System Design Strategies

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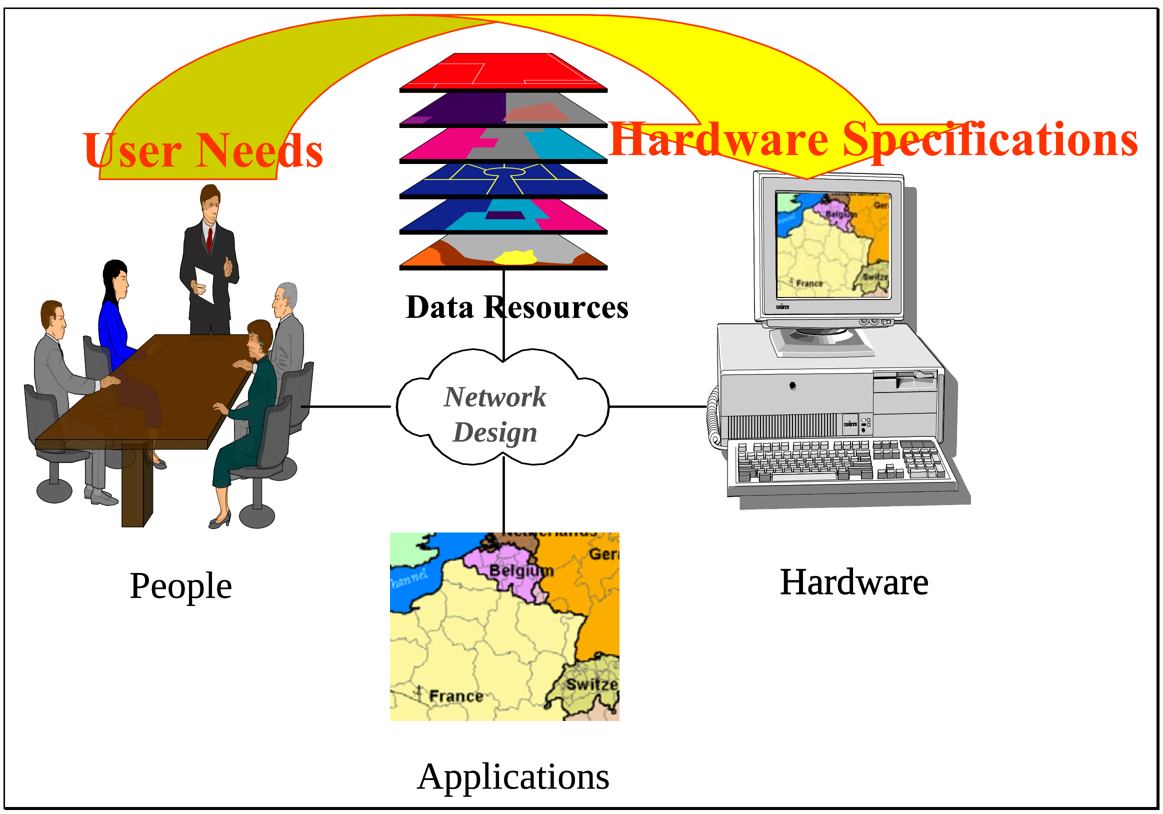
1 System Design Process

The purpose of this document is to share a system design strategy that promotes successful selection of geographic information system (GIS) enterprise architecture solutions. Guidelines include appropriate rationale and logic to deploy and support a system that will satisfy initial performance needs for most of our customers. Once the initial implementation is operational, the system environment can be further tuned and adjusted to fit specific customer requirements.

1.1 What Is System Architecture Design?

System architecture design is a process developed by ESRI to promote successful GIS implementations. This process supports existing infrastructure requirements and provides specific recommendations for hardware and network solutions based on existing and projected user needs. Application requirements, data resources, and people within an organization all are important in determining the optimum hardware solution. The ESRI system architecture design process provides specific system architecture design and associated hardware specifications based on identified user operational workflow requirements.

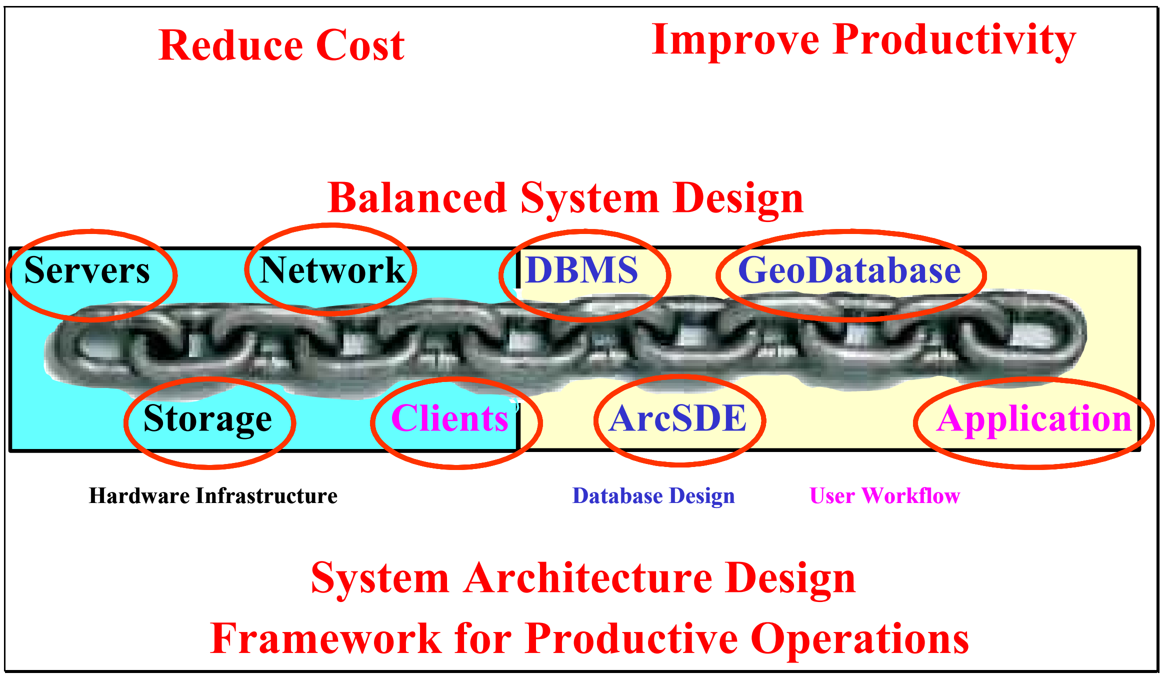
Figure 1-1
What is System Architecture Design?



1.2 Why Is System Architecture Design Important?

A distributed computer environment must be designed properly to support user performance requirements. The weakest 'link' in the system will limit performance. The system architecture design process develops specifications for a balanced hardware solution. Investment in hardware and network components based on a balanced system load model will provide the highest possible system performance at the lowest overall cost.

Figure 1-2
Why Is System Architecture Design Important?

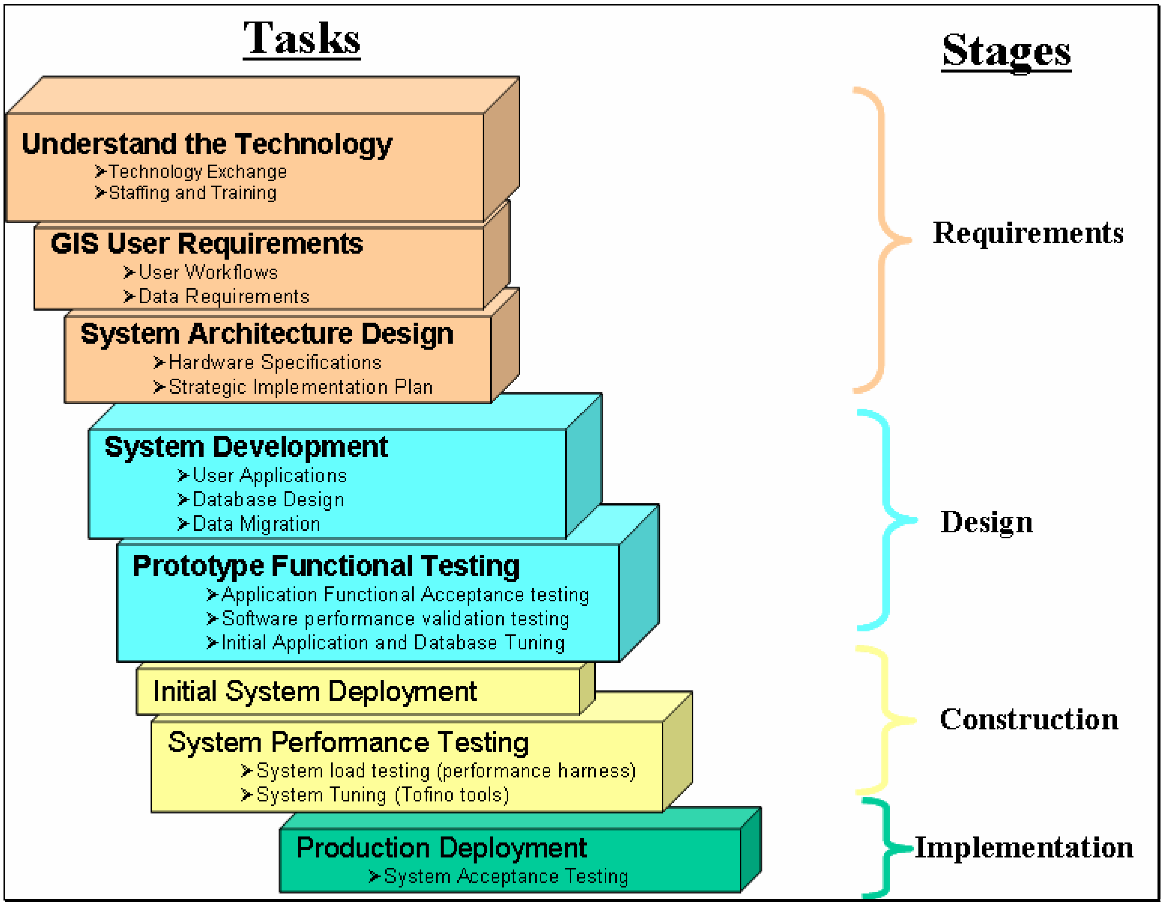


System architecture design provides a framework for supporting design and implementation of a successful enterprise GIS. User workflows must be designed to optimize interactive client productivity and efficiently manage heavier geoprocessing loads. The geodatabase design and database selection should be optimized to support performance requirements. System platform selection (servers, client workstations, storage) must be based on user workflow requirements. System architecture strategy must address performance needs and bandwidth constraints over distributed communication networks – operational environments must be designed to conserve shared resources. System architecture design provides a solid foundation for building a productive operational environment.

