Commonwealth of Massachusetts MassGIS Web Mapping Services (2005—Enterprise System)

System Summary

The value of data that government agencies collect and manage is only fully realized when applications are built to provide access to the data. Applications that are universally available (e.g., Internet-based) and inexpensive or free multiply the value of the data accordingly. The MassGIS Web Mapping Services provide access to a wealth of digital mapping for Massachusetts. Not only have the Web Mapping Services improved data access for customers coming to MassGIS's own Web site, but they have made the same online, live Web-mapping capability (including attributes and spatial-query functionality) available to other government Web sites through an open XML interface. This greatly leverages investments in data, hardware, software, and skills at MassGIS. The Web service approach has added value to existing state agency Web-based interactions with the public. Agencies can include maps on their Web sites without having to build or maintain the supporting infrastructure. The services also interoperate with other server map data so data from different servers can be combined and presented in a single view. A total of 14 Massachusetts government entities have developed Web applications that use the MassGIS Web Mapping Services (screen shots and URLs are included later in this document). While we did not initially have the tools to adequately track usage, we do now. The services are experiencing high usage. In 2005, some 1,581,924 requests were logged, an average of 4,334 per day. Use of the services has also been accelerating. In the remaining months of 2004, an average of 2,389 per day was seen (an increase of 81 percent average daily requests for the second period over the first).

The services are exemplary because they:

- **Improve service delivery and solve online data collection problems.** State and local government agencies have improved the quality of data collected and services delivered on their Web sites by adding GIS maps as a new feature to Web applications without investing in the GIS back end. State and local government agencies can also use the services to augment their existing Web-mapping capabilities by adding MassGIS data (e.g., color orthophoto basemap). Because the Web-mapping services can interoperate with other Web-mapping capabilities, agency data layers can be combined with MassGIS layers even though they are in different physical locations. MassGIS Web Mapping Services offer a standardized way of integrating mapping into Web sites, avoiding a possible proliferation of nonstandard Web-mapping systems across agencies that do not communicate well. MassGIS is creating a central registry of map layers from various agencies that will serve as a common repository of Massachusetts data served from remote as well as local servers.
- **Make MassGIS data more accessible. MassGIS is the place to go for high-quality statewide GIS data.** Before the Web-mapping services were available, data was distributed through CDs or by downloading through various tiling schemes. Now, hundreds of data layers and symbolizations of them can be used in any public agency Web site. These data layers not only create map images but also provide information in response to spatial queries such as: "What vernal pools are within this bounding box?" or "What is a list of the verified market sales points that were sold for greater than $300,000 and were sold before June 1, 2000?" In addition, the Web-mapping services enabled the creation of the general-purpose application OLIVER (**O**n**LI**ne **V**iew**ER**) that provides mixing and matching of layers and intuitive data download.
- **Save public agency money and reduce duplicate efforts.** Spatial information resources can be centralized at MassGIS and served to government entities. These entities do not need to purchase or install hardware, spatial databases, and Web-mapping software, or train staff on these systems. Web application developers do not need to understand the underlying database and Web-map creation software to

create maps in their applications. They use the standard, documented XML Application Programming Interface (API). Publicity about the services means that agencies have avoided redundant efforts because they know they can use MassGIS services.

