing* (RM-ODP, ISO/IEC 10746) [13-14] and the OGC Reference Model (ORM) [15], and addresses the first three of the five possible viewpoints. The Engineering and Technical Viewpoints are not considered in this document because each requires detailing specific hardware, software and communications technologies and identifying their roles in implementation. These will be defined for the central PAMAP repositories as needed (starting with the PAMAP Reference Architecture Pilot Project). However, these viewpoints are also either implicitly or explicitly defined within the evolving community and network of federated data providers working with PAMAP.

Viewpoints	Brief Description
Enterprise	Describes business perspective, purpose, scope and policies.
Information	Is concerned with the semantics of information and information processing.
Computational	Interacts between computational components linked by communication networks, their interfaces, their operations and binding rules. Also often referred to as "Services" viewpoint.
Engineering	Describes the hardware and software components and infrastructure used in a distributed system.
Technical	Considers the choice and suitability of physical implementation.

Figure V1- 1. Architectural Viewpoints (ISO 10746)

Discussion and detailed background information about the PAMAP project's Reference Architecture development are considered in more detail in volume 3. While making access to spatial/textual data easier and more efficient, a Reference Architecture is required that enables and allows the following:

- Production system integrity;
- Machine readable metadata in on-line catalogues of selected data and services;
- Digital rights management;
- Privacy and security of sensitive information assured;
- Conditions for data access and supply;
- Pricing and charging models, and
- Improved understanding of data semantics.

3. Background

As stated in the PAMAP Leadership Plan, the PAMAP project is "a collaborative effort among local, state and federal governments to build a base of geographic information that serves the needs of the individual partners and provides decision making capabilities at all levels of government. The state provides orthophotography and elevation/topography while counties provide key vector data that align to the orthophotos and conform to a standard." This project has developed as a way to meet the growing needs for accurate and timely base map data across the state, which could also be integrated with other state-level data sets to help fulfil the mission of the US National Map (http://nationalmap.gov/).

Since PAMAP was conceived in 2002 by Dr. Jay Parrish, Director of the Pennsylvania Bureau of Topographic and Geologic Survey (BTGS), a number of significant steps have been completed:

- Strategic planning workshop, resulting in the PAMAP Leadership Plan document completed in July 2005 [1].
- Raster Requirements, Conceptual Design, and Implementation Plan for the PAMAP Program also completed in 2005 [2-4].
- Vector Requirements for the PAMAP Program, completed in May 2006 [5].

These reports (and others still waiting completion [7-10]) define various parts of what should become a well-considered and effective plan for capturing state-level data to be distributed to the counties (i.e., the raster plans), and for counties to capture higher-resolution data for modernizing their own operations as well as to integrate with the other counties throughout the state (the vector plans). The reports so far cover many operational issues, such as vector feature capture guidelines, data content standards (the Pennsylvania Geospatial Data Sharing Standard, PGDSS

[6]), handling the edge-matching of features across county boundaries, and centralized data management strategies for selected data themes.

As a result of the discussions and work undertaken to carry out these data collection plans, many people familiar with the PAMAP have come to see it as primarily "about the data" and, more specifically, about the framework data layers described in the above PAMAP documents. However, PAMAP has a much broader vision that goes beyond just managing the framework data layers. The vision is to enable other communities in the Commonwealth (academia, commercial entities, citizen groups, and even individual citizens in some cases) to not only access, but to actively contribute data for use in conjunction with the framework layers and other hosted data. PAMAP will facilitate and demonstrate the benefits of linking business processes and sharing spatial and other information resources across organizational lines. The linking is independent of where the data, information and processing tools, accessible over the internet, are physically located and what type of computer system is used.

For this vision to be realized, that is, integrating local-level data into a coherent, statewide product, as well as integrating the state-level data into a coherent US National Map, it is necessary that PAMAP's design includes a well defined, long term strategy and plan for a service-oriented reference architecture. This architecture is needed to serve as a guide for the continued evolution of data sources and processes in the Commonwealth, including the choice between federation or centralization of specific datasets, or the manner in which updates from data providers will be integrated into the statewide framework on an ongoing basis, or how data rights issues will be handled.

PAMAP stands at the threshold of the future. Without an overarching reference architecture to guide future decisions in the evolution of Pennsylvania's geospatial data and data related policies, it is almost certain that different data developers and custodians will choose data structures and processes without consideration for the public good in terms of interoperability across the Commonwealth. The public good is particularly served by interoperability at times of emergencies such as hurricanes, flooding, wildfires, toxic spills, and acts of terrorism, when diverse government agencies, jurisdictions, citizen groups, and commercial entities are all called to share data and services with utmost cooperation and efficiency. Even in the absence of such emergencies, interoperability serves the public good by enabling more integrative and interdisciplinary academic and public research, and by stimulating software entrepreneurship to develop web-enabled geoprocessing and other workflow services that can be more widely used.

Thus the PAMAP program development team has recognized the need at this stage to conduct additional research, workshops, and pilot studies to arrive at a durable, robust architecture for PAMAP that will remain viable and adaptive to still more changes in the technical, political and social milieu in which it evolves.

4. Assumptions

The vision for the PAMAP is to advance the state of spatial information sharing and standards based portals towards a situation portrayed in Figure V1- 2 below, where:

- Information products of improved quality are provided to customers that are easier to access within an environment where there is a scheduled reduction in the complexity of the processes (awareness, training and costs).
- The capabilities and opportunities provided by the Internet are used to complement existing delivery methods, such as call centers and counters, and to improve quality, timeliness and accessibility to services and products.
- Services and products are provided without the user having to know where within the Government, or private sector, the services and data originate;
- Services and products are provided to all users able to use simple Internet services. Users uncomfortable with or not connected to the Internet continue to use existing shop-counter services.
- Single authoritative sources of data are maintained and are made available using the Internet for processing through services of known quality to deliver current information in an auditable and cost effective manner.