1.3 What Does It Take to Support Successful GIS Operations?

There are several critical stages of planning and implementation that support a successful implementation. Understanding the importance of each phase and the key objectives that support success will lead to more successful enterprise implementations.

Figure 1-3
Enterprise GIS Deployment Phases



- **Requirements Stage.** Understanding GIS technology alternatives, quantifying GIS user requirements, and establishing an appropriate system architecture design deployment strategy is critical during the requirements stage. This is a planning phase where 'getting it right' can save considerable effort and money throughout the following implementation.
- **Design Stage.** System development and prototype functional testing builds the components and confidence to support the follow-on deployment. This is where customers typically invest the most effort and expense to establish effective enterprise operations.
- **Construction Stage.** This is where the solution comes together to support the initial operational unit. This is an important time to validate performance and capacity planning, and demonstrate the hardware and infrastructure will support production deployment.

- **Implementation Stage.** This phase demonstrates success. Good planning, development, and testing will support a smooth deployment, productive operations, and satisfied users.

There is a significant advantage in ‘getting it right’ from the start. This is best done by taking the time to understand the technology, quantify user requirements, select the right software architecture, and deploy the right hardware infrastructure.

If you don’t get it right from the start, it will cost money to make it right later in the project. The cost of change increases exponentially as you get further along in the project.

Figure 1-4
Can You Afford Not to Plan?

GIS Cost Waterfall

Cost of a change

$1 - in the requirements stage

$10 - in the design

$100 - in construction

$1000 - in implementation

(Moody, 1996)
Database Programming & Design
October , 57-64

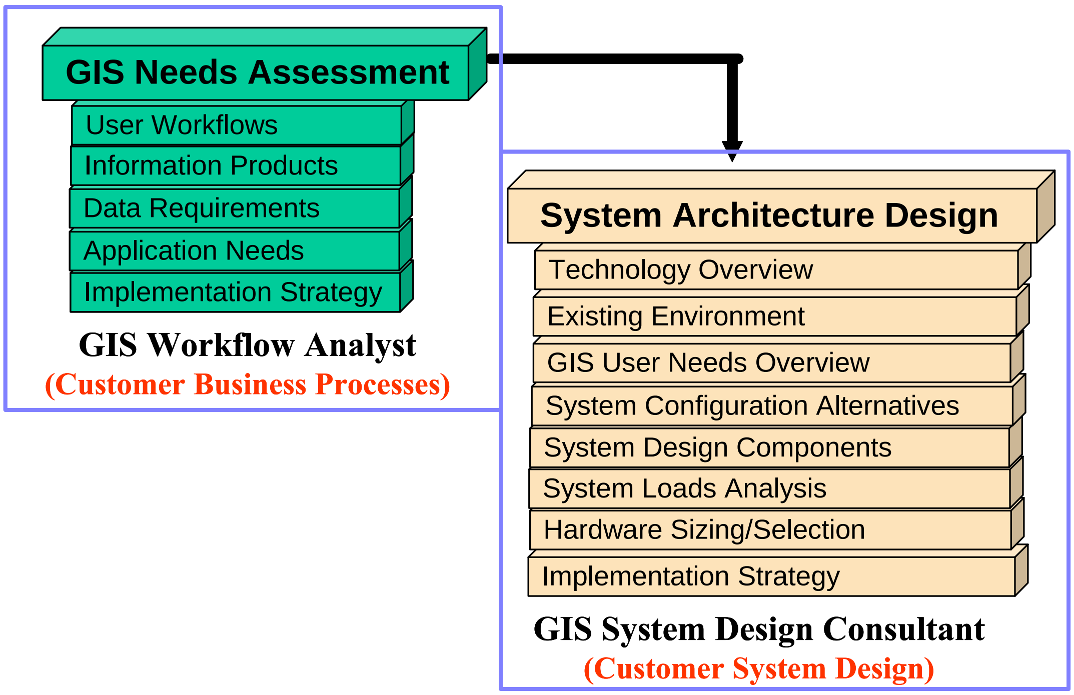
1.4 System Design Process

The enterprise system design process includes a GIS needs assessment and a system architecture design review. The system architecture design review is based on user workflow requirements identified in the GIS needs assessment.

- **GIS Needs Assessment.** The GIS needs assessment includes a review of user workflow requirements and identifies where GIS applications can improve user productivity. This assessment identifies GIS application and data requirements, and an implementation strategy for supporting GIS user needs. The user requirements analysis is a process that must be accomplished by the user organization. A GIS professional consultant familiar with current GIS solutions and customer business practices can help facilitate this planning effort.
- **System Architecture Design.** The system architecture design assessment is based on user requirements identified by the GIS needs analysis. The customer must have a clear

understanding of their GIS application and data requirements before they are ready to develop system design specifications. System implementation strategies should identify hardware purchase requirements "just in time" to support user deployment needs.

Figure 1-5
System Architecture Design



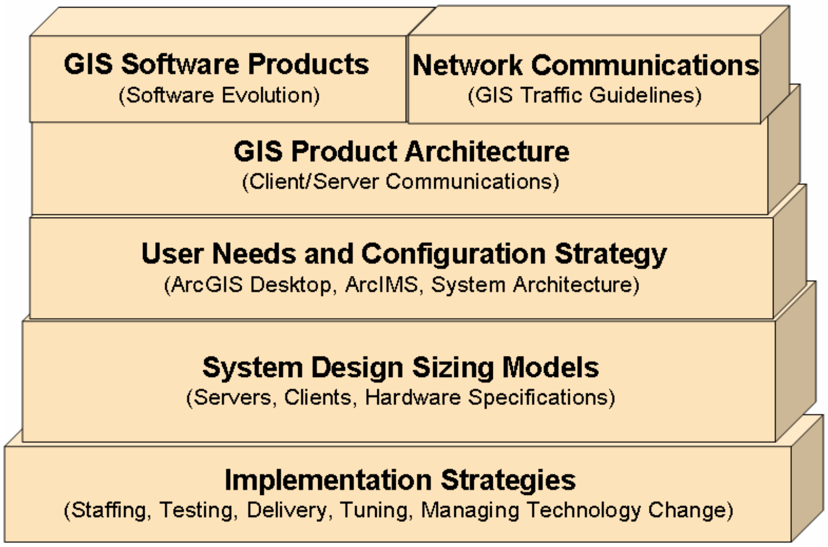
The ESRI system architecture design assessment begins with a technology exchange. The technology exchange provides a foundation for client support during the design process. Client participation is a key ingredient in the design process. The design process includes a review of the existing computer environment, GIS user requirements, and system design alternatives. The system design tools provided by ESRI translate user performance requirements to specific platform specifications. An integrated implementation strategy is developed to support GIS deployment milestones.

1.5 Supporting Technology

Distributed GIS solutions include integration of a variety of vendor products. Each product implements a component technology required to support the enterprise computing environment. Integration of this multi-vendor environment is made possible through voluntary compliance with generally accepted industry interface standards.

A general understanding of the primary supporting technologies associated with a GIS enterprise solution provides a foundation for supporting the system architecture design process. Figure 1-6 identifies the key technologies supporting a distributed GIS environment.

Figure 1-6
Supporting Technology



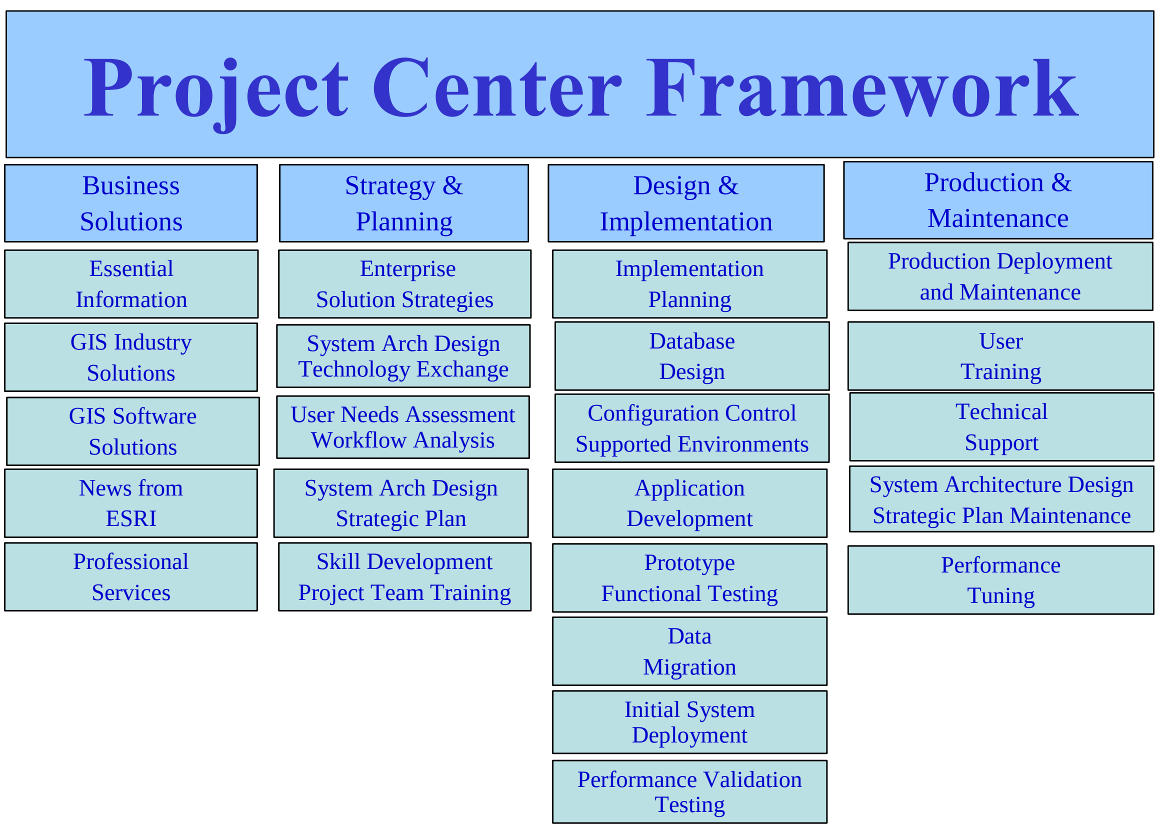
- **GIS Software Products**. A variety of GIS software was developed by ESRI over the past 33 years. Each product solution was developed to support specific user requirements. Section 2 describes how these solutions fit together to support the growing needs of the GIS user community.
- **GIS Product Architecture.** An enterprise GIS solution includes a variety of ESRI and third party vendor products. These products must interface with one another to support an integrated GIS solution. Section 3 provides an overview of the system architecture components required to support distributed GIS operations.
- **Network Communications.** Network communications provide the connectivity for a powerful GIS enterprise solution. A fundamental understanding of network communications helps users develop better applications and more efficient shared data resources. Section 4 provides an overview of network communication concepts and identifies GIS design standards for successful distributed GIS environments.
- **User Needs and Configuration Strategy.** The system architecture design process starts with a customer user needs assessment. The results of the GIS user needs assessment establishes the basis for the system architecture design analysis. The design process includes a methodology to translate peak user performance requirements to an appropriate GIS configuration architecture and defines the required hardware vendor specifications. Section 5 provides an overview of the user needs assessment and analysis required to develop an appropriate distributed GIS architecture design strategy.