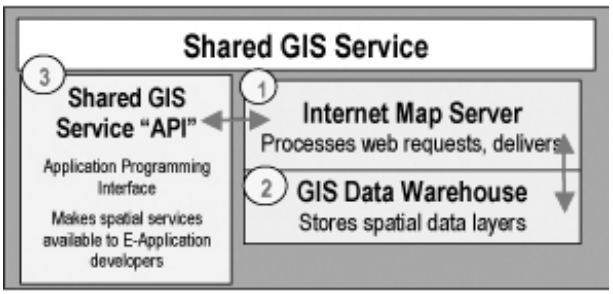
Motivation for System Development

MassGIS was tasked with creating Web-mapping services by the central information technology office under the Commonwealth's CIO. The Commonwealth of Massachusetts embarked on an aggressive e-government initiative entitled "Mass.Gov" in March of 2001. The commonwealth's consultant, Accenture, completed a strategic plan for the commonwealth's Information Technology Division (ITD) and laid out a conceptual architecture for a Mass.Gov portal. GIS was identified as one of four common statewide "shared services" that should be provided to e-application developers to create the content to be offered through the portal. (The other three services were E-Payments, Customer Relationship Management, and Security.) The Accenture report stated: "Creating shared services . . . helps avoid the costs of agencies duplicating the development of these services at additional costs. And it helps all agencies more quickly implement new services because these components . . . will be readily available to plug in. The shared services should actually speed the rate of implementation of new robust interactions and transactions." Also, " . . . smaller agencies may not have been able to provide key mapped services because of the prohibitive expense of GIS. If the application component is already available it could spur the development of a host of new geographic services."

A vision and high-level design for the GIS-shared service was subsequently developed by Applied Geographics, Inc., in a June 2001 report, "The Shared Geographic Information System (GIS) Service of Mass.Gov." (This report was prepared for the Massachusetts Executive Office of Administration and Finance Information Technology Division (EOAF-ITD) and the Executive Office of Environmental Affairs-MassGIS.) The following is taken from the Executive Summary:

"What is the Shared GIS Service?

Once developed, the shared GIS service will be data and technology that allow Mass.Gov E-Application developers to easily include maps or spatial analysis products (e.g., driving directions, or a list of nearest entities) in Mass.Gov Web pages. Rather than having to build a mapping functionality as part of their E-Application, the shared GIS service will allow state agencies to use an existing, high-performance resource. The shared GIS service will be composed of three main pieces of technology:



In many ways, the new shared GIS service is analogous to MapQuest.com [or now Maps.Google.com – ed.]

Whereas MapQuest or Vicinity serve a limited quantity of general purpose data on a nationwide basis, the shared GIS service will deliver highly detailed spatial data, specific to Massachusetts."

System Benefits Achieved

- **Providing map information to enhance state agency Web sites**
  MassGIS has invested and maintains the hardware and software necessary to warehouse and serve the data layers and spatial information through the Web services. Developing the Web services capabilities made sharing this centralized resource possible, thus realizing an efficient use of financial and human resources and a significant cost savings for many government entities. Agencies could focus on improving core services rather than developing a new capability. Furthermore, Massachusetts government entities can add maps to Web sites within their own programming language and server environment. The open source OpenGIS XML API is the only restriction. This flexibility was critical because various government agencies have investment in different types of servers, operating systems, and staff skills.
- **Easier access to the MassGIS database of statewide GIS information**
  The Web services enhanced access to the MassGIS large database of statewide GIS data, creating a new ability to mix and match layers, and offering more convenient extraction of data. OLIVER can download data as shapefiles for any area of interest. Previously, download of MassGIS data was based on tiles. The user had to figure out which tiles were appropriate, download multiple files, and more data than needed (a slower download). With OLIVER, the user can get just what he or she needs.
- **Improved data collection and display capabilities**
  Several state agencies have improved data collection or the usefulness of data they display by deploying the Web services. The Department of Environmental Protection collects information about regulated facilities through a Web-based application; previously, the coordinate information provided by users of the application was notoriously unreliable. By incorporating a map from the MassGIS Services into the

application, users are able to provide a correct coordinate by selecting the correct location on a map. The Department of Revenue has for some time posted a tabular listing of market sales information on its Web site. This site enables assessors to search for comparable sales for unusual properties (e.g., gas stations, bowling alleys). However, a key missing component was the location of these sales. The application now is built around the MassGIS Web Mapping Services and enables users to see a map showing sales locations. The Division of Capital Asset Management (DCAM) had very poor records for the locations of state-owned buildings and facilities. It recently deployed a Web-based application that displays the existing locations developed using an address. DCAM staff who manage buildings and facilities use a mapping capability developed using the Web services to move points representing buildings or facilities to their correct locations; they orient themselves using the orthophoto basemap.