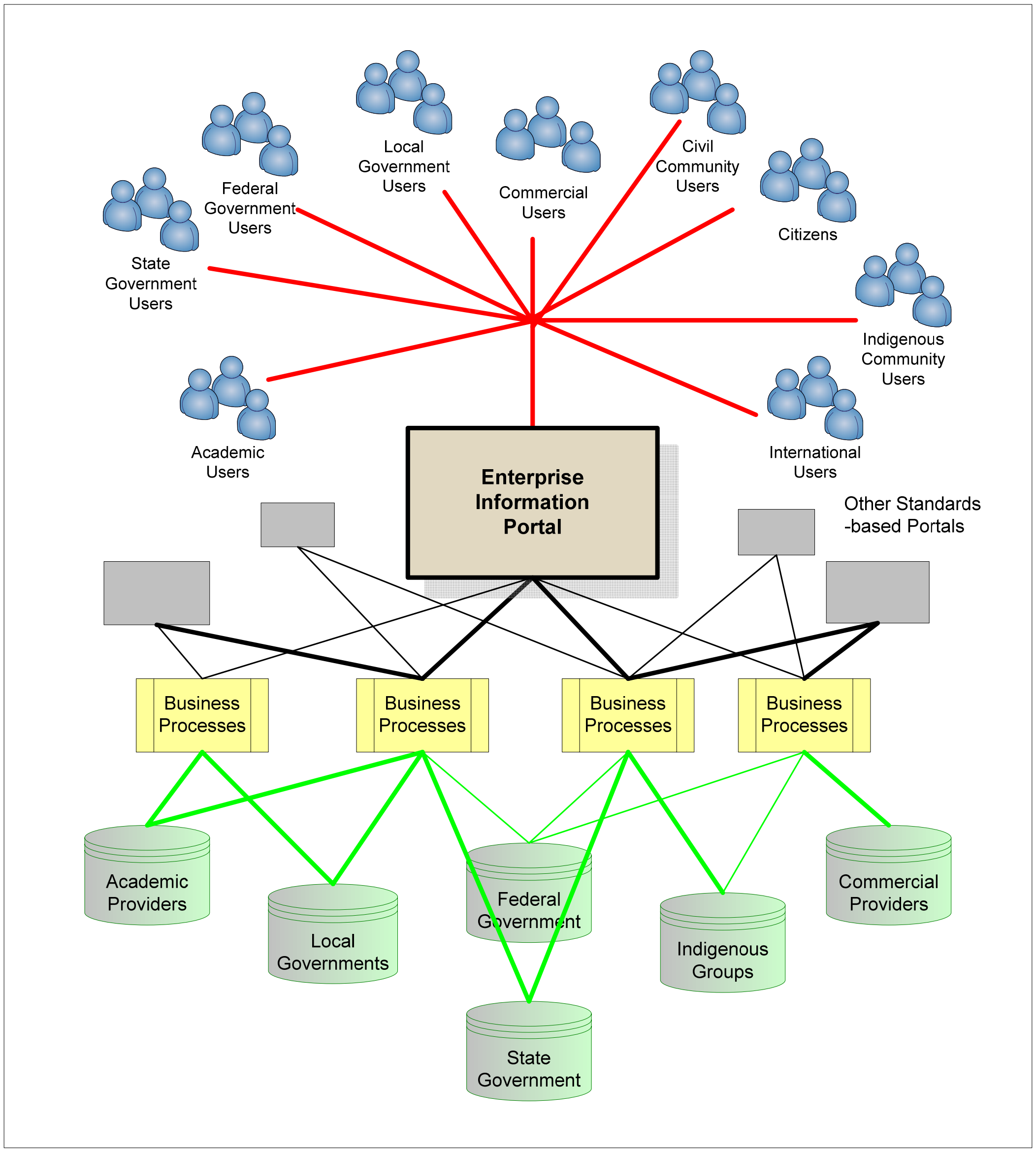

Figure V1- 2: Enterprise Viewpoint for the SIDP

Information seekers and users of various types use common standards-based Internet portals to gain access to an entire distributed community of authoritative content. Business processes manage and account for access to content and add value by generating user-specified products. Users may also be able to access services and products directly or via other portals.

4.1. Role of Technology

Technology such as the Internet provides the means for achieving the PAMAP vision; it is not the ‘*raison d’être*’.

Previous efforts undertaken by the geospatial industry in analysing spatially related information products and services have tended to focus on the technologies available and/or used, occasionally losing sight of users and their requirements. This has placed many and varied hurdles between services and those to be served, such as:

- Users require knowledge of and access to particular technologies;
- Users must have familiarity with specialized technologies such as geographic information systems; and
- Users must have familiarity with diverse methods used inconsistently in different Government departments and between private sector suppliers.

4.2. Vendor Neutrality: the Role of Open Standards and Specifications

Standards and specifications are necessary for achieving the PAMAP vision. However they are not the '*raisons d'être'*.

The information industry, including Government services, can learn from the experiences gained in manufacturing industries that have used technology to speed the time to market for physical products.

Manufacturing spatial/map products "just-in-time" is possible because of specifications and standards. Standards allow manufacturers to specify that a product of known performance will have specific plugs and sockets and when put in place will do a particular task properly. A product integrator (say, a vehicle assembler) can search for all products meeting a specified need (described according to the same standard) regardless of manufacturer, then select a supplier to meet their business needs.

The equivalent in the technology of information is that a particular computer-based service set has certain specified performance characteristics wherein the process will receive input in certain specified forms, and deliver a specified result. The service may further rely on using specific data that are themselves described in certain specified ways, and can be selected on their fitness-for-purpose and cost. A "yellow pages" service allows users and programmers to discover services and data that can be combined to deliver the required product.

Such an approach is referred to as "just-in-time" information product manufacturing. Open specifications and standards underpin this ability. "Open" in this sense does not imply "open source" but rather that the *process* by which the standards are developed is consensus-based and open to full participation by any interested developer. "Open standards" are also meant to be publicly available at little or no cost. The purpose of having open standards is to ensure ease of data sharing, thus enabling ad hoc relationships between data providers and users to be readily formed as business and emergency conditions warrant. Protocols are now in place for using the Internet for the interchange of such things as personal medical information, bank details, lodging tax forms and filing mining claims. Such practices raise often-stated concerns about security, confidentiality, integrity, non-repudiation, data licensing and fee structures. Most if not all these issues are being addressed by specialist groups in industry and are not considered to be barriers to adoption. If the private sector in Pennsylvania and the USA can apply these principles for their billions of dollars in transactions, then counties and local governments should be able to learn and apply these techniques to PAMAP data, as well.

4.3. Distributed Implementation and Institutional Neutrality

In the past the *only* possible way to integrate information services was by either co-locating them, or by connecting them via expensive customized networks. Obviously this concentrated power in the hands of those who owned the systems and managed information.

The ubiquity of the Internet fundamentally undermines this historical state. The Internet and the Web provide an environment that enables institutional neutrality when considering content and/or service integration.

The Internet allows all custodians of products, services and data to function as equals. Centralization is no longer the default; it remains an *option* to be chosen on the basis of business requirements, special capabilities (for example, operational reliability; security management; economies of scale, specialized infrastructure) or where previous investments need to be amortized.

Note that the PAMAP has no mandate to address the internal business requirements of individual participants, or how they meet them. It does have everything to do with the way in which information flows between the public, private companies, agencies and levels of government to facilitate service delivery.

4.4. Federated Systems and Custodial Management

The PAMAP is underpinned by integrated spatially related information services that are **federated**. There is now a relatively long history in design and understanding of federated architectures for information management. As stated in one early source, "The federated architecture provides mechanisms for sharing data, for sharing transactions (via message types), for combining information from several components, and for coordinating activities among autonomous components (via negotiation)." [11] The term "federated" is used throughout this project to mean that agencies are independent and have their own accountability. They operate according to the principle of "mutual best interest" (indeed a public imperative) by collaborating to provide efficient, accountable, auditable delivery of authoritative information products, services and data to Executive Government, within government, to businesses, and the public.

Custodians are responsible for managing the products that users receive, the services that generate them, and the data that are employed.

4.5. Shared Services

The Internet provides a scalable, vendor-neutral, institution-neutral means for achieving the goal of shared services. These shared services are user-focused and support specified business requirements. They support the concepts of supply chains and value chains. Shared services may also be built upon existing "legacy" services. It has been demonstrated many times that existing systems can be augmented with open-specification interfaces ("wrappers") that extend their accessibility to the Internet without compromise to security or integrity. Thus, their investment value is retained or even enhanced.

Each shared service may be small or large, sophisticated or elegantly simple. Some services might be implemented in just a few lines of code, created and developed by a single programmer and not even have data associated with them but instead only rely on the needed data being sent to them from other services elsewhere in the Internet. Others may be full-scale production systems accessing sophisticated databases, supported by a staff of dozens and for which new service applications need to be structured and quality-assured.

For the purposes of the complete implementation of PAMAP, relevant "services" will need to meet very specific criteria concerning their interfaces to the Internet, the protocols they use to communicate with other services, and the structures of the messages passing between services. (See SIDP Notional Architecture, Vol. 4, App. A-2 "Web Services, Agents and Protocols" [22]).

4.6. Incremental components-based access

Shared services can be accessed **incrementally** and **independently**. Incremental access – doing things in small steps – provides frequent opportunity to assess the effectiveness of new services in meeting PAMAP needs. This will be an on-going process as participants' expectations of product and service sophistication grows with the evolution of the project.

The PAMAP will demonstrate the effectiveness and potential of shared services and their incremental uptake, and build the confidence of the industry to consider such an approach. As a result each participant will be able to determine whether their business requirements are better met by retaining existing practices, implementing their own new service or using services operated elsewhere in Pennsylvania or in the world. Or, they may take the latter approach while assessing user requirements and, if justified, then invest in developing their own new service.

The PAMAP will also be extending efforts undertaken at a national level such as the National Spatial Data Infrastructure (NSDI, see http://www.fgdc.gov/nsdi/nsdi.html) and the US National Map (http://nationalmap.gov/). Each provides a crucial forum in which departments and agencies, local government and the private sector exchange information about their planned service developments and perhaps developing services cooperatively and sharing the cost. Alternatively, they may agree that one member develops one service and another develops a different service to avoid duplication and provide mutual benefits.

It is envisaged that the PAMAP will use a similarly collaborative approach and create draft guidelines/summaries of their experience as a contribution to the spatial industry's appreciation of the opportunities and pitfalls of the approach

.

5. Overview of the Reference Architecture

5.1. Architecture Requirements

The primary requirement of the PAMAP is that the project be based on open[1] non-proprietary standards. This does not mean that data access is free of cost or restrictions, just that the standards to which the system adheres are freely available. Therefore, the reference architecture for the PAMAP applies the principles and standards recommended as best practices in the OpenGIS Web Services Architecture[2] and other internationally recognized and adopted standards.

