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Implementing geoportals: applications of distributed GIS

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Abstract

As GIS implementations mature and GIS use expands beyond the current core GIS community the need to discover and disseminate GIS capabilities grows. The Internet and the age of distributed computing provide the technical framework on which distributed GIS is built. As key application of distributed GIS, geoportals provide a gateway to discover and access geographic Web services. Four key geoportal projects are presented that help to define distributed GIS, and illustrate the challenges to be met in order to achieve the goal of wider GIS usage.

Keywords: Geoportals; Geographic web services; Distributed GIS; Geography Network; Geospatial One-Stop

1. Introduction

Since the late 1990s, the geographic industry has seen increasing interest and activity in the deployment of web sites that provide access to geographic content. There are several drivers behind this activity. One is the advent of the World Wide

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Web and an interest by many industries to harness it to help drive growth. At the same time, the GIS industry itself has come of age. This maturation has led to a new phase of growth for the industry that focuses on dissemination of geographic knowledge and capabilities. Finally, there is an increasing recognition in business, both public and private, that geographic content and GIS capabilities add value to many business processes. Geographic portals represent an applied response to this need to disseminate geographic data and leverage the GIS community's substantial investment in GIS capabilities and content (NRC, 1999).

Over the last six years the GIS community has become increasingly focused on the dissemination of GIS capabilities within, as well as outside of, organizations. There is recognition within the community that the web provides a new medium for participation (Longley & Batty, 2003), and its response has come in the form of software technologies that provide the capability to implement GIS in a distributed environment. To build effective, relevant technology, GIS vendors have traditionally worked with key users and partners to implement solutions that both satisfy the requirements of specific projects and foster the development of core software that supports these and other customer deployments. During the last six years the author has participated in GIS vendor–user partnerships on four major projects that have pushed the limits of GIS technology beyond the desktop architecture to distributed GIS. The experiences gained in implementing these projects point the way to using Internet technologies to disseminate GIS capabilities.

This paper reviews the four key projects, the stages of distributed GIS they represent, and the lessons that have been learned from them to date. These projects help us to see how to evolve geoportal applications into truly distributed GIS. Additionally, a definition of geoportals is presented from an industry perspective, and the GIS system components and standards needed to support portal implementations are discussed. Finally, this paper outlines a way forward for geoportals and distributed GIS, the challenges to be faced, and the rewards to be gained.

2. What is a geoportal?

A technical definition of the word "portal" is "a web site considered to be an entry point to other web locations" (http://www.dictionary.com). Append the term "geo," and the result might be as follows. Geoportal: a web site that presents an entry point to geographic content on the web or, more simply, a web site where geographic content can be discovered.

Many web sites, however, have some association with geographic content or functions. For example, most web sites representing businesses have, at a minimum, addresses for the business locations on their sites, and many have links to map images depicting these locations. What then is the defining characteristic that differentiates a geoportal from other web sites with some geographic content? In most sites, geographic content supports the site but is not the site's primary focus. So to refine the definition further, a geographic portal is a web site where the discovery of geographic content is a primary focus.

The origins of geoportals can be traced to the early growth of the Internet. Web sites like MapQuest (http://www.mapquest.com) and MapBlast (http://www.mapblast.com) are examples of portals that capitalized on the advent of the Internet and the interest of the public to locate places and map them. (MapQuest was sold to AOL for $1.1 billion at the height of the ''dot com era'' ZDNet, 1999). Even after adjusting for the hype factor, this is still a significant indicator of the value of geographic technology in popular media. The US Federal Geographic Data Committee's (FGDC) Clearinghouse web sites represent one of the earliest spatial data infrastructure (SDI) web portal initiatives. The FGDC portals were driven by the first US presidential requirement to support the sharing of geographic information, the National Spatial Data Infrastructure or NSDI (FGDC, 2003; Longley, Goodchild, Maguire, & Rhind, 2001).

Common to each of these early geographic portals is the application of GIS in a distributed computing environment. Today, implementation of geographic portals is based on distributed GIS technologies. Additionally, the successful implementation of a distributed GIS relies on well-formed geographic portal applications to assure the system's relevance to the user community it serves. This strong relationship between the platform (distributed GIS) and the application (the geographic portal) is the subject of the next section.