- **The capability of connecting isolated islands of data at agencies in a central registry**
  State and local government agencies can combine MassGIS data with their own data in Web applications without having to acquire and serve the MassGIS data themselves. Thus, updates are transparently and automatically provided instead of having to be tediously downloaded. If agencies have their own specialized data and serve it over the Web, because of the interoperability of the services, their data layers can be combined with MassGIS layers even though they are in different physical locations. The Web services provide a "glue" for connecting data sets. MassGIS is in the process of creating a searchable registry (cascading Web service) that will contain not only MassGIS-served data but also data served from local communities or other government agencies.

Unexpected benefits

- Data contributions to MassGIS increased.
  The "carrot" of being able to have their data layers in the Web services for display and download has been an incentive for data contribution.
- Limitations of proprietary systems overcome.
  The Department of Conservation and Recreation was able to purchase a facility management system from a third-party vendor without being concerned that it would not interoperate with MassGIS's current spatial database format.
- Funding was attracted from outside agencies to extend the capabilities of the Web-mapping services.

System Design Issues Encountered and Overcome

- **MassGIS could not rely solely on ArcIMS.**
  While ArcIMS provided many of the capabilities MassGIS was looking for, it did not provide all the needed capabilities. Specifically, it was not appropriate for all tasks and content types, its interface was not so stable as required, it could not support simple applications (e.g., URLs in Web pages), and it could not integrate sufficiently with other services implemented on other platforms (for example, a Web-based facility management application sold by FAMIS). The solution to these problems was building the MapAccess middleware. MapAccess provided separation between client application design and the specifics of service provision through ArcIMS.
- **Some standards were not sufficiently developed.**
  The original vision included the use of Simple Object Access Protocol (SOAP), Universal Description, Discovery, and Integration (UDDI), and Web Services Description Language (WSDL). However, these technologies were not developed enough when our system was being created for use in the Web-mapping services. In the past few years, they have since matured and eventually they will be incorporated in the MassGIS Web Mapping Services.
- **Additional servers were needed.**
  ESRI, the company that makes both the ArcSDE and ArcIMS products, recommends that the two products reside on separate servers for performance reasons. At first, MassGIS had all software components on a single system. Once ArcIMS was moved onto its own server, MassGIS saw a large increase in performance (maps were served about twice as fast).

What Differentiates This System from Other Similar Systems?

Differences from ArcIMS as a stand-alone Web-mapping system:

- **OGC compliancy**
  The MassGIS Web Mapping Services implement many of the OpenGIS Consortium standards and specifications, such as WMS (map creation), Geocoder, Gazetteer (spatial information), and WFS-T (online data editing). MassGIS Web Mapping Services also support different versions of WMS, for example, 1.1.0 and 1.1.1. OGC interfaces enable the idea of a data portal.
- **More flexibility in data presentation and organization**
  ArcIMS serves one map service at a time to a client, while the MassGIS Web Mapping Services allow layers to be mixed and matched from multiple map services. With the Web-mapping services, each layer or style needs to be represented only once in the configuration files.
- **Ability to add non-ESRI components**
  With ArcIMS alone, other brands of Web-mapping functionality could not easily be added. But because of the XML to AXL translator, additional service components can be added to the back end or components can be switched out. As long as the XML API remains the same, the client applications won't be affected.
- **Easier data organization**
  In the MassGIS Web Mapping Services system, there

is a structure of layers and styles. Each layer has one or more styles. Each style points to a certain server, a certain ArcIMS map service, and a certain layer ID within that map service.

- **Ability to add layers from various agencies into one registry—cascading Web-map service**
  Layers from other agencies can be added to the MassGIS Web Mapping Services registry. MassGIS does not need to know the data storage and presentation details. A town can serve data from its server, in a different projection, and the MassGIS server will combine the layers into one map image.

Differences from commercial Web-mapping services (such as ESRI's ArcWeb Services):

- Up-to-date local Massachusetts data served
  While ESRI and other companies offer Web-mapping services, the data served is not MassGIS data. The MassGIS services can provide data with more detail than those available commercially.