- **System Design Sizing Models.** A fundamental contribution provided by the ESRI system architecture design consultant is the ability to translate user desktop application performance requirements to specific hardware and network specifications for an enterprise-wide design solution. Section 6 discusses the technical assumptions supporting the ESRI sizing models, identifying fundamental performance relationships between the distributed computing platform components supporting the GIS hardware solution. Section 7 identifies how to apply these sizing models in the real world of rapidly changing hardware technologies. Simple sizing tools are provided for each GIS platform environment generating specific platform specifications based on peak user loads. The sizing tools are generated based on the performance sizing models developed in the previous section.

1.6 Project Center Framework

There are several levels of requirements definition, design, and development that support a successful GIS implementation. Understanding the importance of each project phase and the key objectives that support success contribute to successful enterprise implementations.

Figure 1-7
Project Center Framework



- **Business Solutions.** The most effective solutions build on lessons learned. GIS currently supports a broad variety of business solutions. Successful GIS operations today establish a foundation for building future business solutions.

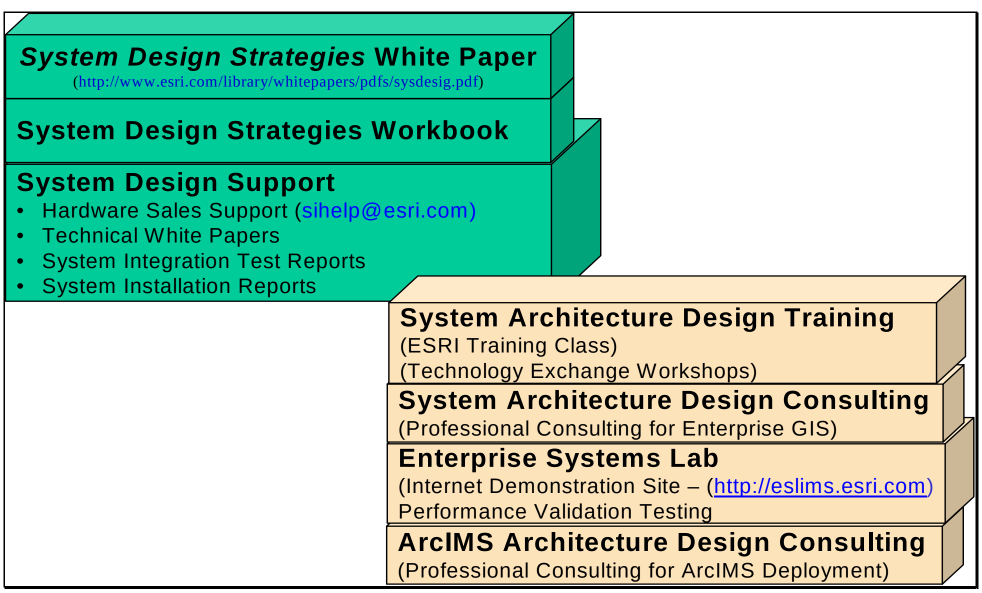
- **Strategy and Planning.** Early development of an enterprise solution strategy provides a framework for successful system implementation. System architecture design and associated hardware requirements must be established by real business workflow needs. The system architecture design strategic plan provides a foundation for supporting enterprise GIS deployment.
- **Design and Implementation.** System development and prototype functional testing builds the components and confidence to support deployment. This is where customers invest the most effort and expense to establish effective enterprise operations. Initial system deployment is where the solution first comes together to support operational requirements.
- **Production and Maintenance.** Successful enterprise GIS operations are normally the product of several years of evolutionary business change. Managing technology change is a fundamental challenge in supporting effective business operations. Periodic system architecture design strategic plan updates, effective system maintenance, periodic system performance tuning, on-going technical support, and user training work together to put technology to work in supporting productive business operations.

The Enterprise Support Team was established to provide an ESRI focus to support a growing number of Enterprise GIS customers. A common email alias, est@esri.com, is available to answer customer questions about the Enterprise Support Team initiative.

1.7 System Design Support Efforts

The ESRI Systems Integration Department was established in November 1990 with the charter to promote successful GIS implementations. Several initiatives were developed over the years to simplify the design of successful GIS environments and reduce implementation risk. The following services are maintained to support the needs of the ESRI user community and promote effective enterprise GIS solutions.

Figure 1-8
System Design Support Efforts



- ***System Design Strategies* White Paper.** The *System Design Strategies* white paper defines the technical issues associated with design of an effective enterprise GIS solution and includes specific sizing guidelines to support hardware selection. ESRI customers, hardware consultants, and GIS technical staff can use this document as a guide for designing future distributed GIS solutions. The guidelines in this document are also useful in understanding existing hardware-related performance issues and identifying proper solutions. The document is updated twice each year and is accessible over the Internet at the following URL: http://www.esri.com/library/whitepapers/pdfs/sysdesig.pdf .
- **System Design Strategies Workbook.** The System Design Strategies workbook is a PowerPoint presentation used in a variety of ESRI systems integration support efforts. Changes are made on a periodic basis to reflect software and technology evolution. The workbook is used as a source document supporting ESRI system design consulting and training efforts.
- **System Design Support.** The ESRI Systems Integration Department provides online hardware marketing support through the sihelp@esri.com email alias. Simple questions related to hardware selection and sizing requirements can be addressed through this site.
- **System Architecture Design Training.** A two-day System Architecture Design for GIS training class is available through the ESRI Learning Center. This class provides an in-depth review of the material presented in this white paper. A class brochure is included as Attachment B. A one-day System Architecture Design workshop is held the weekend prior to the annual ESRI User Conference providing a full technical overview of the material presented in the training class.
- **System Architecture Design Consulting**. Professional system architecture design consulting services are available for ESRI customers. These services can be used to resolve performance problems with existing environments and develop infrastructure support strategies for future successful GIS implementations. These services provide IT professionals with the information they need to support GIS users within their organizations. A generic statement of work for these services is included as Attachment A.
- **Enterprise Systems Lab**. Our Enterprise Systems Lab supports test and evaluation of ESRI and third party products focused on system design and performance for enterprise GIS environments. The Lab maintains an Internet Web site, providing general public access to demos of ESRI products supported by Microsoft Windows Terminal Servers and Citrix MetaFrame technology. The site also includes performance demonstrations of ArcIMS map services. This site can be accessed over the Internet at the following URL: (eslims.esri.com). This site demonstrates a very simple enterprise hardware solution for supporting remote GIS users over an Intranet, or the public Internet, with amazing performance.

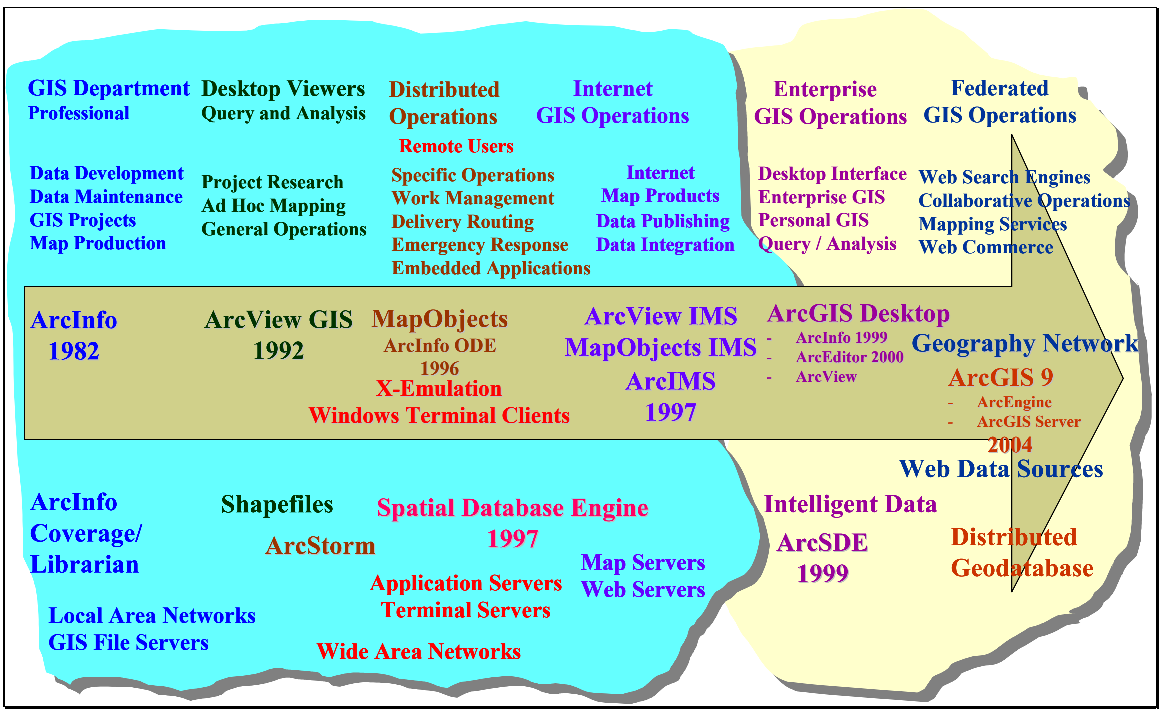
Several activities are included in the annual ESRI International Users Conference in San Diego each summer. System architecture design technical workshops provide a system design strategy refresher. System design architects are available at the Systems Integration island in the ESRI showcase area to provide customer design support during the conference. A System Implementation Papers track provides an opportunity for ESRI users to present their GIS implementation experiences.