3. The technology of geoportals: distributed GIS

Prior to the advent of the Internet, GIS technology, like other software technologies, was limited to the domain of desktop, workstation and in limited cases, server-based computing platforms. The physical restrictions of these computing platforms confined GIS to only supporting the evolution of project and departmental GIS.

Distributed computing has provided the foundational standards and technology on which the Internet and distributed GIS are built. The Internet consists of information technology standards, such as, Transmission Control Protocol/Internet Protocol (TCP/IP), Hyper Text Transport Protocol (HTTP), Hyper Text Markup Language (HTML), and eXtensible Markup Language (XML) as well as software, physical computing, and network infrastructure. The term 'Service-Oriented Architectures (SOA)' is now used to refer to this technology of the Internet (World Wide Web Consortium Architecture Domain: Web Services Activities, 2002). SOAs provide a very flexible framework for supporting a wide range of applications (Barry, 2003). The GIS industry has, in turn, exploited these technologies to build the capabilities known as distributed GIS. Distributed GIS is simply GIS technology that has been built and deployed using the standards and software of the Internet. The great benefit of distributed GIS is that many GI systems can be linked and accessed as a single virtual system.

A key challenge for distributed GIS is the publishing of geographic content. The publishing process takes place in two steps. The first is the preparation of the content and functionality to be accessed, and the second is the presentation of content through a discover application—geoportal. Geoportal applications present the user with the ability to search or browse for capabilities and content that are either used in the discovery application itself or in other applications such as a desktop GIS.

A geoportal is implemented using three distributed GIS (SOA) components; a web site presents the geographic application or portal; web services publish geographic functionality as a web service; and data management software provide a managed relational environment for both raster and vector geographic content. Fig. 1 identifies the various components of a geoportal, their relationships to one another, the enabling technologies and standards with which they are implemented, and finally the key functions implemented in a distributed GIS and used by a geoportal application.

A geographic web site is developed and deployed using standard web development tools, and is comprised of two elements; the web site framework and the functional tools. The web site framework presents the geoportal's supporting information via a graphical user interface to the user. The second element is the functional tools that enable access to GIS functions such as geocoding, gazetteer linkage, and mapping and query functions. These tools do not embed the functionality they present, but rather serve as a proxy to functionality which runs as geographic web services.

Geographic web services publish geographic content and functionality. Information technology (IT) standards, such as eXtensible Markup Language (XML), Simple Object Access Protocol (SOAP), and Web Services Description Language (WSDL), are utilized by GIS vendors to support the deployment of geographic web services. Additionally, the geographic industry has published geographic web services standards, which layer on top of some of these IT standards. Organizations like the Open GIS Consortium (OGC), International Standards Organization (ISO) and Federal Geographic Data Committee (FGDC) are examples of groups whose

Components	Elements	Environments	Functions
Web Portal	**Web Site**	HTML,HTTP,XSL,XML, JSP, ASP	Search, Map Viewer, Publish, Administrate
	Web Controls	Java Beans, .NET	Query, Gazetteer, Mapping, Edit, Geocoding,
Web Services	**Geographic Web Services**	XML, SOAP, WSDL, WMS, WFS, GML	Query, Map render/feature, Transaction, Geocode
Data Management	**DBMS**	SQL	Raster, Vector, Tabular
	Geographic & Tabular Data		

Components: identifies the three major components in a distributed GIS / geoportal architecture

Elements: defines the functional elements of each component in a distribut ed GIS / geoportal architecture

Environments: refers to the information technology standards used to implement each element of the architecture (Hyper Text Markup Language, HyperText Transfer Protocol, eXentsible Markup Language, XML Style Sheets, JAVA Server Pages, ActiveX S erver Pages, .NET— Microsoft's web services technology, Simple Object Access Protocol, Web Services Description Language, Web Map Serv ice, Web Feature Service, Geographic Markup Language, Standard Q uery Language)

Functions: identifies the specific capabilities implemented in each element of the architecture.