- MassGIS Web Mapping Services offer extra functionality
  1. Nearest Euclidean function. The application sends a point and a data layer such as MBTA subway stations and the MassGIS Web Mapping Services return the nearest subway station to the given point.
  2. Server-based image compositing. Compositing on the server allows flexibility in creating images and is necessary to mix and match layers within one WMS. This allows OLIVER to create a map with layers from different underlying ArcIMS map services.
  3. Additional optional vendor-specific tags for highlighting features available in the MassGIS WMS GetMap request: hiliteLayer, hiliteColor, and hiliteXY.
  4. A Web Security Service (WSS) enables different user accounts. Applications using the Web services can serve custom content to specific users or groups of users.
  5. An XML interface for custom data extract.
  6. Generalized Styled Layer Descriptor (SLD) implementation onto both raster and vector images.
- NamedLayer/NamedStyle—Web services administrator sets up layers and styles.
- NamedLayer/UserStyle—The user can dynamically change the symbolization.
- UserLayer/UserStyle—The user can create entirely new "graphics" and style them.

System Hardware, Software, and Data

Hardware

The MassGIS Web Mapping Services currently use four servers: two servers on the state network and two servers available to the Internet. Each set consists of a UNIX machine running Solaris and a Windows server. Each UNIX server runs the database software (Oracle and ArcSDE), the Web server (Apache), the servlet engine (Tomcat), and the application server (JBoss). Each Windows server runs ArcIMS and creates output images (maps and legend files) that are copied to the UNIX machine to be served out to applications. The internal setup is used by state agencies. State agencies develop new applications and maps for internal use only, or for eventual deployment to the external server and the public. The public and some agency staff in regional offices are off the state network and use the external setup. For performance reasons, ArcIMS is separate from SDE. The external servers are connected to the Internet through a switch by way of two wireless 4 Mbps (megabits per second) antennas.

The MassGIS Web Mapping Services require many layers of software. The software stores geographic data, produces map images, and communicates with client applications. End users of the applications need only have a Web browser.

Software

Software Name	Purpose	Approximate Cost
Oracle 9.2	Database—stores geographic data in seamless layers	$40,000
ArcSDE 9.1	Spatial connection to Oracle database—allows ArcIMS to talk to Oracle using spatial language	$16,000
ArcIMS 9.0	Produces Web maps, answers spatial questions about data	$20,000
MapAccess[1]	Web Mapping Services core server code—takes XML request sent by an application and translates it into AXL for ArcIMS; translates AXL responses from ArcIMS into XML response for the application; determines the least number of ArcIMS map services needed to create a map; composites resulting ArcIMS images	$300,000
JBoss 2.4.1a	Application server—runs applications	free (open source)
Tomcat 3.2.3	Servlet engine—communicates between applications and Web services	free (open source)
Apache 1.3.20	Web server—serves images, XML, HTML pages	free (open source)

AWStats 5.5	Web server log analyzer—generates statistics nightly on patterns of use such as browser and operating system types and versions, screen resolutions, counts amount of GB of XML, images, HTML	free (open source)
Shell scripts[2]	Restart system components on a schedule, and if errors count number of images generated daily	free (written by MassGIS staff)

1 custom-built by consultants to OpenGIS standards
2 custom-built by MassGIS staff

Data

The MassGIS Web Mapping Services provide access to a large GIS data warehouse. The warehouse contains data developed for or by MassGIS as well as data from many different organizations and agencies. Data layers are both vector and raster. Raster images include TIF and MrSID types, and some images are in SDE. All vector data reside in SDE, which runs on top of Oracle. Therefore, most data layers reside fundamentally in the Oracle database. The site http://www.state.ma.us/mgis/laylist.htm lists all available MassGIS data layers. Examples of layers include: color orthophotos (1/2-meter pixel resolution), USGS topographic maps, land use (1:25,000 scale), wetlands (1:12,000 scale), soils, open space, zoning, and roads (1:5,000 scale). There are more than 100 data layers. In addition, MassGIS has created hundreds of "themes" or symbolizations of these data layers. Land use can be viewed as 1951, 1971, 1985, or 1999 land use. The Web Mapping Services create layer names and styles that are associated with these symbolizations and each is associated with a particular layer paragraph in an ArcIMS map service (AXL configuration file). Links to metadata are also associated with each layer/style combination, providing extensive information about the data layers such as date of last update, attributes, production method, and a maintenance schedule.