The web services architecture uses an ISO/OSI three-tier model. Referring to the following Figure V1- 3, it can be seen that the model separates presentation from processes governed by

[1] By open, we mean royalty and license free, non-discriminatory, vendor and data neutral, and developed by a well defined industry consensus process.

[2] OpenGIS Web Services Architecture Description [12]

business rules, and processes from the underlying methods for accessing persistent data repositories (whether relational databases, file systems, structured text files such as XML, etc).

Implementing this model in the form of distributed web services will require that communications between tiers, and amongst service components within tiers, can be mediated by open standard Internet protocols transporting transactional messages structured in well-known manners.

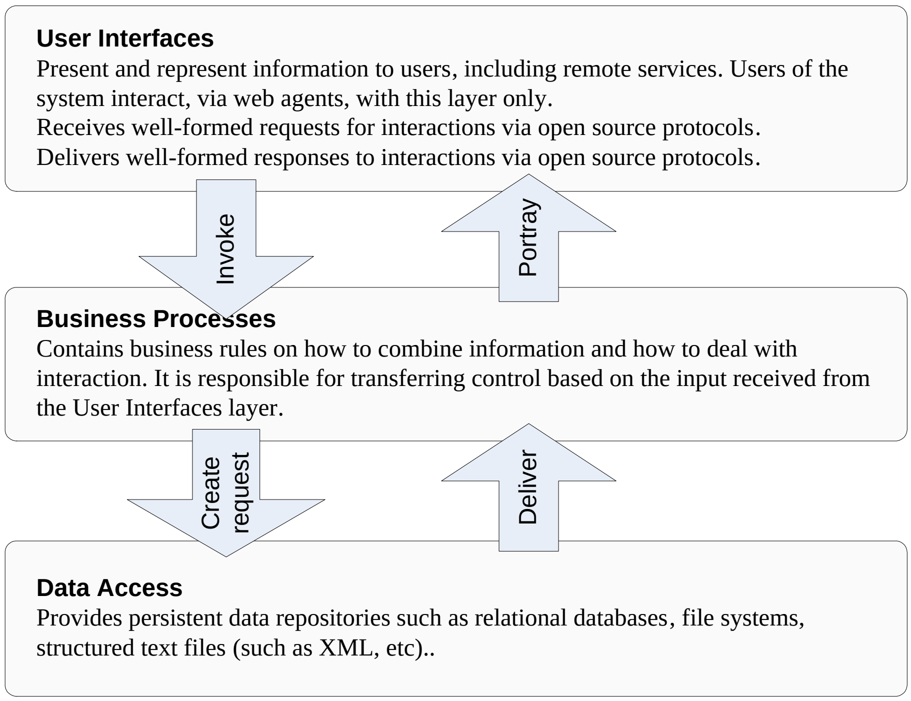

Figure V1- 3: ISO three-tier model for the PAMAP

Each of the three tiers in this model addresses a separate aspect of serving users' business requirements – establishing interfaces for user access, implementing business rules as process services, and manipulating stored data. In the Reference Architecture, communication between tiers, and among elements within tiers, is capable of being mediated via Internet protocols between web services.

The ISO three-tier model also corresponds to a pattern of an architecture definition widely recognized in the object-oriented analysis and development communities, that of the Model-View-Controller-Pattern, or the Boundary-Control-Entity-Schema. According to this, architecture comprises in three layers.

- The **Boundary** is responsible for representing information to the user and receiving interactions. Users of the system interact with this layer only.

- **Control** contains the rules on how to combine information and how to deal with interaction. It is responsible for transferring control based on the input received from the Boundary layer.
- The **Entity** layer holds the data and is responsible for its persistence.

Either of the ISO/OSI or object-oriented perspectives may be taken in considering the reference architecture, though the latter lends some advantage to later discussions of services, components and their interfaces.

The reference architecture therefore features:

- Standards and capabilities of the Internet and the World-Wide Web;
- Adaptable, modular web service components accessed incrementally and managed by many authoritative custodians;
- Dialogues conducted between services over the web discovering services and conducting transactions amongst them;
- Neutrality towards software and system vendors;
- Neutrality towards platforms, and
- Neutrality towards particular institutions.

A characterization of the reference architecture and high level service categories is presented in Figure V1- 4 below.

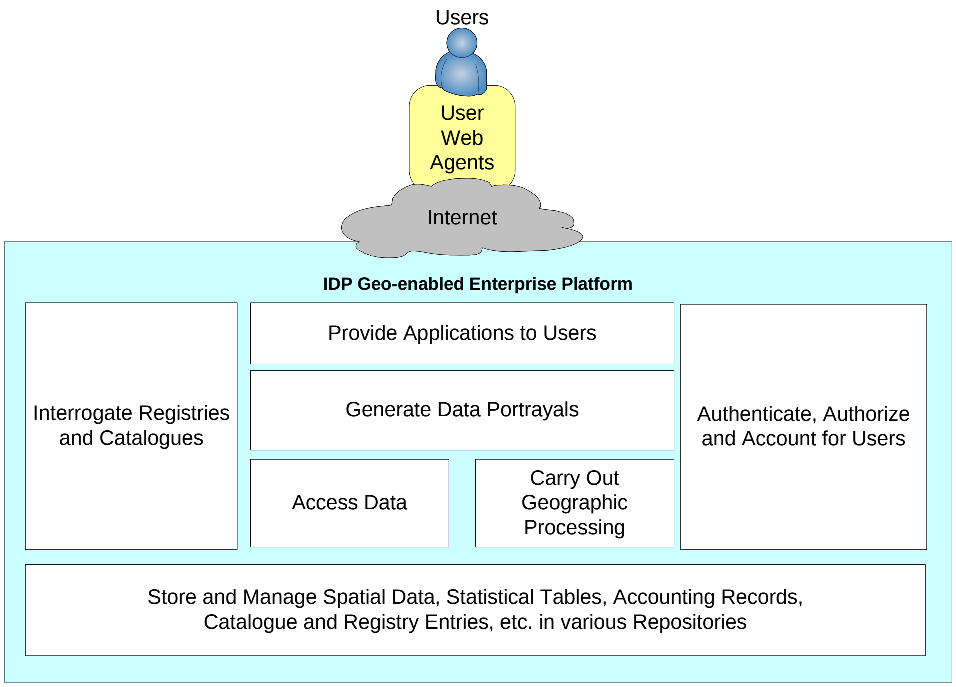

Figure V1- 4: Reference Architecture: PAMAP Capabilities

> The PAMAP platform provides uniform and consistent managed access to distributed web services operated by authoritative custodians. These services comprise seven major categories that address geo-data processing, presentation, access control, accounting and data management.

Referring to the previous figure, the reference architecture identifies seven broad groups of capabilities; within each group various services are implemented as specific content and service components. Each component operates as a web service communicating on a transactional basis with other components, user agents and remote applications via the Internet.

Component services 'plug into' the Internet from many different locations and communicate amongst themselves, and with people using web browsers and similar tools. This is represented in Figure V1- 5 below. Components can be dynamically assembled and combined to perform a variety of "just in time" processing. Discovery services for data and processing services provide the means for identifying capabilities and their governing rules. The internet provides the backbone by which components communicate. Standard internet messaging protocols and mark-up languages define the rules by which messages are created and interpreted.

Instances of envisaged Components are elaborated in considerable detail in the SIDP Notional Architecture, Volume 3 [21]. While not intended to be definitively comprehensive these are nonetheless presented as indicative of the types of the components required by the PAMAP platform.

Components are to be bought or built once and used many times. Examples of components are catalogue services, gazetteers, data delivery servers, data repositories and will be key elements for many different uses in the PAMAP.