Fig. 1. Distributed GIS/geoportal architecture.

work supports the definition of geographic web service standards. Typical geographic web service functionality that is published in a geoportal includes: map rendering; feature streaming; data projection; geographic- and attribute-based queries; address geocoding; gazetteer/place name searches; metadata query and management; network analyses; 3D terrain visualization; and data extraction. This is by no means a comprehensive list, and it provides only a high-level introduction to distribute GIS functions. Users are deploying high-end GIS applications over the Internet using GIS functions like these deployed as geographic web services. The geographic data management component of a distributed GIS supports the active use and maintenance of geographic data. This capability allows both internal and external organizations to access the latest data while allowing the content to be actively managed and maintained. GIS vendors support the deployment of geographic content on standard relational database management systems which are extended to geographic data types and capabilities.

Taken together, geoportals provide distributed GIS applications with capabilities for searching, mapping, publishing and administrating geographic information. Fig. 1 identifies the components of a distributed GIS that provide the functionality utilized in specific geoportal applications. These are:

3.1. Search

Search functions are aggregations of building block tools which are executed in sequential steps. The first step in many applications is to locate a place through one of several methods including a place name search using a gazetteer tool, an address search using a geocode tool, or simply selecting a location from a list. For example, using a gazetteer tool, a user can enter a place name, execute a search for that place, and return a list of candidate locations, allowing a selection to be made. Once a place is identified, most geoportal applications then execute a second step in the search process; they search for a particular set of features or objects that are usually the focus of the geoportal. This search could be for homes for sale based on a neighborhood name or for geographic web services with coverage of a particular city. In many cases searches allow both geographic and attribute criteria for searching. The geographic search can use geographic content directly or content metadata.

3.2. Mapping

While it is not a prerequisite of a geoportals to provide map visualization capabilities, in most instances mapping is implemented to add value to the search process. In the case of an application like MapQuest, the map is the focus of the web site. In other cases, such as an SDI geoportal, a map allows the user to more fully examine published content. Additional functions might be pan, zoom, and feature identify capabilities to aid the user in more thoroughly evaluating the published content. Finally, the ability to view multiple map services in a fused or single map image is also often supported.

3.3. Publishing

The publishing process entails addition, deletion, and modification of metadata content. Depending on the sophistication of the site, publishing can be manual, through a web page interface, or automated through a web service interface (metadata harvesting).

3.4. Administration

The administration function is simply an extension of the publishing function with one additional capability: the review/approval of metadata content submitted for publishing on the portal web site. Spatial data infrastructure (SDI) portal requirements have dictated that administrative privileges be granted to certain administrators so that they can edit and validate published content. Additionally, administrators are responsible for publishing site-level versus content-level metadata. Site metadata is used to support the portal web site presentation.

4. Geoportal implementations

Four case studies are described in this section that illustrate how geoportals are being used in practice. These case studies have been chosen because they illustrate a wide range of commercial, business and government applications. The case study applications range from generating a simple map of a location to providing maps customized to user-defined criteria. They also illustrate how simple high availability mapping and query systems are built; how geographic web services may be integrated from multiple Internet nodes; how online catalogs of live geographic web services may be created, searched, browsed, visualized and linked; and how authoritative governmental online catalogs of live geographic web Services may be created (Open GIS Consortium, 2003). The following sections review the specifics of the four geoportal projects, the experiences gained through their implementation, as well as the lessons learned from them in relation to the evolution of distributed GIS.

4.1. Homestore.com

In 1997, the National Association of Realtors (NAR) established a relationship with a startup company called RealSelect. The relationship with RealSelect provided NAR with an Internet portal web site for home sale searches. Distributed GIS technology had been used at NAR the previous year to build a prototype system for realtors (estate agents) to access a private online mapping and report system. These two efforts were integrated and led to the development of an initial distributed GIS system with mapping, query, and geocoding functionality linked to the REALTOR.com web site (see Fig. 2).

