ArcGIS®: Engineered for Interoperability

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Introduction

Geographic information system (GIS) technology requires interoperability. Much has been written about the multidisciplinary nature of GIS technology with its ability to bring information from many sources and organizations together and perform crosscutting analysis. The interoperability requirements of GIS are well known and key to its successful deployment.

In the 1990s, GIS standards organizations, such as the Open GIS Consortium, Inc. (OGC), began addressing these critical requirements. Standards efforts within the GIS industry coincided with the expansion of the Internet and the advent of distributed computing models designed to integrate computing nodes into loosely coupled Web-based computing networks. ESRI participated in these efforts and made significant contributions to GIS interoperability. By employing industrywide computing standards in its software, ESRI supports both GIS and information technology (IT) interoperability.

In the last decade, ESRI redesigned the architecture of its GIS products in response to emerging IT as well as GIS activities and trends that promote interoperability. This new architecture enhances GIS data management and information interchange and supports emerging Web services, GIS portals, and Spatial Data Infrastructures (SDIs).

The result of these engineering efforts, ArcGIS®, is based on key interoperability and Web computing concepts and is used by tens of thousands of organizations that rely on GIS and IT interoperability.

Evolving Computing Architectures

The notion of GIS as a closed, proprietary system is no longer true. Geographic information is now widely distributed on the Web and routinely integrated into thousands of applications and services. The ArcGIS platform conforms to open standards and enterprise IT frameworks so users can incorporate GIS in any application, on a variety of computing and mobile devices, and use geographic information accessed from databases and Web services kept in almost any format.

Historically, client/server GIS applications that focused on data compilation and application projects have proven invaluable. With nearly 200,000 organizations worldwide using GIS in this way, this model has been so successful that many think of GIS only in this context. As other frameworks for GIS emerge, the model will continue to be a vital strategy for using GIS and will probably remain the way GIS is most often implemented.

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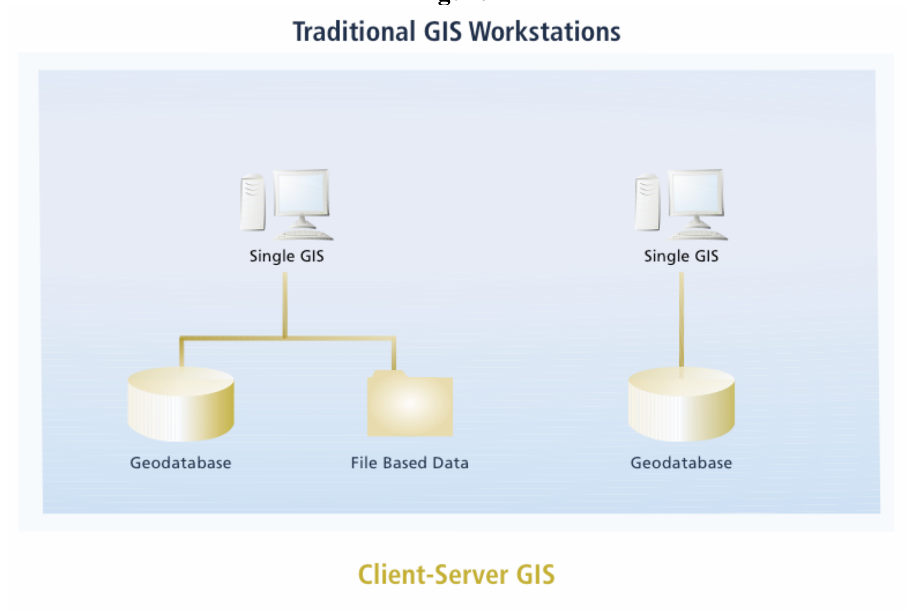
Figure 1



Client/Server GIS applications have proven invaluable and will continue to be an important implementation strategy.

However, GIS is used not only in the familiar client/server setting but also in centralized database management system (DBMS) environments that support multiple GIS users; federated GIS networks of many distributed, heterogeneous GIS computing nodes; and services-oriented architectures that use Web services. ArcGIS is engineered to support GIS use in each of these settings.

In the 1990s, GIS users began exploiting relational DBMS for building centralized information systems. Information was centrally managed and maintained using relational DBMS technology and accessed and edited by multiple users. This enterprise model, widely implemented in the public and private sectors, takes advantage of the robust data management capabilities afforded by relational database technology. It is and will remain a viable framework for GIS.