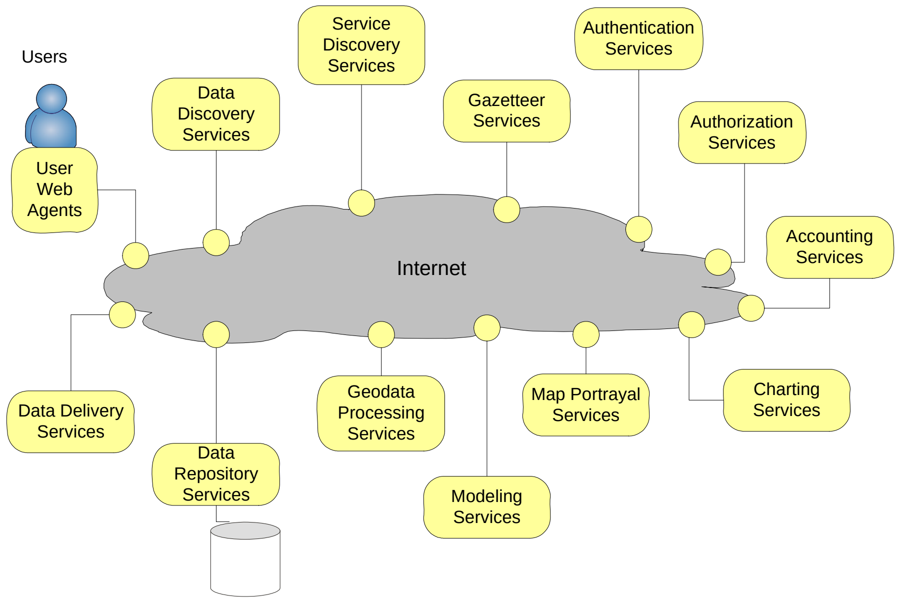

Figure V1- 5: Reference Architecture: PAMAP Web-based Component Examples

The PAMAP platform comprises numerous individual components that 'plug into' a common Internet backbone. Each component presents appropriate open-standard interfaces to the Internet. Service and content discovery via registry services provides for dynamic identification and selection in response to users' requirements.

5.2. Architecture Concepts

Salient points of the PAMAP reference architecture are represented in:

- A community of web services managed by independent custodians and accessed through standard mechanisms such as the Internet;
- The community being defined operationally by those who share a common agreed vocabulary naming the types of features of interest, and rules defining the relationships amongst these features, i.e. communities with a shared ontology;
- Access to data and data processes provided by services, and published by custodians to registries for discovery and reference describing their capabilities, context and rules;
- Separation of services between those accessible by users, those that embody business rules, and those that directly access data stored in repositories; and
- Users, subject to various levels of authentication and authorization, using web agents to access these services through the Internet, and their usage accounted for.

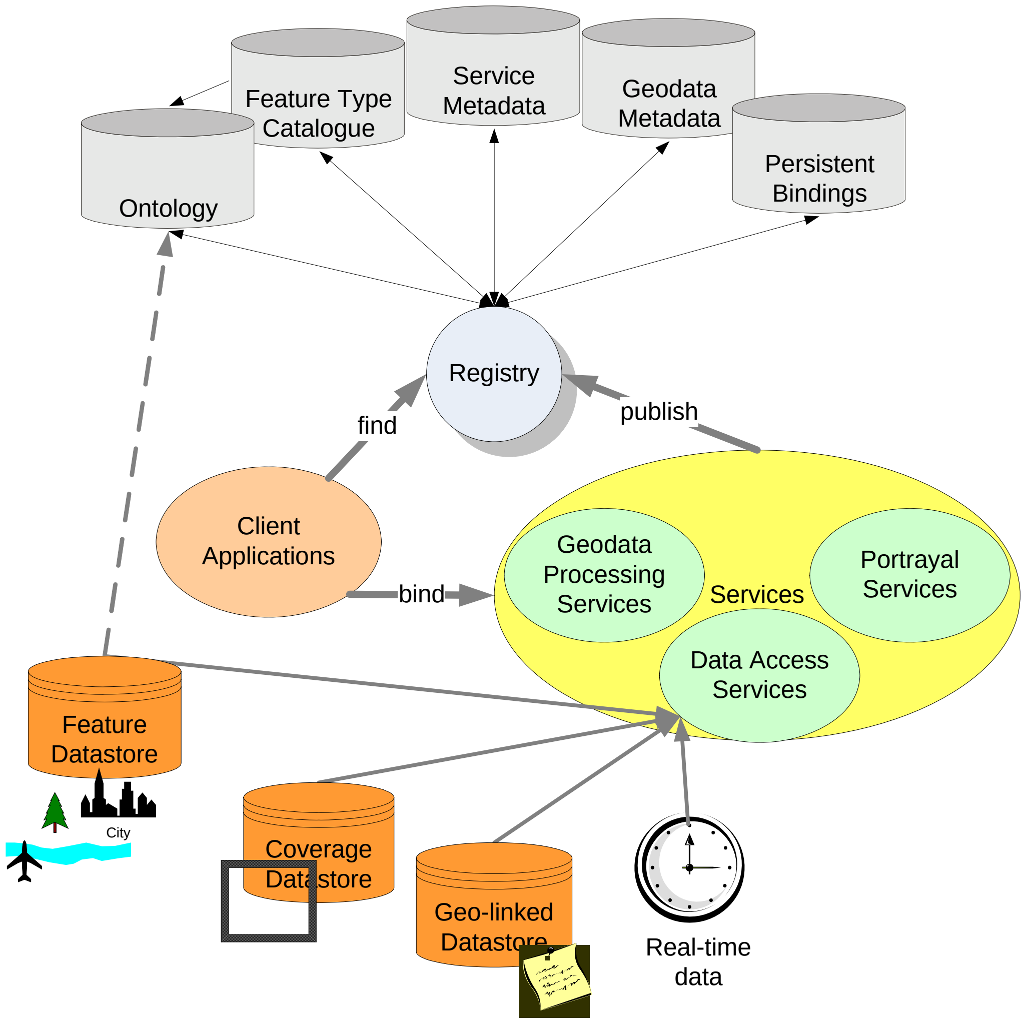

Figure V1- 6: PAMAP Reference Architecture: Broad Types of Data and Services

Services provides access to valued data and services, which are described in registries that include definition of their capabilities, context and governance rules. Users' clients bind to services via internet protocols implementing the governance rules. Data repositories of various kinds provide persistent storage for various types of geo-data. The community of providers shares a common vocabulary and ontology for describing features of common interest and the relationships amongst them.

5.3. Architecture Component Overview

Figure V1- 7 presents a high-level service component view of the PAMAP reference architecture. The salient points for PAMAP are that:

- "Thin" clients are web browsers acting as agents for people accessing services through the World Wide Web. Behind the scenes, these peoples' agents are using the open http protocol to exchange well-structured messages with a web platform configured to act as an interface to PAMAP approved web services.

- “Thick” clients are remote applications acting as their own web agents and able to invoke according to agreed message standards and protocols. Thick clients can be remote GIS desktop applications used directly by people. They can also be autonomous tasks such as statistical analysis and modeling engines.
- Portal[3] service partners configure the web services to conduct business processes such as analysis, data manipulation, presentation of products according to designated symbologies and layouts, and plausibly also to provide interactive help for users.
- Catalogue services support publication of service and data characteristics (metadata) and their discovery by appropriate agents. Catalogues also provide information about the language structures and interface capabilities supported by each service. All services to be accessed in the PAMAP require catalogue references.
- The gazetteer services support searches and other applications (such as portrayal) requiring the names of locations and features.
- The web feature services (WFS) abstract data as topographic features encoded in Geography Markup Language (GML) that are amenable to further analytical or representational processing, such as may be done with “thick” clients. WFS tend to deliver vector data content and attributes, but can also treat content such as gazetteer services as point data.
- The web coverage services (WCS) similarly abstract coverage data (including raster data, but not constrained to rectangular reticules) to thick clients or for portrayal through WMS.

3 In this document, a portal is a website that acts as gateway providing a single access point to multiple resources. It is a web environment that allows an organization or a community of information users and providers to aggregate and share content. It is an organized collection of links to other sites. A portal may be secure and it may be personalized. A geospatial portal is a human interface to a collection of online geospatial information resources, including data sets and services.