2 ESRI Software Evolution

For more than 33 years, ESRI has continued to develop evolving GIS software technology supporting functional requirements identified by the GIS user community. ESRI software developers leverage the latest computer hardware and software technology to maintain ESRI leadership in the GIS marketplace. ESRI aligns its resources to provide the best software and services available to support GIS customer needs.

This section provides an overview of ESRI software and associated product technologies. Understanding the primary role for each member of the ESRI software family will help users identify current application needs and provide a clear vision for migration to a successful enterprise GIS solution. Figure 2-1 provides an overview of the ESRI software history and the associated third party technologies supporting effective GIS enterprise evolution.

Figure 2-1
GIS Enterprise Evolution

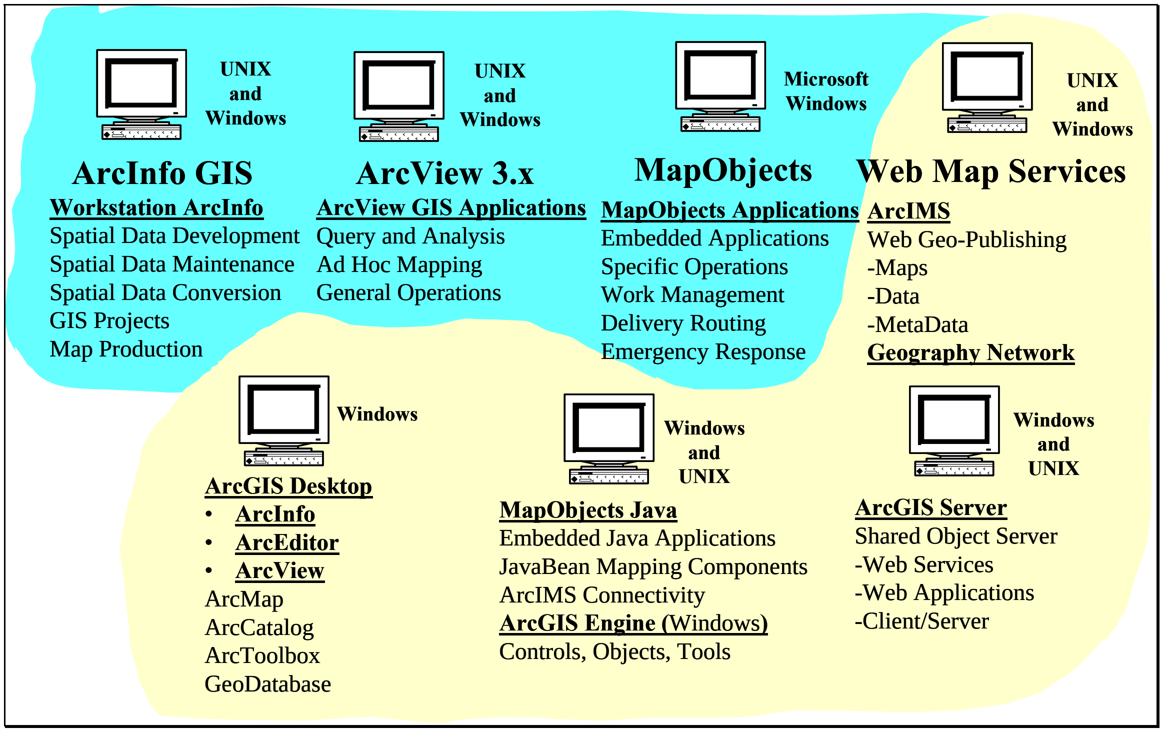


Many ESRI customers have developed effective enterprise solutions with the Workstation ArcInfo and ArcView GIS software provided in the 1990s. The new ArcGIS software provides operational capabilities that were not available with the older technology. Many ESRI customers are in the process of migrating their data and applications from the old file-based technology to the current ArcGIS object-based geodatabase architecture. New customers are supporting enterprise GIS solutions directly with the ArcGIS software technology.

2.1 Desktop Workstation Environment

The traditional environment for GIS applications is on the user desktop. ESRI desktop applications include ArcInfo, ArcEditor, ArcView, and custom applications developed using MapObjects or ArcGIS Engine software. ArcInfo 8 deployed Workstation ArcInfo and ArcGIS Desktop software integrated with ArcSDE geodatabase. ArcGIS 9 further deploys ArcObjects technology in ArcGIS Server and ArcGIS Engine software. Web mapping services can provide GIS information products and geoprocessing services for use by every user desktop through standard Web browser clients.

Figure 2-2
GIS Workstations/Services



- **ArcGIS Software.** ArcGIS is a scalable family of software comprising a complete geographic information system, built on industry standards, that is rich in functionality and works out of the box. Organizations deploy the software of ArcGIS—ArcView, ArcEditor, ArcInfo, ArcSDE, ArcIMS, and ArcGIS Server—in a configuration appropriate for their needs.

  ArcGIS is used for the creation, management, integration, analysis, display, and dissemination of spatial data and geoprocessing services. Strong visualization, editing, and analysis, along with advanced data management, distinguish the ArcGIS software family as the leading GIS software.

  ArcInfo. ArcInfo is the complete GIS data creation, update, query, mapping, and analysis system. Professionals use ArcInfo for spatial data automation since it includes the most comprehensive collection of GIS tools available. As part of the ArcGIS software family, ArcInfo includes all the functionality of ArcView and ArcEditor and adds the advanced geoprocessing and data conversion capabilities that make it the de facto standard for GIS.

ArcEditor. ArcEditor is a state-of-the-art GIS data visualization, query, and creation solution. Designed for the Windows desktop, ArcEditor can create and edit spatial data in an ArcSDE geodatabase. As part of the ArcGIS software family, ArcEditor contains all the capabilities users find in ArcView while adding capabilities for managing geodatabase schema and advanced editing of geodatabases.

ArcView. ArcView is the world's most popular desktop GIS and mapping software, with more than 500,000 copies in use worldwide. ArcView provides geographic data visualization, query, analysis, and integration capabilities along with the ability to create and edit geographic data.

ArcView is designed with an easy-to-use, Windows-like user interface and includes VBA for customization. ArcView consists of three desktop applications: ArcMap, ArcCatalog, and ArcToolbox. ArcMap provides data display, query, and analysis. ArcCatalog provides geographic and tabular data management, creation, and organization. ArcToolbox provides basic data conversion.

ArcSDE Database. ArcSDE is the tool that allows you to store and manage spatial data in your chosen DBMS. ArcSDE is open; it works with a variety of different databases—including Oracle, Informix, IBM DB2, and Microsoft SQL Server—that scale from work groups to large enterprise databases.

ArcSDE plays a fundamental role in a multi-user GIS. With ArcSDE, your ArcGIS software (ArcInfo, ArcEditor, ArcView, and ArcIMS) can work directly with spatial data managed in your DBMS.

ArcIMS Web Services. ArcIMS software is the foundation for distributing GIS data and applications on the Internet. By providing a common platform for exchanging and sharing GIS resources, ArcIMS provides unique opportunities to leverage data from within the organization and to integrate information from other agencies. Key features of ArcIMS include data integration, standards-based communication, the Internet-enabling technology for ArcGIS , easy-to-use framework, a multi-tier architecture, support for a wide range of clients, highly scalable server architecture, and a wide range of GIS capabilities. ArcIMS supports Windows and UNIX platforms.

ArcGIS Server Web Services. ArcGIS Server software will expose the full complement of ArcGIS ArcObjects for deployment on the Web. The ArcGIS Server will be deployed with the ArcGIS 9 software release. ArcGIS Server will be supported on Windows and UNIX platforms.

- **Workstation ArcInfo.** Workstation ArcInfo provides an exhaustive set of GIS tools representing over 33 years of software development effort, making this product the leading GIS professional software available today. Workstation ArcInfo includes a full set of tools to support spatial data development, maintenance, and conversion activities. For many users, this has been the primary software used by GIS professionals to support geographic studies, analysis, and map production. Workstation ArcInfo is supported on both UNIX and

Windows workstations. Most all of the traditional ArcInfo Workstation technology is now supported in the new ArcGIS desktop enviornment.

- **ArcView 3.** ArcView GIS 3 is a user-friendly desktop GIS software, initially developed to support a growing population of query and analysis users within the ArcInfo community. ArcView GIS is able to directly read ArcInfo coverages and to store spatial views in a new GIS shapefile data format. ArcView GIS quickly became very popular, significantly expanding the number of GIS users. It was not long before the number of ArcView GIS users outnumbered ArcInfo users. GIS professionals continue to use ArcInfo to create and maintain spatial data resources and to support high-technology spatial analysis and map products. ArcView GIS provides a simple GIS data access tool supporting general office query and analysis functions and producing simple ad hoc map products. A variety of ArcView GIS extensions have been developed since the initial ArcView GIS release to support the needs of the growing desktop user market, and ArcView GIS is now the leading desktop application throughout the GIS community. ArcView 3 is supported on Microsoft Windows and UNIX platforms.

- **MapObjects.** MapObjects was developed using new Microsoft programming standards for Windows environments. ESRI took advantage of this new object-oriented environment with the release of MapObjects software. With MapObjects, developers can include map products within standard Microsoft application environments. This opened a new world of product opportunities and spawned rapid expansion of the ESRI developer community. MapObjects became a new standard for incorporating GIS in vertical market product solutions. MapObjects is able to read and display ArcInfo coverages, ArcInfo LIBRARIAN files, shapefiles, and Spatial Database Engine (ArcSDE) layers data sources. This is an optimum programming environment to support custom GIS Windows-based applications.

  MapObject Java provides JavaBean mapping components to support Java programmers. Developers will be able to use the new ArcGIS Engine software to develop custom GIS applications with the ArcObjects technology.

- **ArcInfo LIBRARIAN.** As the number of GIS users increase, software management tools are needed to support data maintenance operations. Users update features on a spatial coverage by copying the layer to memory on their workstation and making the appropriate changes, then replacing the updated layer on the GIS data server. Conflicts can occur when multiple users are responsible for updating data on the same layers.

  ArcInfo includes a LIBRARIAN database management module that provides a controlled multiple-user data maintenance environment and supports more efficient management of spatial data resources. ArcInfo LIBRARIAN is a file-based storage solution that provides a continuous tile structure for all data layers on the GIS data server within a single database environment. Users are able to extract individual tiles within a coverage for editing, and the associated tiles within ArcInfo LIBRARIAN are “write locked” to avoid data changes during the update process. Once editing is complete, the updated tile is returned to the ArcInfo LIBRARIAN database and the associated tile is released for other users to update. ArcInfo LIBRARIAN provides an effective and simple way for several people to maintain and manage large continuous GIS data libraries.