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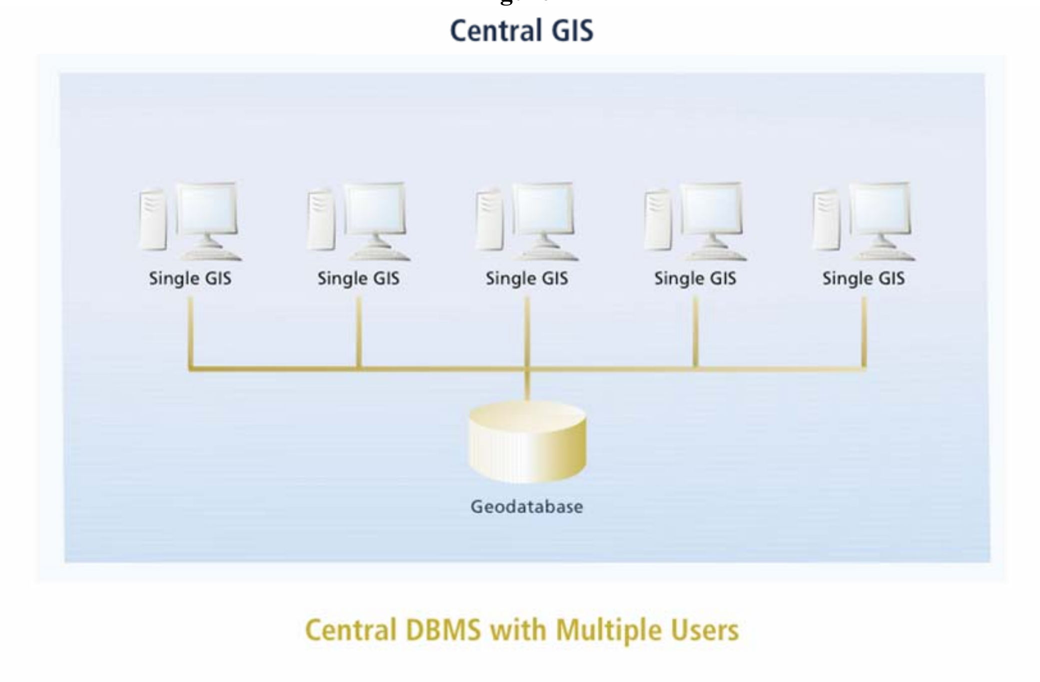
Figure 2



Central GIS takes advantage of the shared data management capabilities of DBMS technology.

Some GIS users need more than centralized systems for information sharing and collaboration. Recently, users have begun using GIS Web services for data sharing and Web publishing. Many user communities have established formal frameworks and participate in National and Global Spatial Data Infrastructures (NSDIs and GSDIs). These loose federations share GIS content and processing logic through GIS portals on the Web.

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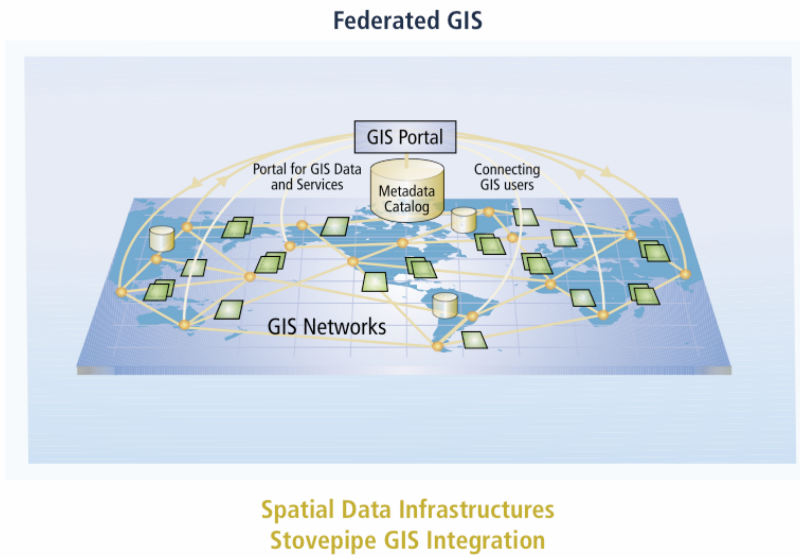
Figure 3