For the last six years hosted mapping and analysis services have been included, first to the REALTOR.com web site, and then to the follow-on homestore.com suite

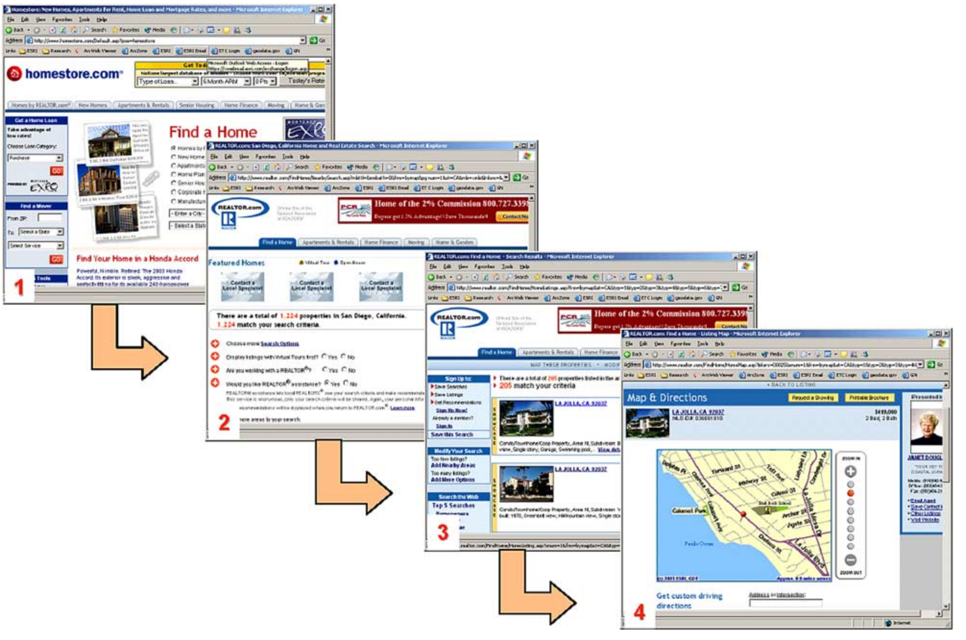

Fig. 2. Homestore.com.

of web sites (Homestore.com, 2003). Homestore.com is the umbrella company and hosts the web site that forms a super-portal focused on finding homes in the US and parts of Canada, for sale or rent. The site deals with new and existing apartments and single-family homes. Functionality served to the sites includes: mapping home sale locations; providing a neighborhood thematic search map with postal code (ZIP code) polygons shaded based on a consumer's desired criteria for a neighborhood; locating home sales by neighborhood; providing directions and maps for routing a customer to a home sale location; and geographic evaluation of a home sale location including demographic, environmental hazards, and flood zone analysis.

Currently, four homestore.com web sites use distributed GIS web services hosted at separate commercial facilities. Homestore.com maintains its portal web sites at its Internet service provider (ISP) facility and accesses the geographic web services from another ISP facility. Approximately 1.5 million geographic web services requests are made each day from the homestore.com web sites. Average map generation time is 0.56 s.

The homestore.com experience helps us to define the requirements of a high-availability, mission critical web portal application. This required level of availability is typically necessary to support geoportals and is the most often overlooked element in building distributed GIS systems. Both the software technology and the computing infrastructure need to be harmonized and up to the task of 24×7 (24 h a day/7 days per week) availability. Once a system has been tested by the demands of such an environment, delivery of an effective geoportal solution is possible. The homestore.com project brought this requirement home quite clearly and provided needed experience of building, maintaining, and sustaining 24×7 production-distributed GIS.

4.2. MapMachine

In March 1998 the US National Geographic Society (NGS) began a project to build an online mapping and atlas web portal to be accessed on NationalGeographic.com (Fig. 3). National Geographic planned the launch of the web site to coincide with the release of the seventh edition of the *National Geographic World Atlas*. NGS had no ability to host the geographic web service content and functionality needed to build the MapMachine application so these services were hosted off-site by ESRI (Redlands, CA). NGS worked in conjunction with a third party web site developer to design the functional capabilities and usability of the site. NGS prepared the MapMachine web site based on the joint design and hosts the web site physically at its own ISP. The web service hosting is provided from a separate ISP facility. The focus of this mapping and atlas portal is to support geographic discovery, addressing the mandate of NGS to support "the increase and diffusion of geographical knowledge" (NGS, 2003). The audience or users of the portal are students of all ages. Functionality centers on an international place finder tool (gazetteer) with more than 6 million English language references (Fig. 4). Once a user selects a location of interest, they can select from more

Fig. 3. MapMachine.