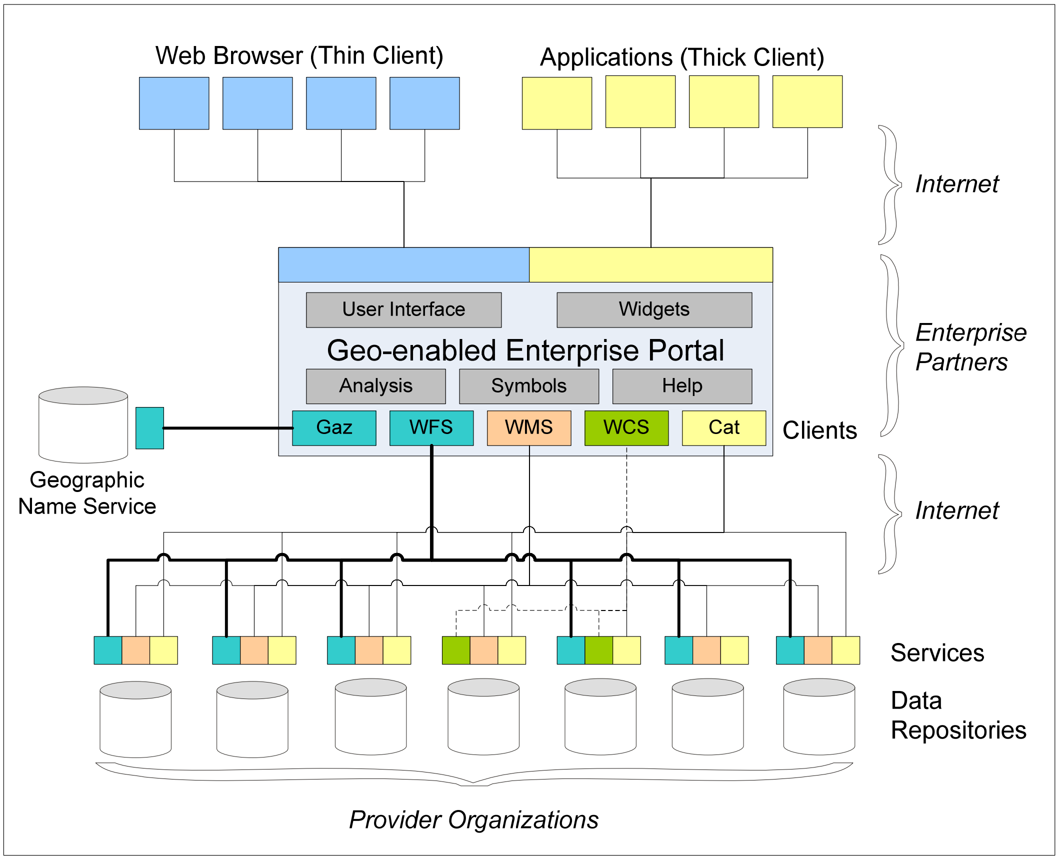

Figure V1- 7: The PAMAP Portal Platform Concept

The enterprise information portal mediates internet-based transactions between client agents (web browsers, remote applications) and a distributed community of service operators and content providers. The services include discovery (catalogues, registries and gazetteers), analysis, transformation and portrayal. OpenGIS and other open specifications define the interfaces amongst these services.

- The web mapping services (WMS) provide pictorial portrayals of data as maps which are readily visualized and manipulated in “thin” clients but they are not amenable to further manipulation. WMS may stream and portray content from WFS.

Figure V1- 8 following illustrates the services involved and the paths by which information flows between the services. The salient points to note for the PAMAP are that:

- User interfaces (UIs in the diagram) and application program interfaces (APIs) interact with the world wide web – or the internet in general – according to public standard protocols and interface specifications.
- All interactions between users, via their web agents, are transactional in nature.

- Information flow occurs between numerous independent services managed by independent custodians.
- All data assets are delivered via services.
- Services and data descriptions are published into registries and catalogues available for search-driven discovery by web agents.

For more detailed discussion of the types of business rules to be accommodated within the framework architecture, see the SIDP Notional Architecture, Volume 2 [20]. A detailed technical discussion (computational viewpoint) of the architecture is presented in Volume 3 [21]. These two volumes provide increasing levels of detail as the Notional Architecture is defined from the Enterprise level to the Computational level. Volume 4 [22] includes a series of Appendices discussing selected issues in greater detail and can be readily added to as specific topics are investigated in greater detail, or prove to need further qualification to clarify aspects of the architecture.

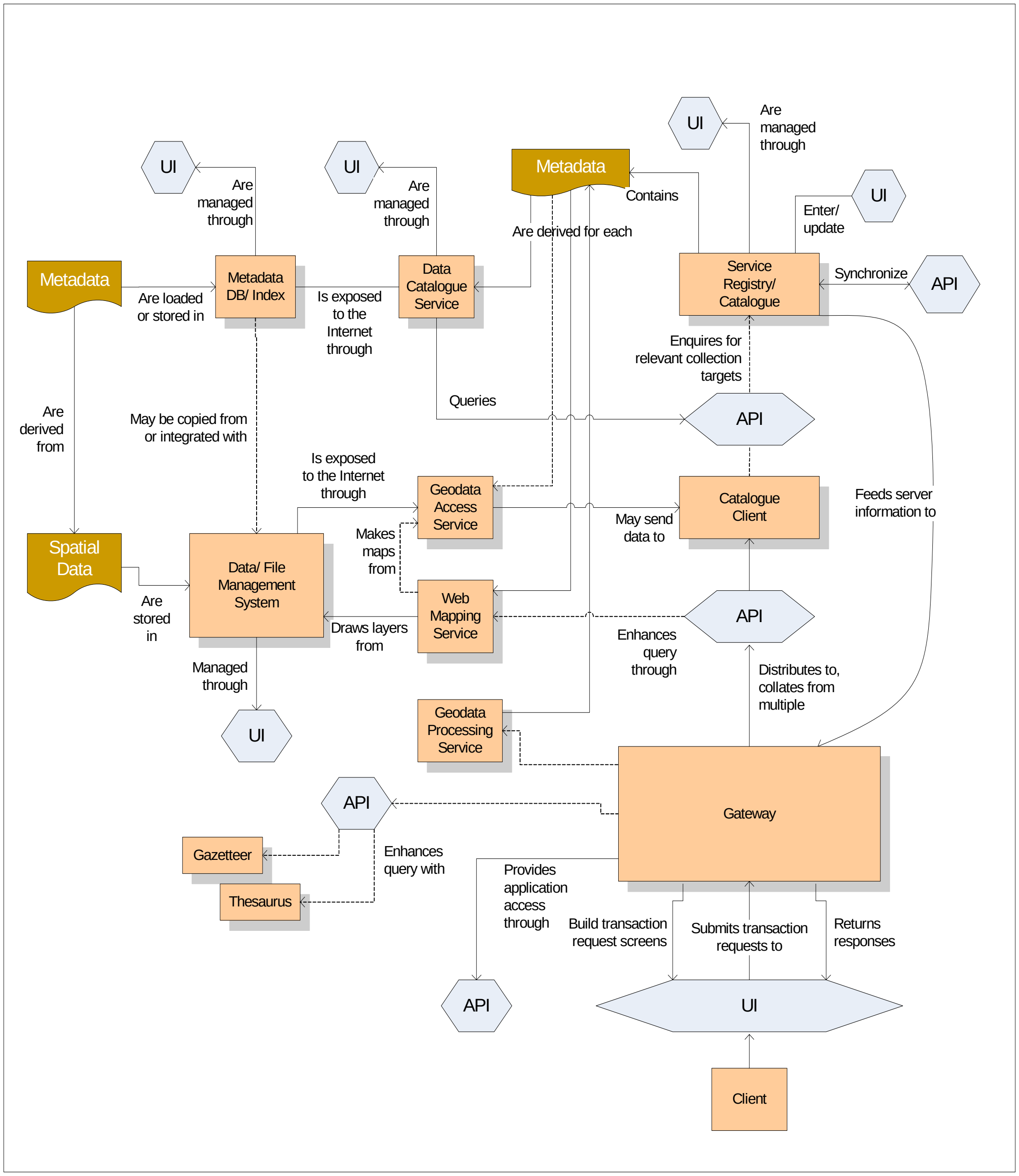

Figure V1- 8: Services and Information Flows

Service components (rectangles, pink) are able to interchange informational messages via the open network standards used in the Internet. Various web service interfaces (hexagons, blue) provide the means by which service capability descriptions are requested, service instances are invoked, and resultant products are returned, amongst services (APIs) and users (user interfaces, UIs). Persistently stored data or various types (banner figures, brown) are accessed and manipulated by relevant services.

6. Conclusions

The Reference Architecture is presented as a dynamic model. The standards and specifications referred to are evolving. There is a wide range of projects being undertaken around the world that are testing the varied aspects of interoperability. There is also an increasing interest in alignment between business processes, workflows and information product manufacturing and delivery. The PAMAP will keep watch on developments in the public arena.

There is also a wide range of initiatives underway by private sector technology developers and suppliers, academia, and systems integrators, including those within the Open Source community. New tools and services are becoming available at an accelerated rate.

The PAMAP is a collaborative project and will continue to actively seek other experts, nationally and internationally, who will be able to contribute experience and insight into the issues facing the project as it progresses. These contacts will assist in meeting some of the goals for technology transfer to Pennsylvania's businesses to take advantage of expertise and experience in open standards from overseas, to build capacity here in Pennsylvania and increase the international competitiveness of Pennsylvania companies.