Where Are We Now? Future Directions

The MassGIS Web Mapping Services have undergone or are undergoing several upgrades and enhancements in these areas:

Hardware

New, faster servers have been purchased and are being set up for both the database function and the application serving function. This should boost the speed of the services, for the current servers are seven years old—that's about 70 years in human years!

Software

Oracle, SDE, and ArcIMS are in the process of being upgraded to more current versions.

A number of improvements have been made to the Web Services MapAccess code, including:

- Use of ImageMagick for image compositing, speeding up compositing
- WFS-T code improved and bugs fixed
- A faster operational metadata system implemented
- Interoperability with different WMS versions improved

Data

New data layers have been added as they have become available.

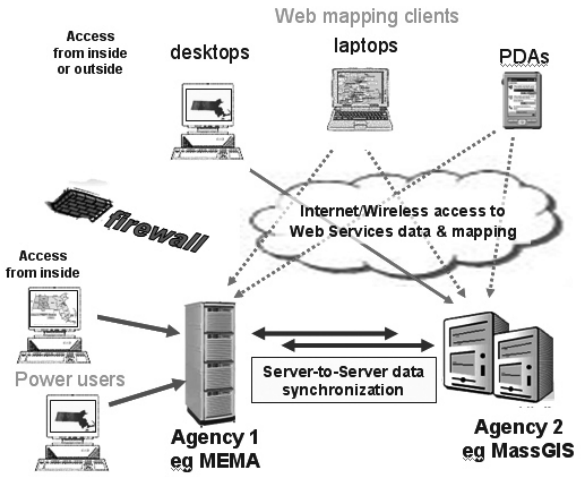
Additional applications using the Web services

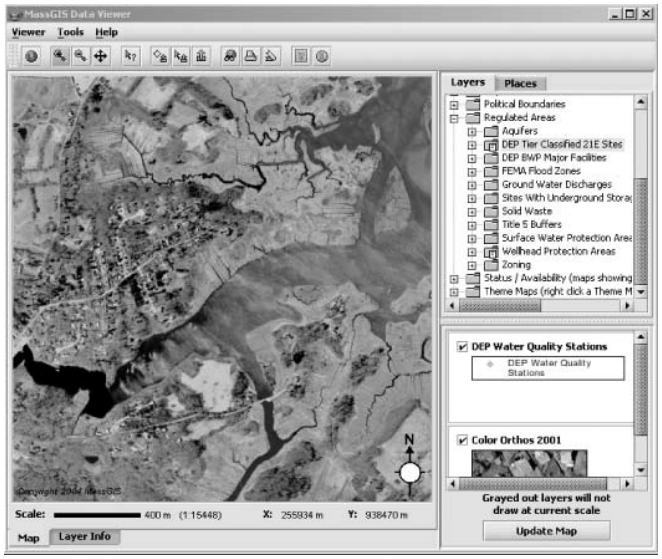
An OLIVER clone was built, called SPOLIVER (State Police OLIVER), with a slightly different look and feel and containing primarily crime and police employment data. A similar concept clone was MOLIVER, for viewing marine and ocean resources. OLIVER can be customized in many ways—by personalizing the menus (which is very easy to do) and by adding or deleting tools.

Future directions

These include the addition of open-source GeoServer (http://docs.codehaus.org/display/GEOS/Home) as another WMS/WFS-T. GeoServer is a collaborative Web mapping services project that has many of the MassGIS Web Mapping Services features and additional ones as well. MassGIS would like to transition into a community-supported system and contribute to its development. GeoServer will be installed on three additional external servers with a load balancer. Some layer caching will be put into place for certain applications that are high use with little data change. GeoServer will allow the use of applications such as MapBuilder (http://mapbuilder.sourceforge.net/) to create lightweight data-editing applications. These types of applications are currently very much in demand. MassGIS also hopes to create a "toolkit" to give to state agencies for their use in serving data and creating applications.