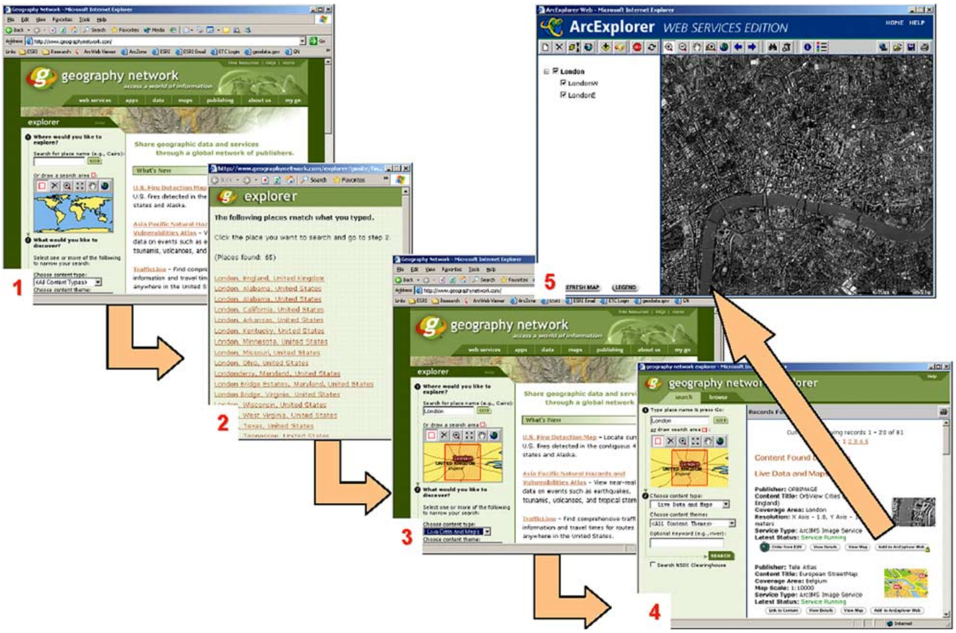

Fig. 4. The Geography Network.

than 65 individual thematic maps services covering the globe. Map services range from local and international street maps to raster NGS atlas images to World Wildlife Fund environmental research thematic maps. The final step allows users to print a custom map view for inclusion in presentations and reports.

With more than 500,000 transactions per day, MapMachine drives more than 50% of the NGS web site traffic. In addition to the mapping functionality, NGS Online has taken advantage of geographic web services to geographically enable its product advertisements. Advertisements for NGS products that have geographic aspect to them, like maps of Europe and European cities, are presented to users as they search for and create maps of Europe. Building and sustaining MapMachine over the last several years has highlighted the issue that provision of international content alone is not enough; international users want localized content and a localized web site. This finding is based on a growing interest from international users in two major growth markets for NGS, Europe and Asia. This has possible implications for the design of all portal applications and their supporting geographic and metadata content. The experience also highlighted a number of design issues: portal sites are usually accessed by users with a wide range of education and technology skills and the site must be simple in design and perform quickly. These two attributes of a portal are key to user acceptance. Performance is enhanced by building lightweight web pages that are easy to download even in low bandwidth situations. A portal must minimize the number of user "clicks" to get to content and, at the same time, maximize the functionality available to the user.

4.3. The Geography Network

The prime focus for the Geography Network portal (http://www.geographynetwork.com) was to publish and share geographic web services (The Geography Network, 2003). From the outset the Geography Network was designed to support the FGDC Clearinghouse network, established as part of the National Spatial Data Initiative by the US federal government. Although the publishing on-line of geographic web services was the primary focus of the geoportal, other geographic content types, from ftp sites to other geographic applications and portals, could be published and found through the site. The Alexandria Digital Library Project, an early online distributed, georeferenced web archive, strongly influenced the site design process (ADL, 2003). Since its implementation, the Geography Network has also served as an example of how a modern distributed GIS can be leveraged to implement SDI-focused geoportals. Many organizations have subsequently used the Geography Network model to build similar portals and networks (Tang & Selwood, 2003).