One of the key findings from the PAMAP Reference Architecture Workshop (see volume 3 of this report) was the clear need for education on the current capabilities and practices with the Internet and Web Services, throughout Pennsylvania agencies and local governments. The pace of change in IT systems and standards has been too rapid for many IT professionals to keep up. Without this level of education, misunderstandings about service oriented architectures and federated systems could lead to active resistance to the PAMAP vision and promise.

7. References

7.1. Bibliography

PAMAP's raster and vector conceptual designs, and PGDSS:

[1] Advanced Technology Solutions, Inc., A PAMAP Leadership Plan, 2005. URL: http://www.dcnr.state.pa.us/topogeo/pamap/leaderfinal.pdf

[2] Advanced Technology Solutions, Inc., Raster Requirements for the PAMAP Program, 2005. URL: http://www.dcnr.state.pa.us/topogeo/pamap/rasterfinal.pdf

[3] Advanced Technology Solutions, Inc., Raster Conceptual Design for the PAMAP Program, 2005. URL: http://www.dcnr.state.pa.us/topogeo/pamap/concdesignfinal.pdf

[4] Advanced Technology Solutions, Inc., Raster Implementation for the PAMAP Program, 2006. URL: http://www.dcnr.state.pa.us/topogeo/pamap/rasterimplplan.pdf

[5] Advanced Technology Solutions, Inc., Vector Requirements for the PAMAP Program, 2006. http://www.dcnr.state.pa.us/topogeo/pamap/vectorrequirements.pdf

[6] Pennsylvania Mapping and Geographic Information Consortium (PaMAGIC), Pennsylvania Geospatial Data Sharing Standards (PGDSS), May 2007. URL: http://www.pamagic.org/pamagic/lib/pamagic/PGDSS_2_5_STANDARDS_Compiled_Final0505.pdf

Pennsylvania Governor's Technology Office standards and directives (some are still in draft):

[7] ITB-INFGT001 – GIS Software Standards

[8] ITB-INFGT002 – Standards for Geospatial Interoperability of Systems and Data

[9] ITB-INFGT003 – Utilization of Commonwealth Enterprise Geospatial Resources

[10] Management Directive – Geospatial Data Sharing Language for Agency Grant Agreements

Seminal literature, specifications, and best practices:

[11] Heimbigner, Dennis, and Dennis McLeod, "A federated architecture for information management." ACM Transactions on Information Systems (TOIS), Volume 3, Issue 3, pp 253-278. ACM Press, New York, July 1985.

[12] OpenGIS Web Services Architecture Description, OGC Best Practices document 05-042r2. URL: http://portal.opengeospatial.org/files/?artifact_id=13140

[13] ISO/IEC 10746-1:1998(E) Information Technology – Open Distributed Processing – Reference Model (RM-ODP): Overview. URL: http://standards.iso.org/ittf/PubliclyAvailableStandards/c020696_ISO_IEC_10746-1_1998(E).zip

[14] ISO/IEC 10746-2:1996(E) Information Processing – Open Distributed Processing – Reference Model (RM-ODP): Foundations. URL: http://standards.iso.org/ittf/PubliclyAvailableStandards/s018836_ISO_IEC_10746-2_1996(E).zip

[15] OGC Reference Model (ORM). OGC White Paper 03-040. URL: http://portal.opengeospatial.org/files/?artifact_id=3836

[16] The OGC Geospatial Portal Reference Architecture. OGC Discussion Paper 04-039. URL: http://portal.opengeospatial.org/files/?artifact_id=6669.

[17] The NSDI Server Architecture Model. OGC White Paper 05-030. URL: http://portal.opengeospatial.org/files/?artifact_id=9984&version=2&format=pdf.

References for Spatial Data Infrastructure (SDI) development:

[18] Horton, R.M., Spatial Interoperability Demonstration Project (SIDP) Notional Architecture Executive Summary. OGC White Paper 05-053, 16 Feb 2005. URL: http://portal.opengeospatial.org/files/?artifact_id=10686.

[19] Starling, R., M. Wilson and R. Mason, Notional Architecture for a Geo-enabled Enterprise Portal Platform for the AusIndustry Spatial Interoperability Demonstration Project, Volume 1 – Summary. OGC-Australasia Ltd, 17 Aug 2004. URL: http://portal.opengeospatial.org/files/?artifact_id=6808

[20] Starling, R., and M. Wilson, Notional Architecture for a Geo-enabled Enterprise Portal Platform for the AusIndustry Spatial Interoperability Demonstration Project, Volume 2 – Technical Considerations: Viewpoints, part 1. OGC-Australasia Ltd, 17 Aug 2004. URL: http://portal.opengeospatial.org/files/?artifact_id=6811

[21] Starling, R., and M. Wilson, Notional Architecture for a Geo-enabled Enterprise Portal Platform for the AusIndustry Spatial Interoperability Demonstration Project, Volume 3 – Technical Considerations: Viewpoints, part 2. OGC-Australasia Ltd, 17 Aug 2004. URL: http://portal.opengeospatial.org/files/?artifact_id=6813

[22] Starling, R., and M. Wilson, Notional Architecture for a Geo-enabled Enterprise Portal Platform for the AusIndustry Spatial Interoperability Demonstration Project, Volume 4 – Appendices. OGC-Australasia Ltd, 17 Aug 2004. URL: http://portal.opengeospatial.org/files/?artifact_id=6812

[23] Starling, R., and M. Wilson, Notional Architecture for a Geo-enabled Enterprise Portal Platform for the AusIndustry Spatial Interoperability Demonstration Project, Volume 5 – Model to assist in the preparation of scenarios. OGC-Australasia Ltd, 17 Aug 2004. URL: http://portal.opengeospatial.org/files/?artifact_id=6831

[24] Kentucky Watersheds: Framework and Coordination, 2006. URL: http://www.watersheds.ky.gov/framework/

[25] KYKWMIP – Kentucky Watershed Modeling Information Portal. URL: http://kwmip.ky.gov/

[26] North Carolina Geographic Information Coordinating Council: NC OneMap Initiative. URL: http://www.ncgicc.com/CurrentActivities/NCOneMapInitiative/tabid/151/Default.aspx

[27] NC OneMap: Geographic Data Serving a Statewide Community. URL: http://www.nconemap.com/

[28] Werschler, T. and J. Rancourt, The Dissemination of Government Geographic Data in Canada: Guide to Best Practices, 2005. URL: http://cgdi.gc.ca/publications/Best_practices_guide/Guide_to_Best_Practices_v12_finale_e.pdf

[29] The Canada Geospatial Data Infrastructure: Architecture Description, 2001. URL: http://www.geoconnections.org/architecture/architecture_description.pdf.

[30] Guimet, J., 2005, Spatial Data Infrastructures, a new paradigm within the domain of Geospatial information. The example of the Catalonia SDI Project (IDEC). URL: http://www.geoportal-idec.net/geoportal/eng/pdf/ide_nouparadigma.pdf

[31] Guimet, J., 2006, Catalonia SDI: How municipalities are joining the regional SDI. First results and conclusions. URL: http://www.ec-gis.org/Workshops/12ec-gis/presentations/Seminar%20room/FRI_REG_SDI/guimet.pdf

[32] Bernard, L., G. Buziek, J. Riecken, U. Voges, and R. Wagner, 2003, GDI NRW: SDI in North-Rhine Westphalia. GINIE Registries & e-Services Workshop. URL: http://www.ec-gis.org/ginie/reg_ws/04buziek.pdf

[33] Riecken, J., 2007, Spatial Information Management in the Context of SDI and e-Government – The German Approach. Strategic Integration of Surveying Services, FIG Working Week 2007, Hong Kong SAR, China. URL: http://www.fig.net/pub/fig2007/papers/ts_1d/ts01d_05_riecken_1530.pdf

[34] Warnest, M., A. Rajabifard and I. Williamson, 2005, A Collaborative Approach to Building national SDI in Federated State Systems: Case Study of Australia. FIG Working Week 2005, Cairo, Egypt. URL: https://www.fig.net/pub/cairo/papers/ts_12/ts12_01_warnest_etal.pdf

[35] ORCHESTRA Architecture Document. OGC Pending Documents 07-024. URL: http://portal.opengeospatial.org/files/?artifact_id=20300&version=1. This is the reference architecture for discovery, access, and use of geospatial content and services for emergency services in the EU. OGC is a participant in this work.