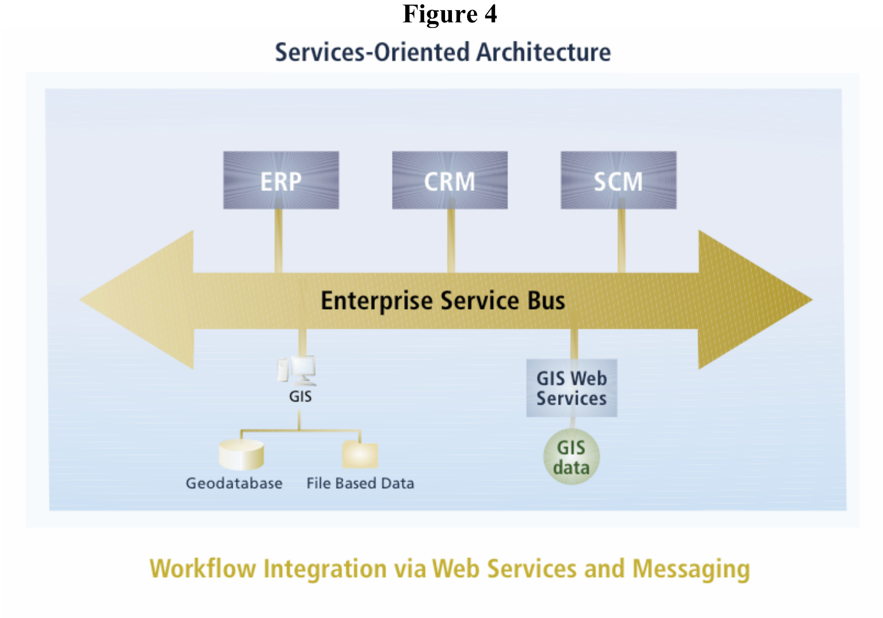
The need for greater collaboration has led to the growth of federated GIS. Federated GIS is based on a distributed collection of GIS nodes that share and use each other's geographic information and services. Catalog portals provide access through a registry of available geographic information services and data sets. GIS users register their information services with the portal where other users can search for and discover available information. Each catalog entry contains a URL or access location for the registered information sets and services, enabling information from multiple users to be combined across the Web through the use of Web services.

A new trend is now underway to integrate heterogeneous application logic using services-based architectures developed originally for Web computing. This concept is referred to as a Services-Oriented Architecture (SOA) and will be used to integrate existing information systems in order to automate business practices, work flows, and information flows both within and across organizations. SOA was developed by IBM, Microsoft, and other leading IT industry organizations to support the building of applications that integrate existing computing technologies into solutions-based systems. GIS will be a key part of these implementations.

For example, using an SOA, a utility could assemble a trouble call system that integrates its existing customer database, command and control system, and fleet management system with a GIS server to locate an affected customer based on a phone number. The system would then find the affected service, perform network tracing and analysis, identify the potential remedy and, finally, route the closest service technicians to the proper location with detailed instructions on the work to be performed.

ArcGIS uses IT and Web services interfaces for managing and exploiting spatial information using messaging. In SOAs, GIS and other IT services are delivered via the same standards-based Web services and messaging protocols, such as XML and Simple Object Access Protocol (SOAP), used in mainstream business and enterprise computing frameworks.

Figure 4



GIS services are delivered via the same standards-based Web services protocols (e.g., XML and SOAP) used in mainstream business and enterprise computing frameworks that incorporate enterprise resource planning (ERP), customer relationship management (CRM), and supply chain management (SCM) systems.

Designed for Interoperability

A modern GIS platform must support this enlarged vision of GIS and be implemented in a manner that readily enables applications to support an organization's work flows and business requirements. ArcGIS has done this by providing a generic software platform that supports an abundance of geographic information types as well as comprehensive tools for data management, editing, analysis, and display.

In this context, GIS software can be increasingly thought of as an IT infrastructure for assembling traditional GIS as well as central systems and spatial data infrastructures and enabling GIS participation in services-oriented architectures—all of which can be interconnected using Web frameworks.

ArcGIS was designed to satisfy evolving requirements for scalable, comprehensive, and standards-based computing for GIS.