The functionality of the site is presented in Fig. 5. The user begins by setting geographical search criteria by type of content and by keyword. Use of all, some, or none of the search criteria is permitted. If the user chooses to limit the search geographically, they can either enter a place and select a location from the candidates presented by a gazetteer search, or manually place a search box on the map tool provided in the interface. Once criteria are selected and set, the user starts a search process that queries the metadata catalog of the site. The search will yield a list of

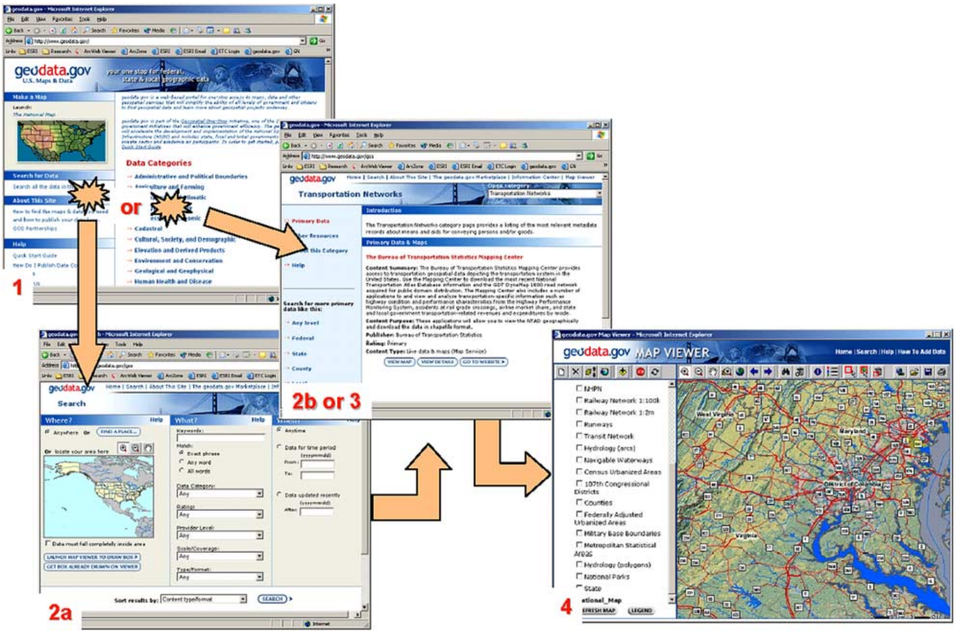

Fig. 5. The geodata.gov website.

records that meet the criteria, and the user can then review the summary information and select to review the detailed metadata for a record or, if the record is geographic web map service-based, the user can review the live service in a map viewer application frame. Finally, users can link to a site registered by the publisher of the record with additional information about the published data.

In early 2004 the Geography Network had more than 6000 elements of published metadata stored in the system. Seventy percent of those elements reference US-based content, with the remaining 30% referencing internationally based content. Of those elements, more than 50% of them reference web or web services-based content. More than 300,000 transactions a day are recorded at the web site, with peak traffic running at more than 400,000 transactions a day. There are an estimated 50,000 users accessing the site each day.

The development and deployment of the Geography Network has yielded a number of significant lessons. An SDI-based geoportal is only as good as the information that is published through the site, and metadata is core to the publishing process. Therefore, the publishing of metadata needs to be as effective as possible. Early in the process of deploying the site, user-publishing activities were minimal because the process required that publishers manually enter metadata by hand, cutting and pasting to the online forms from existing sources. Those that did publish this way did not update their data very often because the required procedures were cumbersome. The team's response was to build a metadata upload process that allowed users to publish using XML documents. Once these capabilities were in place, many more organizations began participating in the publishing process. The next step in the evolution of publishing was to support the automated harvesting of metadata services. Users can now publish content by simply registering a metadata service which is then harvested automatically by the Geography Network on a periodic basis. This allows users with compatible geoportals to publish once to their own services and have that information flow up to the Geography Network geoportal.