[36] UNSDI Vision, Implementation Strategy and Reference Architecture. INSPIRE-UNSDI Discussion Meeting, Ispra, Italy, 15 Dec 2006. URL: http://sdi.jrc.it/ws/INSPIRE-UNSDI/presentations/ticheler_hielkema_inspire_unisdi.pdf

7.2. Acronyms

The following terms are not all used in this report, but are included here due to their relevance to the subjects of Spatial Data Infrastructures, Web Services, Service Oriented Architectures, and geospatial and IT standards.

AAA	Authentication, authorization and accounting
ACXML	Access Control Extensible Mark-up Language (OASIS): see http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=xacml
CAT	OpenGIS Catalogue Service (OGC): see http://www.opengeospatial.org/standards/cat
CMS	Cascading Map Server (OGC WMS): see http://www.opengeospatial.org/resource/products/details/?pid=179
CQL	Common Catalogue Query Language (Library of Congress, USA): See http://www.loc.gov/z3950/agency/zing/cql/
CSDGM	Content Standard for Digital Geospatial Metadata (USA FGDC): See http://www.fgdc.gov/metadata/geospatial-metadata-standards
CSW	OpenGIS Catalogue Service for the Web (OGC): see http://www.opengeospatial.org/standards/cat
DACS	Distributed Access Control System (OGC): see http://dacs.dss.bc.ca/arch-spec.html
EbRIM	ebXML registry information model (OASIS) see http://www.ebxml.org/specs/ebRIM.pdf
EbXML	E-business Extensible Mark-up Language (OASIS): see http://www.ebxml.org/
EROS	Earth Resources Observation and Science: see http://edc.usgs.gov/
EU	European Union
FGDC	Federal Geographic Data Committee (USA): see http://www.fgdc.gov/
GILS	Government Information Locator System (USA) see http://www.access.gpo.gov/su_docs/gils/
GINIE	Geographic Information in Europe: see http://www.ec-gis.org/ginie/
GIS	Geographic Information System
GML	Geography Mark-up Language (OGC): see http://www.opengeospatial.org/standards/gml
GNIS	Geographic Name Information Service: see http://geonames.usgs.gov/domestic/index.html
GOS-P	Geospatial One-Stop Portal (US Government): see http://gos2.geodata.gov/wps/portal/gos
GSDI	Global Spatial Data Infrastructure
HDF	Hierarchical Data Format: see http://hdf.ncsa.uiuc.edu/
HTML	Hypertext Mark-up Language (W3C): see http://www.w3.org/MarkUp/
http	Hypertext Transport Protocol (W3C): see http://www.w3.org/Protocols/
IETF	Internet Engineering Task Force: see http://www.ietf.org/
ISCGM	International Standing Committee for Global Map http://www.iscgm.org/
ISO	International Organization for Standardization http://www.iso.org/
LandXML	An XML schema for land planning: see http://www.landxml.org/
LDAP	Lightweight Directory Access Protocol: see http://www.openldap.org/
MIME	Multipurpose Internet Mail Extension (IETF)
NCSA	National Center for Supercomputing Applications, University of Illinois
NIST	National Institute of Standards and Technology (USA): see http://www.nist.gov/
NSDI	National Spatial Data Infrastructure; for USA initiatives, see glossary below and http://www.fgdc.gov/nsdi/nsdi.html

OASIS	Organization for the Advancement of Structured Information Standards: see http://www.oasis-open.org/who/
OECD	Organization for Economic Cooperation and Development
OGC	Open Geospatial Consortium: see http://www.opengeospatial.org
OSI	Open Source Initiative
OSS	Open-source software
OWS	Open Web Service initiative of OGC Interoperability Program (OGC): see http://www.opengeospatial.org/ogc/programs/ip
PAGIS.org	Pennsylvania GIS Consortium: see http://www.pagis.org (not to be confused with the Pennsylvania GIS Annual Conference!)
PASDA	Pennsylvania Spatial Data Access: see http://www.pasda.psu.edu/
PaMAGIC	Pennsylvania Mapping and Geographic Information Consortium: see http://www.pamagic.org/
PGDSS	Pennsylvania Geographic Data Sharing Standards: see http://www.pacounties.org/pamagic/cwp/view.asp?a=2021&q=502673
PKI	Public Key Infrastructure (NIST): see http://csrc.nist.gov/pki/
PNG	Portable Network Graphics (W3C): see http://www.w3.org/Graphics/PNG/
SAML	Security Assertion Mark-up Language (OASIS)
SCOTS	Standards-based Commercial Off The Shelf software
SDI	Spatial Data Infrastructure (see glossary below)
SFS	Simple Features Specification (OGC): see http://portal.opengeospatial.org/files/?artifact_id=18241; http://portal.opengeospatial.org/files/?artifact_id=13227
SLD	Styled Layer Descriptors (OGC): see http://www.opengeospatial.org/standards/sld
SOAP	Simple Object Access Protocol (W3C): see http://www.w3.org/TR/soap/
TCP/IP	Transport Control Protocol/ Internet Protocol (IETF)
UDDI	Universal Discovery Description and Integration (OASIS): see http://www.uddi.org/
UNEP	United Nations Environment Programme: see http://www.unep.org/
UNGIWG	UN Geographic Information Working Group: see http://www.ungiwg.org/
URI	Uniform Resource Identifier (W3C)
URL	Uniform Resource Locator (W3C)
USGS	US Geological Service (USA): see http://www.usgs.gov
W3C	World-Wide Web Consortium: see http://www.w3.org
WCS	Web Coverage Service (OGC): see http://www.opengeospatial.org/standards/wcs
WFS	Web Feature Service (OGC): see http://www.opengeospatial.org/standards/wfs
WMC	Web Map Context (OGC): see http://www.opengeospatial.org/standards/wmc
WMS	Web Mapping Service (OGC): see http://www.opengeospatial.org/standards/wms
WPOS	OGC Web Pricing & Ordering Service (OGC)
WSDL	Web Services Description Language (W3C): see http://www.w3.org/TR/wsdl
XML	Extensible Mark-up Language (W3C): see http://www.w3.org/XML/

7.3. Glossary

As with acronyms above, the following terms are not all used in this report, but are included here due to their relevance to the subjects of Spatial Data Infrastructures, Web Services, Service Oriented Architectures, and geospatial standards.

Application	A program that performs a specific function directly for a user. Applications can make use of SDI.
Architecture	The organizational structure and operating environment of the SDI, including the relationships between its parts, and the principles and guidelines governing their design and evolution over time.
Binding	Specific syntax and parameter values used by a client to invoke a specific server operation
Capabilities schema	XML schema that prescribes and constrains the syntax and vocabulary for the expression of service capabilities in XML.
Capabilities XML	Specific instance of service-level metadata describing a service instance.
Client	A software component or an application that accesses a service. Clients may be categorized in three ways: **Thin clients** where the client supports only human-interface code, such as a web browser, and X-terminal, a text-only interface or a minimal PDA or WiFi handset, and must support non-proprietary standards. Typically, lack long-tem memory such as disk drives. Application code and data access both run remotely, and so are entirely dependant on external network connection. **Thick clients** where the client supports all the human interface and application code, may support some or all data access code, and may support long-term data memory. Human interface code may be entirely customized and not conform to non-proprietary standards. May not even support human interfaces i.e. may be entirely automated emote processes. May operate at times without network connection. **Chubby clients** have capabilities somewhere on the spectrum between thick and thin clients i.e. may support some application and data code, and may store limited amounts of data. Will usually but not necessarily support human interfaces. May operate well for limited time without network connection.
Component	Software that packages the client or server implementation of a service and can provide the realization of a set of interfaces. A component consists of software code (source, binary or executable) or other equivalents such as scripts or command files.