Geodatabases Provide Open Data Management

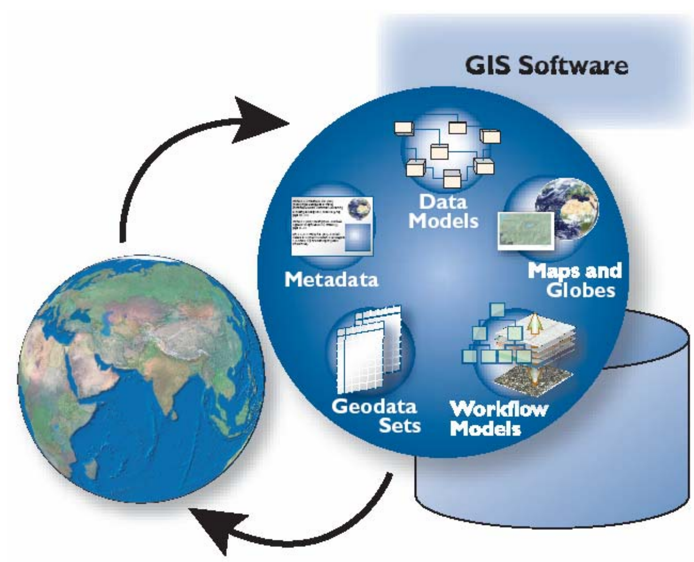
The geodatabase (short for geographic database) provides the common data access and management framework for ArcGIS. It defines the types of data that can be used in ArcGIS—features, rasters, addresses, attributes, networks, topologies, survey measurements, and relationships—and controls how they are represented, accessed, stored, managed, and processed.

Geodatabases support

- Topologies for managing shared geometry between features
- Networks for modeling connectivity and flow

- Relationships for connecting geographic objects based on descriptive information
- Domains for managing the integrity of attribute values
- Feature class subtypes for modeling behavior of subclasses (e.g., highways, local streets)
- Raster mosaics and raster catalogs for managing extensive raster data holdings
- Measurement systems for managing surveys and global positioning system (GPS) observations
- Geoprocessing scripts and models that automate analysis and work flow
- Metadata for documenting and discovering geographic data sets
- Common GIS data models and content standards developed and used by industry groups

Figure 5



ArcGIS is a comprehensive information system. It provides a complete information model for representing and working with the five key elements of geographic knowledge: maps and globes, geodata sets, work flow models, data models, and metadata. Collectively, these elements can be managed and persisted in geodatabases.

The geodatabase provides a well-defined information model for working with data. It can be thought of in several different ways—as the core ArcGIS information model; the application logic that manages the elements, relationships, and rules of geographic information; and a physical DBMS instance that holds a specific collection of geographic data.

The geodatabase as information model facilitates interoperability in a variety of ways.

1. Relational database support. Geodatabases can be managed within DBMSs from several vendors—Microsoft SQL Server, Oracle, IBM DB2, and Informix—and one or all of these DBMSs can be employed in a mixed, federated environment. These databases can grow to very large sizes, and their maintenance can be distributed across many organizations.

2. Simple features. Geodatabases use open DBMS data storage that is based on OGC and ISO Simple Feature Specifications.

3. Comprehensive format support. All external data files and many DBMS files are accessed using common geodatabase logic. Direct use of more than 100 data formats is supported including numerous raster formats, vector formats, computer-aided design (CAD) files, and Geography Markup Language (GML) data sets.

4. XML. Geodatabase XML is an open interchange format for exchanging information between geodatabases and other external systems. ESRI openly publishes and maintains the complete geodatabase schema and content as an XML specification.

5. Change-only updates. With data interchange capabilities, users can share data updates as change-only record sets between ArcGIS and any other system.

6. Openly shared data models. ArcGIS data models are openly published and freely available for adoption and use by the GIS user community. These are based on standards and enable users to collaborate on content standards.