Finally, the quality of metadata content is key to effective publishing to an SDI portal. The process must be streamlined, but the end result must be accurate metadata content or else users will not have confidence in the content of the site (Oram, 2001). Only one method was found to generate these desired results, editorial review of submitted content. As our team gained experience in the publishing process, we found that two separate steps are needed. First, the submission of metadata content must be streamlined. Second, there was a need to review the submitted content in order to verify that it is accurate and meets minimum publishing requirements. Depending on the nature of the site and how it is administered, this review process can be cursory or detailed. In the case of the Geography Network, administration of the site was undertaken as a community service, and the hosting organization had no authority over the submitted content or submitting organizations. Only a cursory review was, therefore, undertaken to ensure that the basic facts were accurate. As we will see in the next example site, this authority of administration allows for a more extensive editorial review to take place, to the benefit of a large community of users.

4.4. Geospatial One-Stop

Geospatial One-Stop e-government initiative (egov, 2003) is one of 24 US federal e-government initiatives launched by the current executive administration (Fig. 5). It has as its primary focus the development of a geoportal that serves the federal government's geographic content product pages and acts a template/catalyst for regional and local government participation and use. Launched in June of 2003, www.geodata.gov has accelerated interest in geoportals both nationally and internationally (Geospatial One-Stop, 2003). The US government recognizes that nearly 80% of all government data has a geographic component (egov, 2003). This initiative is based on growing recognition within the government that innovative IT strategies are needed in order to fully realize the e-government mandate (NRC, 2002).

The GIS industry, including commercial vendors and standards organizations, has responded to meet strategic customer requirements to build geoportal capabilities that are sustainable, cost effective, and robust, leveraging their distributed GIS technology investments. Geodata.gov was designed to streamline the process of accessing information. One design criterion was thus "two clicks to content". In other words, a user should be able to type in the URL or click a link and by clicking a second time on the geodata.gov home page be looking at available content. Fig. 6 illustrates this: when the user clicks on one of the Data Category links, a stored query against metadata tables is executed. The query then returns a set of candidate records based on data category attributes sorted by class: primary, secondary, and

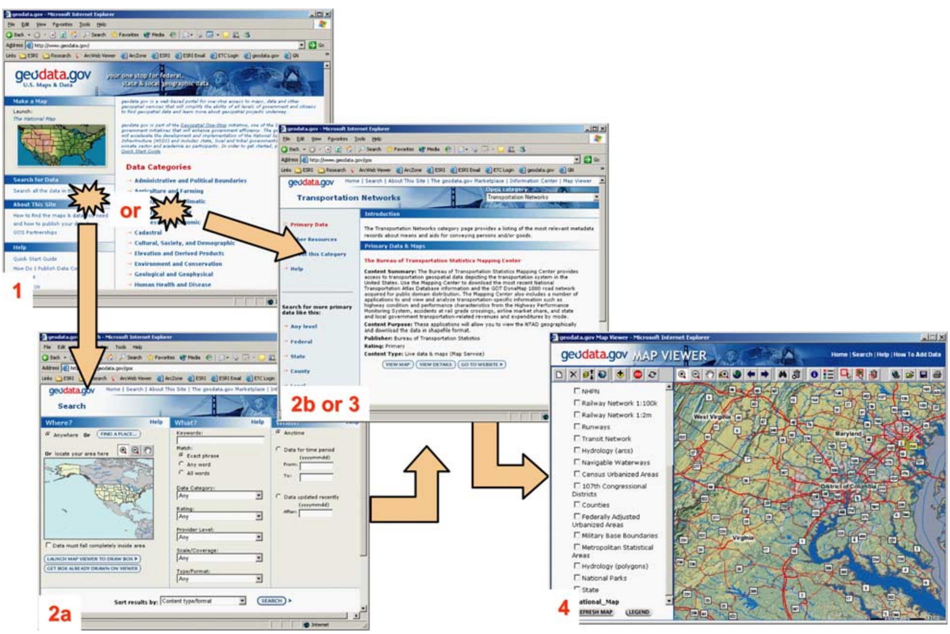

Fig. 6. Geodata.gov.