- **ArcStorm Data Server.** Large enterprise GIS operations identified a need for enhanced transaction management of ArcInfo spatial data resources. ArcStorm software satisfies this need by providing feature-level transaction management, transaction history, and commit logic to support large GIS operational environments. ArcStorm includes several server processes that support transaction management and check-in/checkout processing. An ArcStorm weather service daemon manages the ArcStorm data files and generates additional processes as required for user transactions. ArcInfo provides functions to support maintenance of the ArcStorm libraries. ArcView GIS is able to directly read ArcStorm data using standard NFS protocol (CIFS for Windows servers). Client workstation processes support all read operations. ArcSDE replaces ArcStorm for ArcGIS technology.

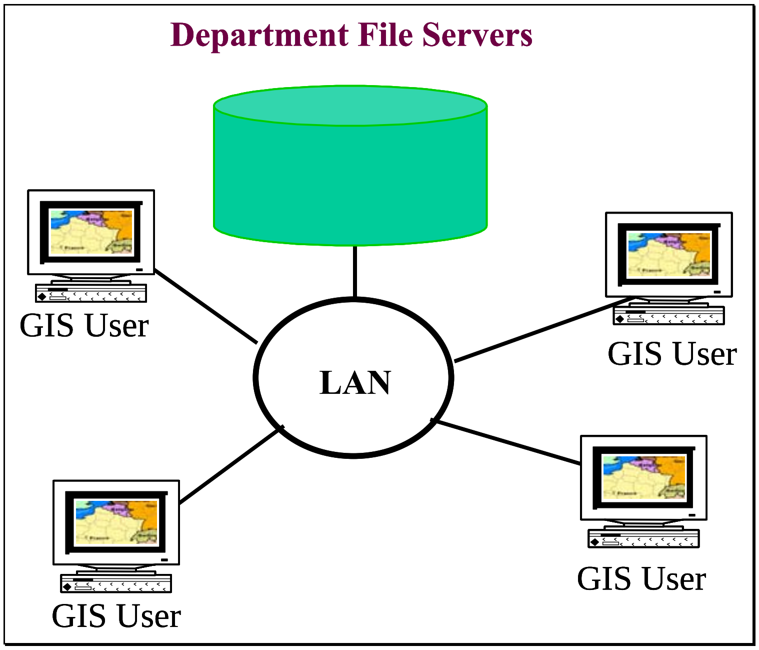
- **Database Integration.** Spatial features within ArcInfo data coverages can be linked to other tabular attribute data throughout the organization. ArcInfo maintains a set of database integrator modules (application program interfaces [APIs]) that provide direct access to attribute data in Oracle, Informix, Sybase, and OpenIngres relational database management systems (RDBMSs). The Windows version of ArcInfo, ArcView GIS, and MapObjects are ODBC-compliant applications, supporting access to DBMS environments through standard ODBC driver connectivity. This connectivity has improved and expanded GIS access to additional ODBC-compliant database environments to include Microsoft SQL Server, IBM DB2, and a host of other data sources.

  A variety of commercial gateways support online access to mainframe and AS400 legacy data business systems. Commercial replication services and administrative data transfers provide GIS user access to data from the more difficult proprietary data sources.

2.2 Organizational GIS Evolution

GIS implementations grew in size and complexity throughout the 1990s. GIS started on the user desktops, and evolved to support GIS operations with department-level file servers. A majority of the GIS community is currently supported by department-level GIS architectures. Figure 2-3 provides an overview of a department-level GIS architecture.

Figure 2-3
Departmental GIS

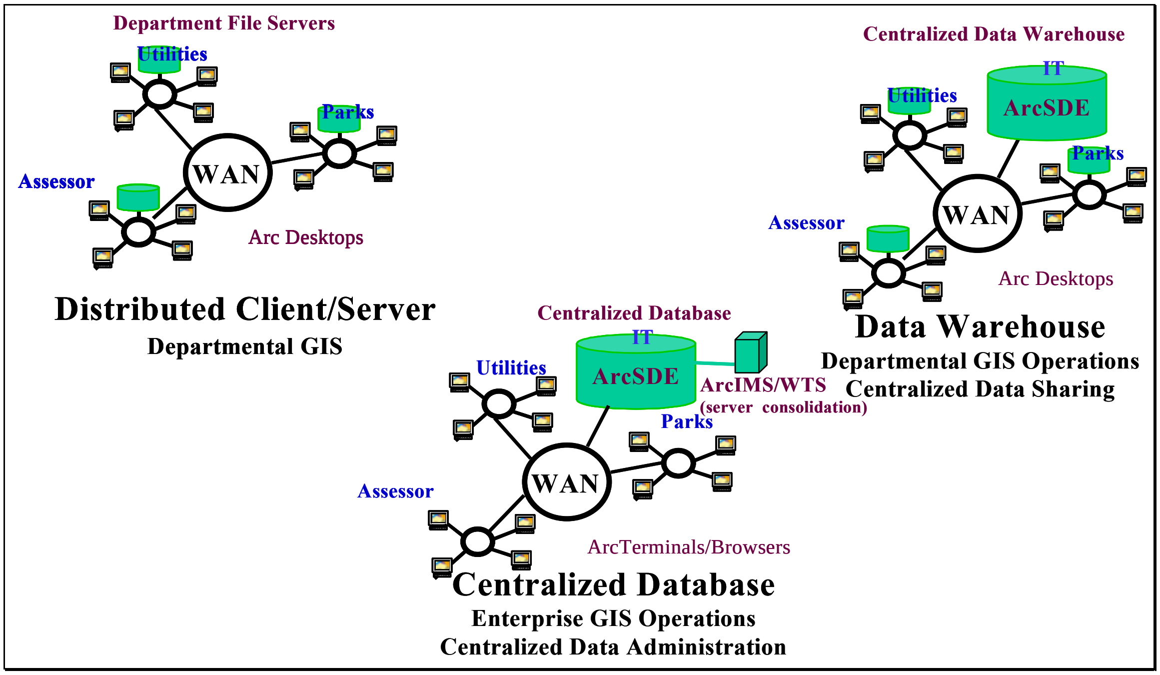


As GIS within a typical organization evolved over time, several departments would have local GIS operations which require data resources from other departments within the organization. The organizational wide area network (WAN) became a way of sharing data between department servers. Data standardization and integrity issues would surface within the organization, since data were developed and managed from different department-level sources.

The initial Spatial Database Engine (SDE) release in the mid-1990s supported enterprise data warehouse operations, and many organizations combined department GIS data resources on a central ArcSDE data warehouse. GIS staff were established within IT departments to integrate enterprise-wide GIS data resources within the data warehouse providing integrated data standards across the organization. The common data warehouse provided a reliable shared GIS data source for departments throughout the organization. This was a very common migration path for local government GIS operations.

Figure 2-4 provides an overview of organizational architecture alternatives.

Figure 2-4
Organizational GIS



The electric and gas industry started using GIS in the early 1990s to support management of their power distribution facilities. Most of these implementations were supported by a central database. Remote users were supported with terminal access to application compute servers (terminal servers) located in the central computer facility with the GIS database.

Many organizations today are migrating their department file-based GIS database environments to a single central enterprise ArcSDE database, and supporting terminal client access to these consolidated server environments. Departments retain responsibility for their data resources, updating and maintaining these data through terminal access to central ArcGIS applications. The central IT computer center supports general administration tasks, such as data backups, operating system upgrades, platform administration, etc. Users throughout the organization are provided browser access to published ArcIMS services over the Intranet. The complexity and sophistication of the ArcSDE geodatabase make central administration and support the most productive alternative for most organizations.

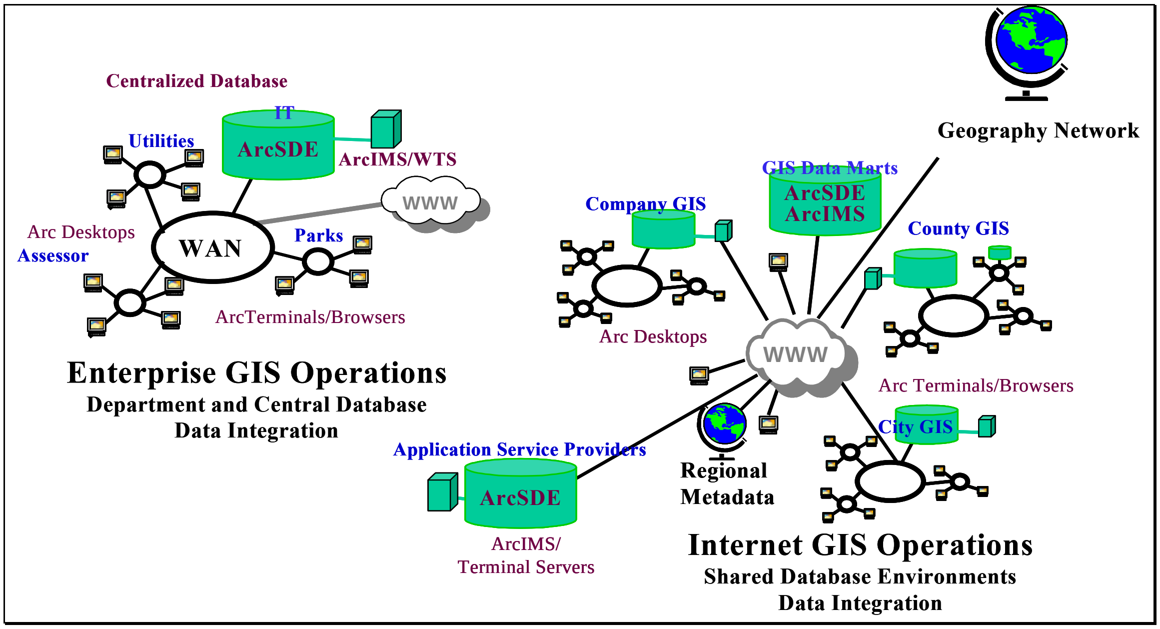
2.3 Community GIS Evolution

Year 2000 introduced a growing Internet awareness, demonstrating the tremendous value of sharing information between organizations and nations. Internet access was extended from the workplace to the home, rapidly expanding the user community. Communities and companies developed and deployed services to customers over the Internet. The Internet provided opportunities for organizations to share data and services between organizations. Users had access to data and services from a multitude of organizations through the Internet.