At the current time, MassGIS is negotiating with a number of other state agencies to set up a simple, self-sufficient platform for serving their own GIS data to clients who will be able to access the MassGIS services as well. Finally, the dream of distributed GIS access will be realized.





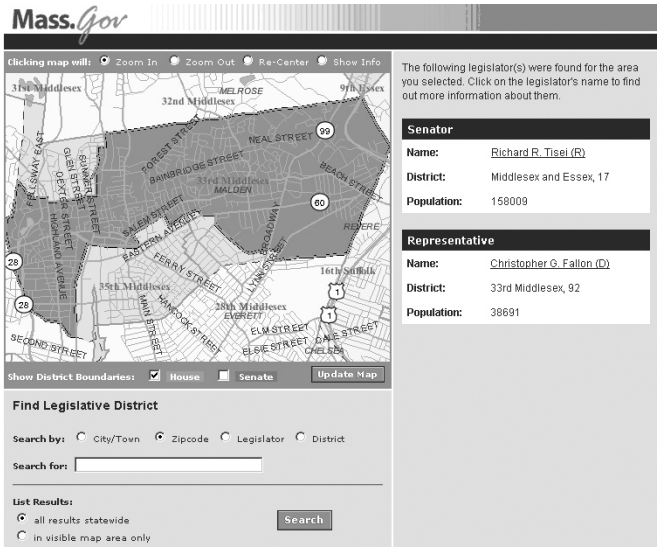
Examples of System Images and Screen Shots

The MassGIS Web Mapping Services have been used for many purposes, including:

- MassGIS OLIVER—data view, data download, map printing
- Department of Revenue—real estate sales analysis
- Town of Douglas Online Maps—buildings, aerial photos, parcel information for residents
- Department of Agricultural Resources—animal disease reporting and analysis
- Department of Environmental Protection—regulated entities; locational information capture
- Executive Office of Environmental Affairs—land-use planning
- Information Technology Division—assistance to public in locating legislators, demographic information
- Coastal Zone Management—historic shoreline change
- Division of Capital Asset Management—update location of state-owned buildings
- Massachusetts Association of Conservation Commissions—biodiversity education

OLIVER **(OnLIne ViewER)** (written in Java). OLIVER allows users to view *all* the MassGIS data layers and their symbolizations. The user can browse data through a set of hierarchical folders, organizing content into useful categories. The user can zoom in to an extent chosen from a list of places, organized into categories. OLIVER allows the user to enter an address. Data extraction is perhaps the most useful feature. http://maps.massgis.state.ma.us/massgis_viewer/index.htm

Department of Revenue (DOR) LA3 Recent Sales Application (written in JSP and Java Beans) Helps the public find recent sales of residential and commercial properties. Augments a similar



preexisting tabular Web application by providing a map view. The user can search by type of sale and/or a date range and/or a price range. The number of matches is displayed with brief information about the matches appearing in a table at the bottom of the application. More information can be obtained from a point by using the information tool. The dots, match number, and table are updated as the user zooms. http://maps.massgis.state.ma.us:8080/LA3/pages/main.jsp

Information Technology Division (ITD) Legislative District Viewer (written in JSP and Java Beans)

Helps the public identify their state legislators. The user can zoom to a city or town (including partial strings and fuzzy spelling) by zip code, by legislator name (including partial strings or fuzzy spelling), or by the name of the district. If the query produces more than one result, a list is provided on the right side. Links to legislators' Web sites are provided. The user can also use the Show Information tool to click to any part of the map (for example, his or her street) and see legislators. Additional MassGIS-specific highlighting parameters are used in the GetMap request to highlight the district orange. http://maps.massgis.state.ma.us/legisdistrict/pages/main.jsp

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