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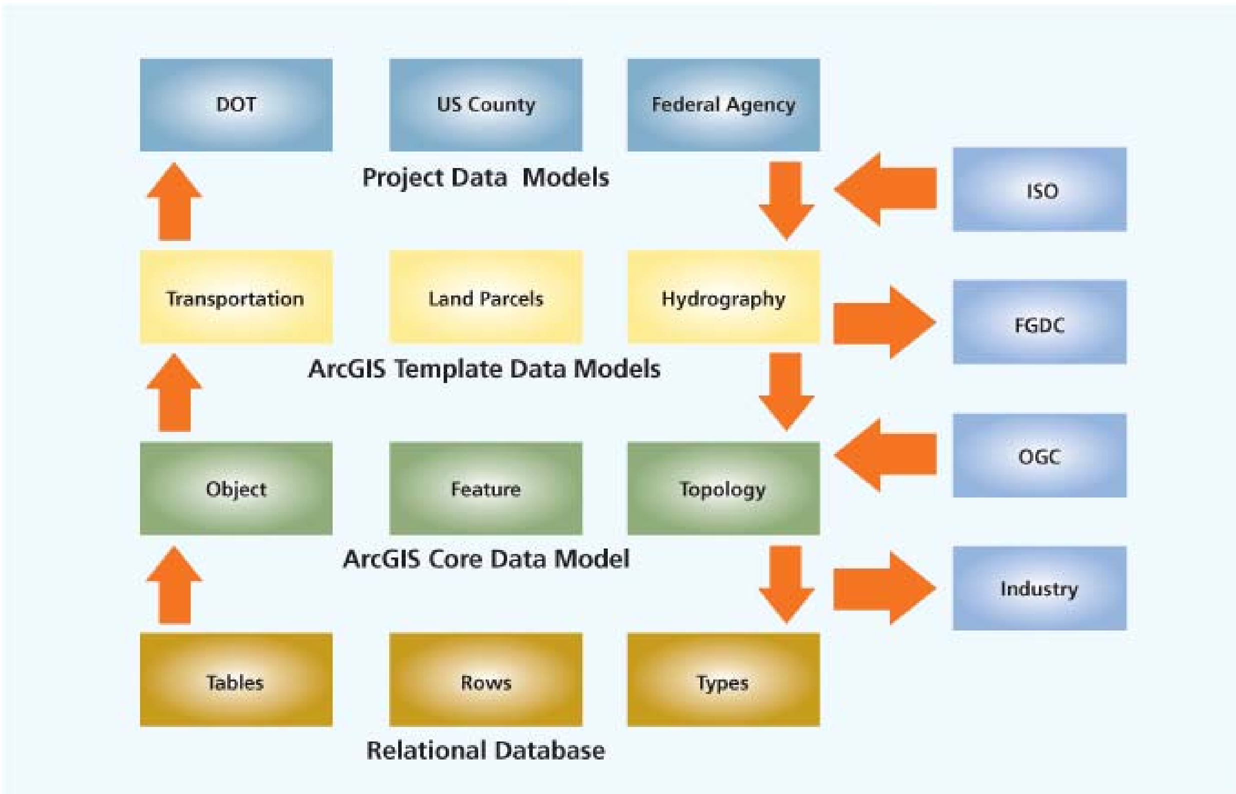
Figure 6



Standards-based ArcGIS data models provide a common framework for users to manage and share geographic information for many applications. Each design is based on existing standards and builds on key DBMS and GIS concepts.

Thousands of organizations have integrated and extended their existing GIS data by migrating it to the geodatabase to enrich both content and behavior. Many of these organizations are adopting the ArcGIS data models and content standards for building and maintaining GIS databases.

Geodatabase software logic provides the common data access and management framework shared by all ArcGIS products and applications and is included in ArcGIS Desktop, ArcGIS Engine, and ArcGIS Server. It implements data integrity and behavior. Ubiquitous, reusable GIS logic delivered as a comprehensive set of GIS software components can be deployed on desktops and servers and embedded in IT applications and mobile devices. ArcGIS also provides comprehensive tools for editing, analysis, visualization, mapping, and data management.

By providing powerful GIS logic that is designed to work with simple, scalable data structures that are persisted in personal geodatabases as well as versioned databases, ArcGIS can be deployed in many settings from a single user to large multiuser systems.

Support for Common GIS Data Formats

The concept of data integration—spatially combining different data sets for visual and analytical purposes—is fundamental to GIS. ArcGIS is unique in its ability to incorporate, maintain, and apply more than 100 fundamentally different digital data formats. GIS users commonly employ vector features in many formats, raster imagery, CAD drawings, tables, survey and COGO measurements, GPS observations, linear referencing systems, and data in profiles such as Topologically Integrated Geographic Encoding and Referencing, GML, and Spatial Data Transfer Standard.