ESRI introduced the Geography Network, a metadata search engine that collected information about GIS data and provided direct Internet links between the customer and the data or service provider. ArcIMS provided a way for organizations throughout the world to share GIS data and services. The Geography Network provides a foundation to bring GIS data and services together, supporting a rapidly expanding infrastructure of worldwide communities sharing information about the world we all live in. Promotion of data standards and improved data collection technologies unlock enormous possibilities for GIS information products to help us better understand and improve our world.

GIS data resources are expanding exponentially. A few years ago, GIS data servers would seldom require a database over 25 to 50 Gigabytes in size. Today we are seeing a growing number of GIS implementations with ArcSDE data servers supporting database environments with over a Terabyte of GIS data.

Figure 2-5
Community and Federated GIS



State-level agencies are consolidating data to support municipalities and commercial activities throughout their states. National agencies are consolidating data to support their user requirements and sharing data between state and national communities. Community-level data marts are being established to consolidate GIS data resources and support Internet data sharing to organizations throughout county and state regional areas.

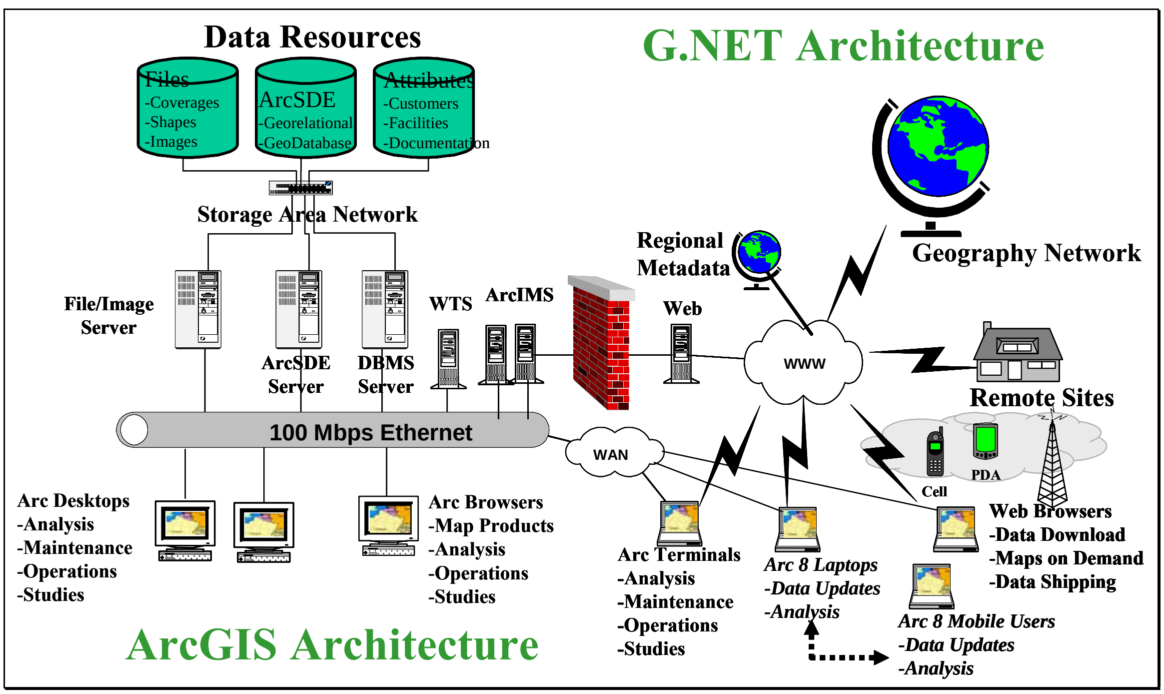
Many organizations are outsourcing their IT operations to commercial Internet Service Providers (ISPs). Application Service Providers (ASPs) support organizations with IT administration, providing opportunities for smaller organizations to take advantage of high-end GIS database and application solutions to support their business needs. State governments are hosting applications and data for smaller municipalities throughout their states so the smaller communities can take advantage of GIS technology in supporting their local operations.

Regional Geography Networks (G.Net) sites support sharing data throughout regional areas and within large state and federal agencies. The ArcIMS software provides a metadata search engine that can be used by any organization to share their data and support their community operations. Cities can establish metadata sites to promote local commercial and public interests. States can consolidate metadata search engines for sharing data and services with municipalities throughout the state. Law enforcement can establish search engines to support national data sets. Businesses can establish metadata search engines to support distributed operational environments.

2.4 GIS Technology Alternatives

Current GIS technology is available to support a rapidly expanding spectrum of GIS user needs. Solutions are supported by ESRI products integrated with a variety of vendor-enabling technologies.

Figure 2-6
ESRI Core GIS Technology



Data storage and data management technologies are growing in importance, as organizations continue to develop and maintain larger volumes of GIS data. Direct connect storage solutions are evolving to Storage Area Networks (SANs) enhancing IT options for managing a large volume of data resources.

Supported data servers include file servers, ArcSDE servers, and attribute data servers. Desktop ArcGIS applications are supported on local workstation clients. These same applications can be supported for remote clients using Windows Terminal Servers. Windows Terminal Servers can also support local terminal clients.

ArcIMS provides published map servers to Web browser clients throughout the organization. ArcIMS can also provide public map services to clients across the Internet. ArcGIS clients are able to connect to ArcIMS as intelligent browser clients, enabling connection to unlimited data resources through the Internet Geography Network, as well as organization resources served through ArcIMS services. Users can access applications from home or from other locations. Mobile ArcGIS users can create red-line datasets in the field and submit them to a central ArcIMS site for final processing. ArcGIS desktop applications can include ArcIMS services as data sources with local ArcSDE and file servers, expanding desktop map production and analysis to include available Internet data sources. The "ArcGIS architecture" is supported by a combination of ArcSDE data sources, ArcIMS Web services, and ArcGIS desktop technology.

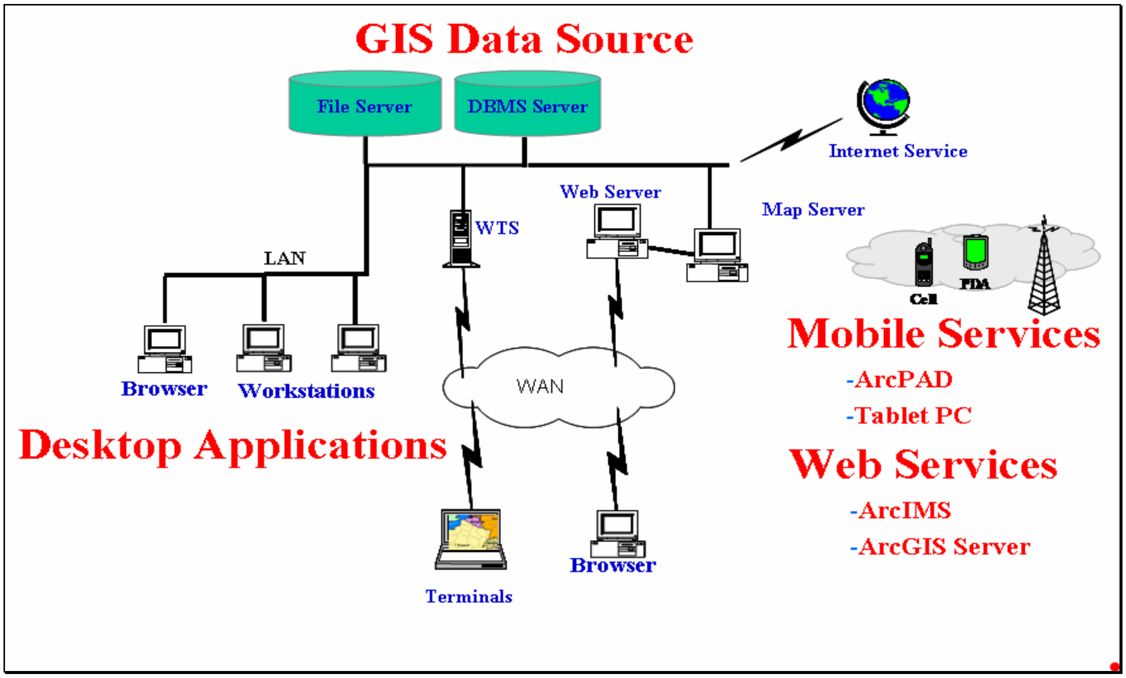
Implementation of the Geography Network metadata search engines, along with local metadata sites supported by ArcIMS 4 software, rapidly expand user access to data sources beyond the organization. This "G.Net architecture" expands traditional organizational GIS information resources to include Internet data sources providing a rich data environment to support growing GIS user needs.

A variety of design alternatives enable organizations to develop an enterprise GIS solution that best supports their user requirements.

2.5 GIS Software Selection

Selecting the right software and the most effective deployment architecture is very important. The ArcGIS technology provides many alternative architecture solutions, and a wide variety of software, all designed to support specific user workflow needs.

Figure 2-7
GIS Software Technology Alternatives



- **GIS Data Source.** Operations may be supported on local disk or CD ROM, shared file servers, ArcSDE DBMS servers, or Web data sources. Local data sources support high performance application workflow with minimum network latency. Remote data sources allow connection to a variety of published data sources, with the drawback of potential bandwidth congestion and performance issues. There are architecture solutions that reduce the performance issues and support distributed data access.
- **Desktop Applications.** The highest level of functionality and productivity is supported with the ArcGIS desktop applications. Most professional GIS users and GIS power users will be more productive with the ArcGIS Desktop software. These applications can be supported on the user workstation or through terminal access to software executed on central Windows Terminal Server farms. Some of the more powerful ArcGIS Desktop software extensions perform best on the user workstation with a local data source, while most ArcGIS Desktop user workflows can be supported more efficiently on a Terminal Server farm. Selecting the appropriate application deployment strategy can have significant impact on user performance, administrative support, and infrastructure implementations.
- **Web Services.** The ArcIMS and ArcGIS Server technologies provide efficient support for a wide variety of more focused GIS user workflows. Web services also provide a very efficient way to share data to support remote client workflows. ArcIMS provides the most efficient way to publish standard map information products. ArcGIS Server provides enhanced funtionality to support more advanced user workflows and services. Web services are a cost-effective way to leverage GIS resources to support users throughout an organization and associated user community.
- **Mobile Services.** A growing number of GIS operations are supported by more loosely connected mobile GIS solutions. ArcGIS technology supports continuous workflow operations that include disconnected editing and remote wireless operations. A disconnected architecture solution can significantly reduce infrastructure costs and improve user productivity for some operational workflows. Leveraging mobile services can provide alterative solutions to support a variety of user workflow environments.