Conceptual Architecture	An overview of the services, data, technology and institutional environment of SDI. It describes, in general terms, both what the SDI will include, and how it will operate.
Core Service	A service that is critical to the ongoing operations of the SDI. The Service Registry Service is an example of a core service. It is used to keep track of where SDI services can be found, so if this service were unavailable, client applications would not be able to locate the services required in order to complete a task.
Coverage	A continuous representation of a portion of the earth's surface. A coverage may be a collection of features (like a vector dataset) or it may be a raster or gridded surface representing one or more attributes.
Coverage Data	Gridded data, imagery, swath data, and continuous functions. Contains values for every point in a geospatial data. Relevant specifications may include: • SDTS - Spatial Data Transfer Standard • GeoTIFF - Georeferenced Tagged-Image File Format • HDF – Hierarchical Data Format
Custodian	The authoritative manager of an SDI resource, whether data set, service or component, who is responsible for declaration of the policies regarding utilization and accounting for the resource.
Datastore	Any type of persistent storage for Information Queensland components and data. Content may be static or dynamic. May include database systems, file systems, structured text storage, XML repositories etc.
Event	An occurrence of interest to users or developers of the SDI. Events can be things such as the adjustment of a feature in a framework data layer, a flood in the Red River basin, or the release of a new specification for a SDI service.
Framework Data	The set of geospatial data that provides the reference framework for all other SDI compliant geodata. See the (US FGDC) NSDI Framework Overview, and the (Canadian) CGDI Framework Data Definition for more detail. Several geospatial data themes common to base maps are considered to be of fundamental importance to many applications. Known as "Framework Data," these themes for PAMAP are: buildings, elevation contours, hydrography, geodetic monuments, geographic names, orthoimagery, tax parcels, political boundaries, road centerlines, and other transportation-related data, such as airports and railroad centerlines. PAMAP shall be able to access both Framework Data sources and other, non-Framework data.
Geodata	Georeferenced spatial data such as a road network or a satellite image. Geodata explicitly describes the spatial extent of a set of features or describes a measurable surface. It includes both geospatial data and geolinked data. See also Wikipedia.

Geodata Resource Registry	Peer registries that contain metadata about geodata resources. These registries identify the agencies that are responsible each attribute dataset, and descriptions of that attribute data. They also contain information on how to access the data.
Geolinked Data	Geodata that are referenced to an identified set of geographic features without including the spatial description of those features. Geolinked data are normally attribute data in tabular data (such as population counts) that refer to a known framework (such as municipalities), where their unique identifier (such as the municipality name) refers to the elements (the municipalities). The term "geolinked data" refers to all attribute data that is not directly attached and bundled with the geographic coordinates to which it applies.
Geospatial Data	Geodata with explicit geographic positioning information included, such as a road network from a GIS, or a georeferenced satellite image. Geospatial data may include attribute data that describes the features found in the dataset.
GeoTIFF	Georeferenced Tagged-Image File Format: see http://www.remotesensing.org/geotiff/geotiff.html
Interface	The named set of related operations that structures how a client interacts with a server. The state and functionality of the underlying component is hidden, and is only made externally accessible through its interface (i.e. the interface is the only "public" or "visible" part of the component). The same interface may be provided by several components and used by many components or applications.
LandXML	Facilitates the exchange of data created during the Land Planning, Civil Engineering and Land Survey process. LandXML is an XML application that utilizes XML Schema to define relationships and custom data types. Much like GML, LandXML is a fairly robust application of XML as a data format, targeted specifically towards land planning, engineering and survey applications. See http://www.landxml.org/
Library	A type of registry intended for recording references to entity types (as distinct from recording instances) i.e. a look-up. Content is generally static once instantiated
Map	A pictorial representation or portrayal of geographic data
Master System	A primary system that is mirrored to other identical systems, so as to ensure that any important information or services can be accessed in an identical fashion from multiple sites.
Metadata Standard	Data will be documented according the FGDC Content Standard for Digital Geospatial Metadata (CSDGM) and/or the ISO 19115. A free version of ISO DIS 19115 (the latest draft before final adoption) and a subsequent corrigendum (01-053r1) are available from OGC.
Operation	An interaction between a client and a server, resulting in a transfer of information or an action. An operation can be either an interrogation (i.e. request-response) or an announcement (i.e. notification).

Portal Services	Provide "one-stop" access to the Provider Services. An online access point to a collection of geospatial data -- more precisely, to a collection of services that provide data or relevant functionality. A Portal does not store or maintain the data and its associated services; rather, these are distributed in many computers nationwide and maintained by the agency or organization that is responsible for its data and services. Portals shall be based on open standards and specifications that are defined collaboratively by a various interested parties, are freely published, and are able to be implemented by any vendor or organization.
Primary System	A system that provides a core service and thus is critical to the operations of the SDI. Although a primary system may not be mirrored to other sites, or even the most popular implementation of a particular service, they are publicly identified and funded to ensure that core services are implemented on at least one system.
Process	A system offering a single interface for the execution of a single task creating one or more products. Processes may be grouped to provide a service.
Provider Services	Include map, data, gazetteer, catalogue and any other services hosted and maintained at remote sites independently of PAMAP and are accessed by it. The role of the Portal Services is to provide "one-stop" access to the Provider Services.
Reference Architecture	A set of policies that guide the development, usage, and evolution of the SDI of which PAMAP is a part. The reference architecture is not a wiring diagram of hardware and software components, but a conceptual model of the data sources, types of users and applications, and their associated roles and relationships to meet the long-term requirements for the SDI. The reference architecture serves as a guide for making decisions in the growth of PAMAP and other data sources and processes in the Commonwealth, such as the choice between federation or centralization of specific datasets, or the manner in which updates from data providers will be integrated into the statewide framework on an ongoing basis, or how data rights issues will be handled. A resource containing a consistent set of architectural best practices for use by all the teams in your organization or enterprise. (Rational Edge) Provides a frame of reference for the description and definition of scenarios encapsulating user requirements and the data access, processing and display services needed to meet the long-term requirements of the SDI.
Registry	A listing of the specific, individual services, components, datasets, or other things that comprise the SDI or are relevant to its users. Instance registries are used to identify, locate, and describe individual instances. Many registries refer to associated Type Libraries that record the allowed types within registry classes e.g. types of services, types of user authorities.
Request	Invocation of a server operation by a client

Response	Result of an operation returned from a server to a client
Schema	A schema is an expression of the type using a particular data modeling language. Types provide the basis for classification taxonomies for sets of schema definitions. In the OGC the application data-modeling language is GML and each schema fragment corresponding to a given type is defined in GML.
Server	(a) A software component that delivers a service. (b) A physical implementation of such a component, that provides the realization of its operations.
Service	A collection of operations, accessible through one or more interfaces, that allows a user to evoke a behavior of value to that user. A server is delivers each service. A service may encapsulate may processes. A "service instance" is another name for a server (b).
Service capabilities	Service-level metadata describing the types, operations, content, and bindings available at a service instance. Organization, classification, and presentation of those entities may also be conveyed by the capabilities information.
Service Registry	Contains metadata about individual services, including the type of service, and information about how to access the service. A Service Registry Service provides a mechanism to: 1. Register the characteristics of certain types of services (in a Service Type Registry) and register the existence of specific services (in a Service Registry); 2. Search Service Registries; and 3. Retrieve detailed information (metadata) that describes a service, in order to evaluate its suitability to meet a need. A Service Type Registry contains information about specific *types* of services, including the name of the service type, and its definition. A Service Type Registry is being maintained manually, at http://www.geoconnections.org/architecture/systems/ServiceTypeRegistry
Site	A location (e.g. URL) at which a system is accessed.
Spatial Data Infrastructure	A framework of spatial data, metadata, users and tools that are interactively connected in order to use spatial data in an efficient and flexible way. (Wikipedia) Another definition is the technology, policies, standards, human resources, and related activities necessary to acquire, process, distribute, use, maintain, and preserve spatial data. [US OMB] For more info, see US NSDI.
Spatial reference system (SRS or CRS)	A projected or geographic coordinate reference system. See OGC Abstract Specification, Topic 2, for more info.

Styled Layer Descriptor	Metadata describing presentation of geographical types for portrayal in WMS and WFS Addresses the need for geospatial consumers (either humans or machines) to control the visual portrayal of data. It can be used to portray the output of Web Map Servers, Web Feature Servers and Web Coverage Servers. Uses consistent XML-based methods persisting in an SDL library.
System	Servers and data organized to accomplish one or more **Services**. A system may be accessible at more than one site.
Type	A type refers to a kind or class of geographic entity. Types are meaningful elements in a particular universe of discourse.
Web Agent	People or software that act on the web information space. Software agents include browsers, servers, proxies, spiders, and multimedia players mediating interactions on behalf of a person, entity, or process.
Web Service	Application logic accessible across a network using standard Internet protocols. Web Services combine the best aspects of component-based development and the Web. Like components, Web Services represent functionality that can be easily reused without knowing how the service is implemented. Unlike current component technologies that are accessed via proprietary protocols, Web Services are accessed via ubiquitous Web protocols (e.g. http) using universally accepted data formats (e.g. XML).