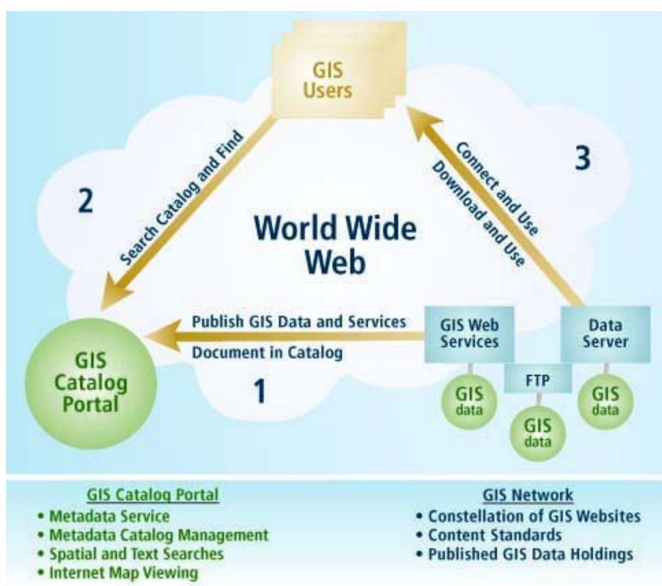
In recent years, GIS has evolved into an information system that links activities to databases maintained through transactions that serve a myriad of applications. Many of these systems, started on the departmental level, now serve enterprises in a manner similar to ERP software.

Sharing Geographic Information

Geographic information is inherently distributed and loosely integrated. Rarely can all the necessary information be found in a single database instance with only one data schema. GIS users must often rely on others for GIS data.

The ESRI user community publishes more than 100 million Web maps daily using ArcGIS and ArcIMS® applications powered by geodatabases and ArcSDE®. Several thousand ArcIMS and ArcGIS Server Web sites deliver standards-based Web services in applications that are distributed worldwide.

Figure 7



GIS portals enable GIS users to publish and discover geographic information so that it can be more easily shared.

This vision has been in existence for more than a decade and is being implemented as NSDIs and GSDIs. A GIS network is an implementation of an SDI that connects users and enables sharing of geographic knowledge via the Web. GIS portals have been established in hundreds of situations including the National Spatial Data Infrastructure for India (www.nsdiindia.org), the Geospatial One-Stop (www.geodata.gov), the Delaware Data Mapping and Integration Laboratory (www.datamil.udel.edu), and the Bureau of Land Management's GeoCommunicator site (www.geocommunicator.gov).

ESRI is committed to supporting robust GIS portals with functionality for publishing and consuming standards-based Web services in ArcGIS and ArcIMS. ArcGIS provides support for a number of key interoperability initiatives for federated GIS including the following:

- Metadata. Metadata documents describe the content published at GIS portals. A GIS catalog portal site can also harvest catalogs from a constellation of participating sites so it can reference data holdings contained at other sites. Metadata content standards from the Federal Geographic Data Committee, ISO, European Economic Union, and other organizations define the standards for how metadata documents record information for GIS data sets and Web services. Each standard is an extension of a general catalog standard such as the Dublin Core.

- XML and Web services. Web services protocols have been developed by OGC, the World Wide Web Consortium, and other organizations. Web services have focused on the use of XML and the definition of specific XML protocols. In the past decade, most organizations have defined their own XML specification. ESRI designed and published the open ArcXML specification. Subsequently, the computing industry has adopted SOAP for XML messaging. OGC has focused on the development of a series of interoperability specifications for GIS on the Web. These include XML specifications for

  - Web Map Service (WMS), which generates map images
  - Web Feature Service (WFS), which streams vector features
  - Web Coverage Service (refers to raster data sets and not traditional ArcInfo coverages)
  - Catalog interfaces for the discovery, access, and querying of catalog servers