Selecting the proper software and architecture deployment strategy can have a significant impact on user workflow performance, system administration, user support, and infrastructure requirements.

2.6 GIS Configuration Alternatives

GIS environments commonly begin with single-user workstations at a departmental level within an organization. Many organizations start with a single GIS manager, and evolve from a department-level to an enterprise operation. This was common through the early 1990s, as many organizations worked to establish digital representation of their spatial data. Once these data are available, organizations expand their GIS operations to support enterprise business operations.

Spatial data are presented as layers of graphic lines, points, or polygons stored in a proprietary file format as GIS layers, similar to traditional Mylar sheets. These layers are overlaid by the client application to render a map image. Spatial data can be stored in proprietary file formats or as spatial feature types within a database table. Standard file formats include coverages and shapefiles. LIBRARIAN provides a tiled coverage format supporting data maintenance operations. ArcStorm includes a variety of server processes to manage database integrity with associated tabular attribute data sources.

Data can be shared between users in a variety of ways. Most organizations today have user workstations connected to local area networks (LAN) environments, and locate shared spatial data on dedicated server platforms. User applications connect to shared data sources to support GIS operations.

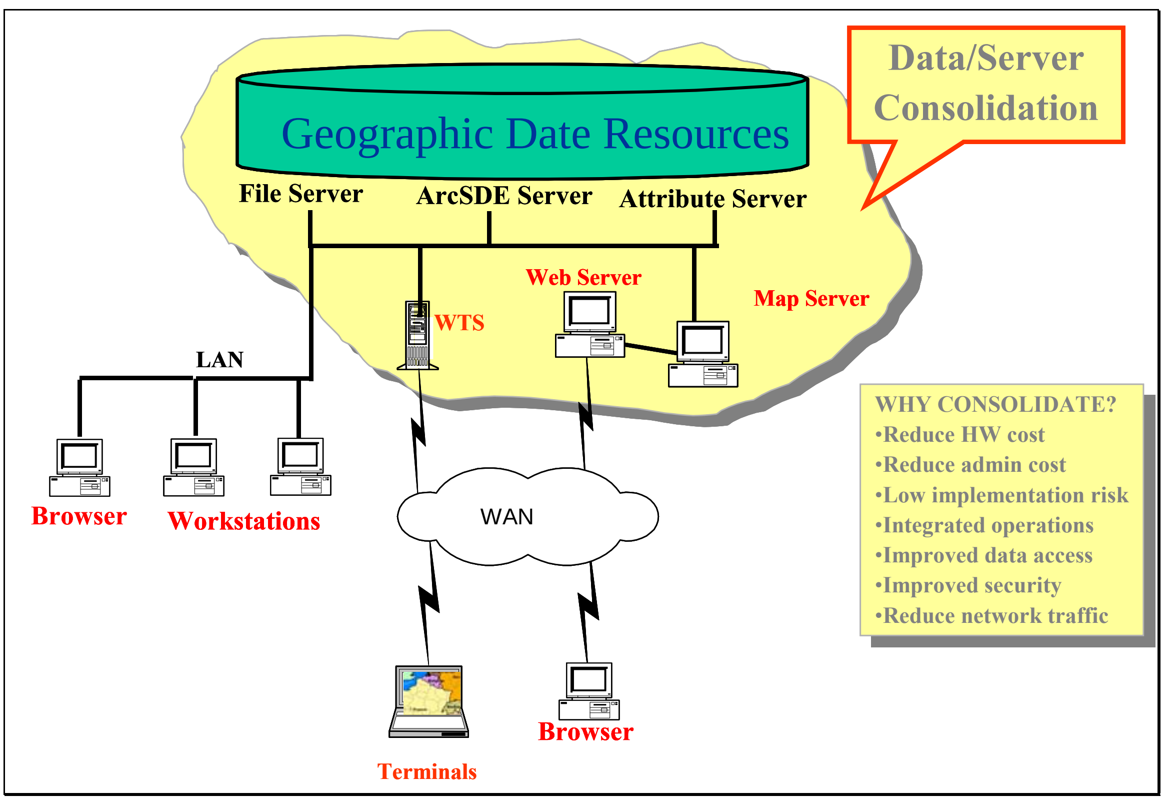
- **Centralized Data Configuration Alternative**

  The most simple system architecture is supported by a central GIS database. A central database architecture supports one copy of the production database environment, minimizing administrative management requirements and ensuring data integrity. Figure 2-8 provides an overview of a central data configuration architecture.

  GIS desktop applications can be supported on user workstations located on the central LAN, each with access to central GIS data sources. Data sources can include GIS file servers, ArcSDE database servers, and related attribute data sources.

  Remote user access to central data sources can be supported by central Windows Terminal Server farms, providing low bandwidth display and control of central application environments.

Figure 2-8
Centralized Computing Environment



Centralized application farms minimize administration requirements and simplify application deployment and support throughout the organization. Source data is retained within the central computer facility, improving security and simplifying backup requirements.

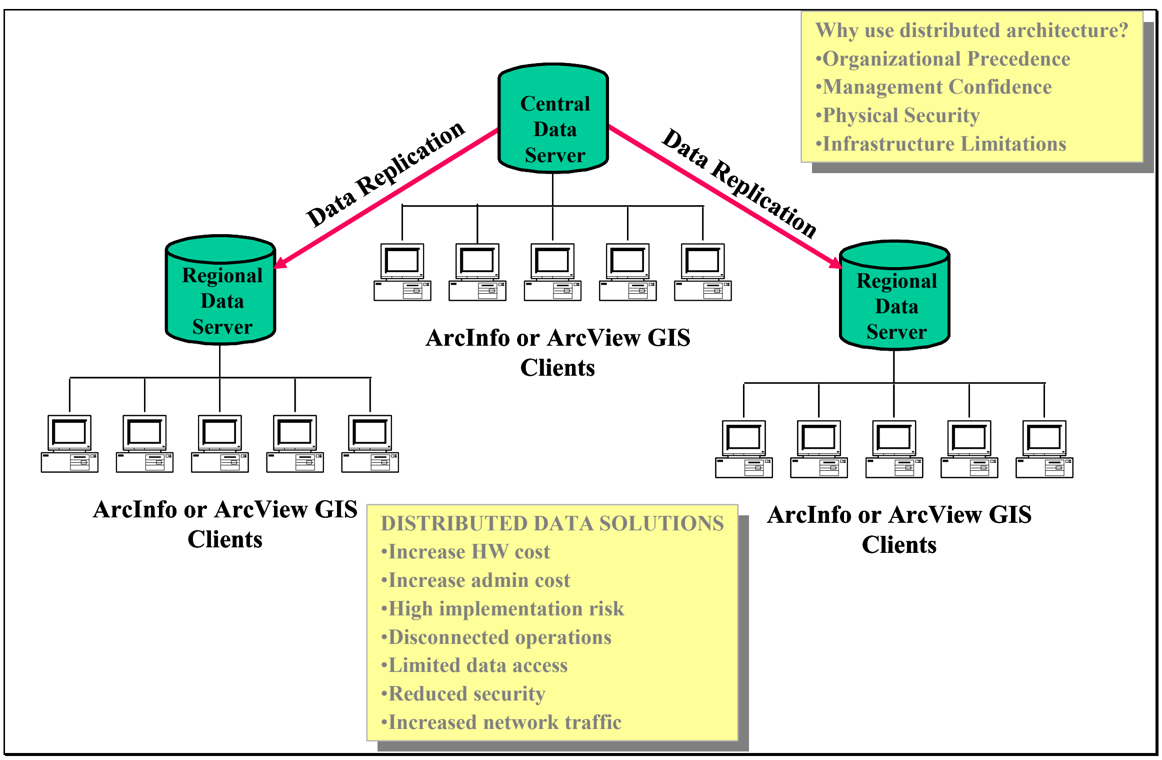
A variety of ArcIMS map services can support standard browser clients throughout the organization. Web mapping services support low bandwidth access to published GIS information products and services.

Distributed computing technology today can support consolidated architectures at a much lower risk and cost than similar distributed environments. For this reason, many organizations are in the process of consolidating their data and server resources. GIS can benefit from consolidation for many of the same reasons experienced by other enterprise business solutions. Centralized GIS architectures are generally easier to deploy, manage, and support than distributed architectures, and provide the same user performance and functionality.

■ Distributed Data Configuration Alternative

Distributed solutions are supported by replicated copies of the data at the remote locations, establishing local processing nodes that must be maintained consistent with the central database environment. Data integrity is critical in this type of environment, requiring controlled procedures with appropriate commit logic to ensure changes are replicated to the associated data servers.

Figure 2-9
Distributed Computing Environment



Distributed database environments generally increase initial system cost (more hardware and database software requirements) and require additional on-going system administration and system maintenance requirements. Distributed solutions are provided to support specific user needs, and generally increase system complexity, cost, and system deployment timelines.

In many cases, standard database solutions do not support replication of spatial data. GIS users with distributed database requirements must modify their data models and establish procedures to administratively support data replication. DBMS vendors have recognized the necessity to provide a spatial data replication option, and new releases are supporting some levels of spatial data replication. ESRI is also working on a solution to support geodatabase syncronization between multiple ArcSDE servers. The complexity of current geodatabase environments have complicated implementation of an automated efficient spatial replication solution.

2.7 ESRI ArcGIS Implementation

Many ESRI customers have been working with ESRI products and data formats for many years. As a result, there are a large number of custom applications and data sets that have been developed and maintained in various locations throughout the GIS community. This proliferation of data and applications has resulted in a variety of data and application environments.

The ArcGIS technology is particularly suitable for an enterprise GIS implementation and can help ease the transition from the existing “stovepipe” GIS environments into a true enterprise implementation. The geodatabase technology in particular will provide tangible benefits in accomplishing this transition. The ArcGIS technology is also suitable to those new users who are spatially enabling their existing tabular data resources to support implementation of enterprise GIS operations. Many spatial data resources are available to support organizations as they migrate their operations to take advantage of GIS technology.

Geodatabases come in two varieties—personal and multi-user[1]. Personal geodatabases, implemented in Microsoft Access, are suitable for project-level GIS. Multi-user databases deployed using ArcSDE require a DBMS such as Oracle, Microsoft SQL Server, Informix or DB2. Storing spatial and attribute data directly in a commercial database gives a geodatabase capabilities that are not available, or are more difficult to achieve, with other formats. Some of these benefits are listed below.