tertiary. Users can then select an individual record and browse the metadata; view the live content if the record represents a map service; link to the publisher's site; or further refine the query using geographic, attribute, or temporal filters. Alternatively, rather than use the quick search functions that the Data Category links provide, the user can arrive at the site and choose to go straight to the map viewing tool and use it to retrieve live map service records and view them or use the advanced query tool. The site also offers an interface for content publishing. This interface allows users to enter metadata about their organization and the content they are publishing. The interface provides for addition, deletion, and modification of records. A private set of pages (privately published) is also available to allow geodata.gov partners to administer site content and review content records submitted for publishing.

Currently, geodata.gov has more than 7000 elements of published metadata stored in the system. Ninety percent of those elements reference US-based content, with the remainder referencing internationally based content. Of those elements, more than 70% reference web- or web services-based content. More than 150,000 transactions per day are recorded at the web site, and traffic was estimated to reach 250,000 transactions a day by mid-2004. Phase 1 of system development is complete and the system has been operational since June 29, 2003. Anticipated Phase 2 development plans will cover the building of a web site template so other levels of government can prepare a geodata.gov for their organization and users. Additionally, new functionality will be added to the site itself to enhance usability and the capabilities of the search and map visualization tools.

The implementation of geodata.gov yielded a number of crucial lessons. Community participation is imperative to the success of an SDI geoportal, in particular one of this scope. The design and deployment of the geoportal web site is just the first step in the process: the content which geoportals are intended to reference is the real goal. Participation in the GIS community activity surrounding a geoportal initiative, as well as, the active support of the site in terms of publishing viable content is essential to successful data dissemination (NRC, 1994). Without appropriate, professionally maintained and reliable content, a geoportal is just another web site that may not lead anywhere. The partner community forms the core of participation in the geoportal web site and, therefore, partners must be committed to administering the site as well as publishing primary content sources for their respective domains. The content must be published in a professional manner, requiring review of submitted content and the active maintenance of data classification (category) information. Finally, the more successful the initial site is, the more demand intensifies the need for clear and concisely articulated content standards to be defined and adopted.

5. The way forward

The GIS community has worked for many years to build distributed GIS technology that supports geoportals implementation. Most of the early focus was on the implementation of functional portals. As the need has grown for geographic communities to share their geographic content with other communities and non-GIS users, efforts have turned to multiple web services standards as well as packaging the tools needed to implement SDI portals. However, technology alone will not ensure the success of distributed GIS systems.

As more and more GIS user communities implement geoportals these systems are driving broader acceptance and use of shared geographic data both within the GIS community itself as well as with non-GIS users. One of the largest barriers to the adoption of GIS by non-GIS users has been access to GIS content. Geoportals enabled by geographic web services provide a means to overcome this barrier to non-GIS users. These users no longer need to search and manage the content on their own. Geoportals point the way to content, and the publishing organizations continue to provide the management functions. GIS and non-GIS users alike simply access the service and thereby access the latest content that organizations have to offer. However, even with the access barrier breached there is still work to be done. System usability remains as a challenge.

Any geoportal is only as good as the content it exposes. The current lack of form and format standards is being acutely felt by users, in particular non-GIS users, as they lack training to transform content to a useful form. There is now a window of time in which the issue of content standards needs to be addressed; if not addressed soon users will begin to loose confidence in the content referenced by geoportals. High availability is another key geoportal requirement. If users cannot access the content they need "on-demand" then confidence in the business resource is diminished. Publishing content 24×7 is not a simple or inexpensive process technically, and many organizations with the mandate to do this publishing do not have the necessary skills or resources in terms of staff and monies needed to do the job. These are crucial considerations to address if the goal of widespread GIS dissemination is to be achieved.

GIS communities are recognizing that providing access to geographic content is an important GIS activity that requires a long-term vision in order to realize the possible impacts to society that GIS offers (Cutter, Richardson, & Wilbanks, 2003). web services, service-oriented architectures and distributed GIS are the foundation technologies through which society will realize the benefits of GIS, and geographic portals play a key role, guiding the way to the emergence of societal GIS.

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