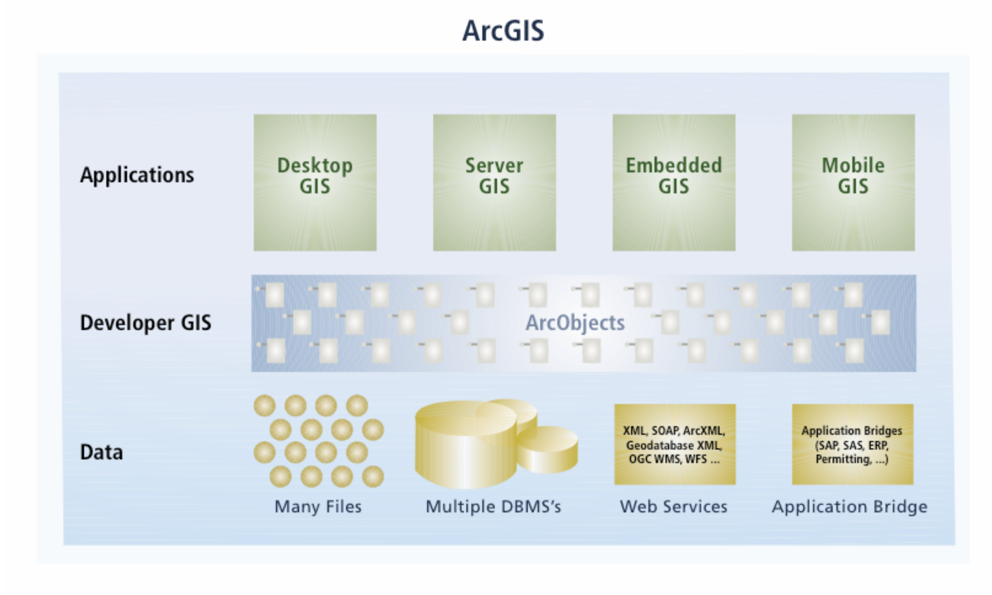
For more information, visit www.opengis.org.

Comprehensive Strategy for Interoperability

Collaboration among GIS users is crucial. The distributed nature of GIS has many implications for interoperability between GIS organizations and systems with respect to data management, hardware environments, deployment of application logic, Web services integration, and openly documented application program interfaces (APIs) and documented XML data schemas. ESRI has addressed interoperability comprehensively by implementing a variety of standards, strategies, and techniques in ArcGIS.

ESRI Interoperability Strategies
Presentation: Support GIS access using any client and device including emerging "rich clients."
Services: Support broad Web and IT standards (e.g., XML, SOAP) as well as focused GIS standards (e.g., OGC). Share and openly publish key ESRI protocols.
Application Logic: Enable common GIS logic to be deployed anywhere and used with industry standard APIs. Build direct application bridges for selected systems.
Data: Directly use, as well as translate to and from, any GIS format. Openly support any viable DBMS or file system. Publish key GIS formats from ESRI. Provide comprehensive API to ESRI data sources. Compile and share common data models.
Platforms: Platforms are expanding—in addition to hardware and operating systems, they also include Web servers, databases, and application frameworks. ESRI intends to support a comprehensive platform environment for both vendor-based systems (e.g., Windows: .NET and SQL Server; Sun: Java and Sun ONE; and IBM: WebSphere and DB2) as well as open source systems (e.g., Linux: Java and Apache).

Figure 8



ArcGIS was designed and engineered with interoperability in mind.

ArcGIS was designed and engineered with interoperability in mind. Here are a few examples.

- ArcGIS supports the storage and management of geospatial data within multiple and heterogeneous DBMSs.
- Because ArcGIS operates in a heterogeneous computing environment that includes Windows, Linux, Sun Solaris, and various types of mobile devices and Web browsers, it can connect to and work with information on many central DBMS

servers across a range of platforms. ArcGIS is enabled for grid computing, which scales well in blade computing frameworks.

- ArcGIS users can deploy GIS logic such as mapping, editing, and geoprocessing anywhere—the traditional workstation desktop environment, embedded in custom applications, running on mobile devices, or managed in a server environment.

- Users can deploy GIS as Web services that use open and interoperable standards such as WMS, WFS, ArcXML, and SOAP. These Web services can act as services to other GIS applications and can be integrated with other standards-based IT applications such as ERP and CRM software.

- ArcGIS supports open and documented APIs for C++, .NET, Java, and COM. Developers can access, update, and use all GIS functions.

- ArcGIS supports a fully documented XML-based exchange for geodatabases. The complete information model for the geodatabase is openly published as an XML specification for programmers.

- ESRI supports efforts promoting GIS standards and adheres to industry standards and commonly adopted practices that meet the fundamental requirement for interoperability. By addressing a larger vision of interoperability that encompasses far more than just data formats and GIS-based Web services protocols, ESRI is helping GIS become an integral part of mainstream IT.

More Information

For more information about ArcGIS, visit www.esri.com/arcgis, and to learn more about standards and ESRI, visit www.esri.com/standards.