- A uniform repository for geographic data. All geographic data is centrally stored and managed in one database.
- Data entry and editing is more efficient. The use of subtypes, domains, and validation rules helps maintain database integrity and reduces database maintenance.
- Sets of features are continuous. Geodatabases can accommodate very large sets of features without tiles or other spatial partitions.

[1] This section has been derived from the article by Colin Childs, ArcUser, July-Sept 2001

- Multi-user editing. ArcSDE geodatabase environments use a data management framework called versioning that lets multiple users access and edit features simultaneously and reconciles any conflicts.
- Feature-linked annotation. Geodatabase annotation can be linked to the feature that it describes. When the linked feature is moved or deleted, the related label is moved or deleted.
- Users work with more intuitive data objects. A properly designed geodatabase contains data objects that correspond to the user's model of data. Instead of generic points, lines, and areas, users work with objects of interest such as parcels, roads, and lakes.
- Using a geodatabase can be simple and straightforward. Geodatabases can be created, accessed, and managed through the standard menus and tools in ArcCatalog, ArcToolbox, and ArcMap. However, the geodatabase model supports intelligent features, rules, and relationships that advanced users can employ in complex GIS applications.

In addition to the benefits of the geodatabase technology, the ArcGIS desktop applications provide a Windows-based suite of GIS data query, analysis and management, and tools. These tools often provide comparable functionality to the applications that have been developed by ESRI users in the past using custom AML and Avenue applications. The commercial off-the-shelf (COTS) ArcGIS functionality can also be extended as needed using the COM-based ArcObjects technology. ArcIMS and ArcReader provide additional GIS capabilities for users who need browse and query access. Transitioning from existing data and applications to the ArcGIS technology will provide tangible benefits and efficiencies for the GIS community.

2.7.1 Data Transition Strategies

GIS data are traditionally stored, updated and managed at the local workgroup level. This results in duplication of many of the data themes and additional effort in reconciling the various datasets when aggregation of these data are required at higher levels within the organization. This aggregation becomes even more difficult when the schemas for the various workgroup datasets are inconsistent.

An important first step in resolving the difficulties with aggregating data for enterprise-level analysis is to define data standards to which all data managers are required to adhere. The standardization process, however, can be time-consuming and institutionally difficult because of differences in local business processes and geographies. Depending on the business area, the prospect for data standardization may be more or less challenging.

ArcGIS provides a number of tools that can help in the standardization and management of data. On the database design side, ArcCatalog and/or Visio’s UML CASE tool can be used to define a geodatabase schema. The schema defines entities (feature and object classes) and their definition (field size and type, nullability, default values, domains, etc.), as well as relationships between entities. These schemas can be defined from scratch, from existing agency designs or developed based on the geodatabase template models provided by ESRI at: (http://arconline.esri.com/arconline/datamodels.cfm).

Implementing the standardization can be accomplished in several ways. Three of the alternatives for implementing data standards are: (1) centralization of data storage and access through terminal server technology, (2) disconnected editing and reconciliation of centrally managed data, and (3) periodic aggregation of local datasets adhering to enterprise data standards.

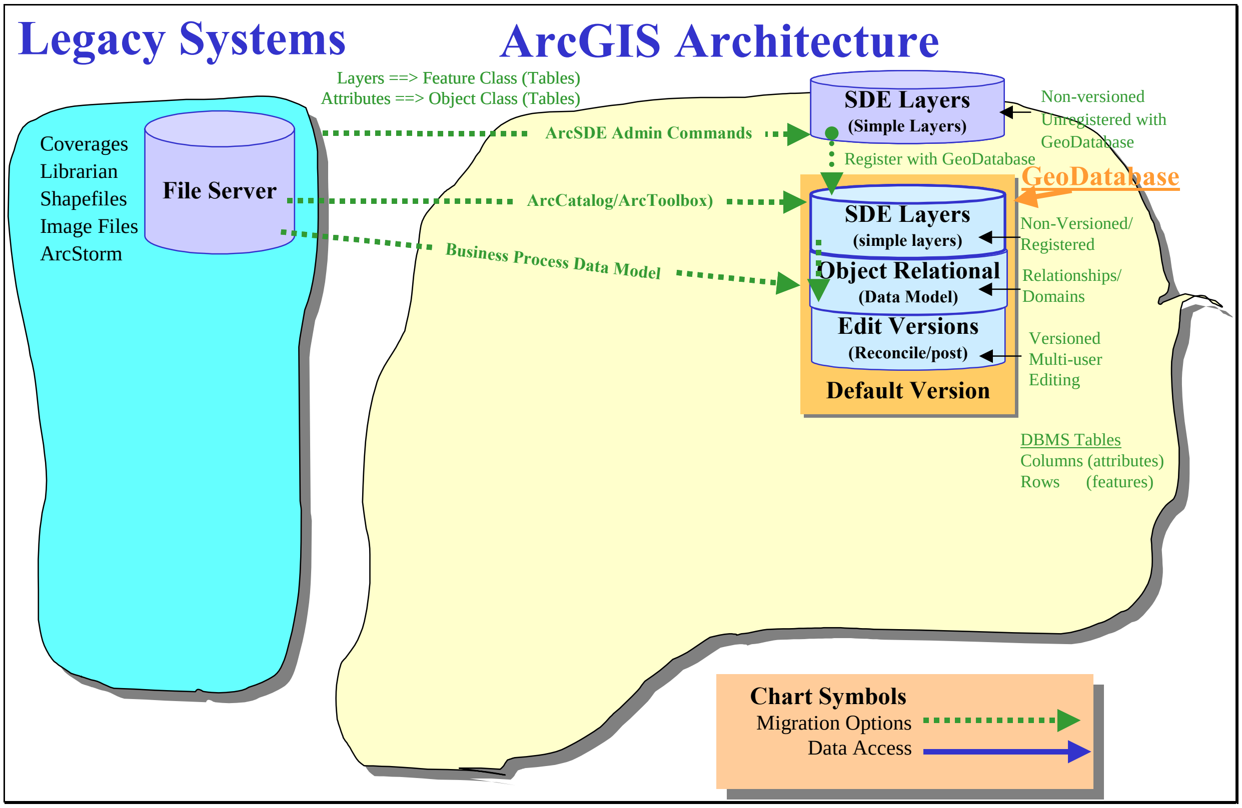
The simplest way to integrate data would be to enforce the schema definition so that all data imported into the ArcSDE database conforms to a single definition. This could be done through process or by centralizing the database and providing local access to the centralized database. The advantages to this approach include the centralization of data administration responsibilities and tight enforcement of the database schema.

An alternative to centralization is to define data standards for the essential elements of the schema, and allow local users to extend the “essential” model to include their added-value information. In this manner, the custodians responsible for aggregating local datasets would be able to map the required fields to the enterprise standard and ignore the additional information as desired. ArcCatalog provides an in-the-box graphical user interface (as well as programmable objects) for mapping the fields from one schema to another. ArcGIS layer files also provide tools for aliasing field names in the physical model to local names that may be more user-friendly. This can ease the difficulty of standardization when local nomenclature is different. The advantages to this approach include the flexibility for allowing local users to add fields into the schema for their local business needs.

Regardless of the alternative that is chosen, the migration of existing GIS data will be required at some level. Although ArcGIS supports the management, query and analysis of shapefiles and coverages, the content of the existing data would eventually need to be massaged to adhere to enterprise standards. In cases where the data are edited and maintained by multiple users, transitioning to a multi-user geodatabase in ArcSDE will provide the most robust model for managing data transactions.

Figure 2-10 provides a data migration roadmap to convert legacy ArcInfo and ArcView data sets to both SDE simple layers (non-geodatabase) and into the geodatabase data model. It also shows how SDE simple layers can be integrated into the geodatabase data model and the different components and processes involved.

Figure 2-10
Data Migration Road Map



The options for migrating data from simpler to more robust data structures are as follows:

- Move file-based data (shapefiles, coverages, librarian tiles, etc.) to ArcSDE simple layers using the ArcSDE administration tools (command line). At this level, ArcSDE provides an improved data warehouse environment for an enterprise spatial data source.
- After creating ArcSDE layers, they may be registered with the geodatabase. Once a layer is registered with the geodatabase, the resulting *feature class* can be versioned to support multi-user data maintenance operations. Domains, relationship classes, and other object-relational behavior can be added to feature classes, further extending the geodatabase capabilities.
- Users can also move file-based data directly into the geodatabase using ArcCatalog or ArcToolbox. This migration path allows the user to create new feature classes or append updates to existing geodatabase feature classes. This is the preferred migration path once a geodatabase is established.

Legacy ArcInfo and ArcView clients will be able to view and query data in the default version of the new geodatabase. ArcIMS Image and Feature services also access the default version of the ArcSDE geodatabase.

2.7.2 Application Transition Strategies

In addition to the diversity of database schemas supported in the GIS community, there are also numerous custom applications that have been developed for managing and analyzing the data. While many of the different customer business processes may have unique aspects, the fundamental responsibilities for managing GIS data resources should be the same. As such, some of the applications required for managing GIS data resources could be standardized. Developing data standards is an important step in creating common GIS applications. Even so, the ArcGIS desktop tools provide a wealth of functionality for managing and analyzing data regardless of the data schema.

Legacy applications include ArcInfo custom applications, ArcView 3 custom applications, and ArcView 3 standard clients. Many of the functions developed in the custom applications are included in the ArcGIS standard clients or can be incorporated in the data models, which will reduce the requirements for custom application programming with the ArcGIS technology.

Technology upgrades include migration of clients to ArcIMS-published map services, ArcGIS desktop client applications (ArcView 8, ArcEditor 8, or ArcInfo 8), or custom ArcGIS applications. The transition to ArcGIS from an existing operational environment will require a number of steps.

Training. Users should be trained in the capabilities and use of the COTS ArcGIS technology. Training a group of super-users or domain experts first will provide the background required for the next step in the transition: the application gap analysis.

Needs Assessment and Gap Analysis. A user application needs assessment and gap analysis should be completed to document functions required by each GIS user and to identify any functions that are not supported directly in the COTS ArcGIS desktop software. This analysis should identify those users that can migrate directly to ArcGIS and those users that must wait for custom ArcGIS applications. Custom applications can be built using any COM-compliant programming language (e.g., Visual Basic, C++) with the ArcObjects technology.

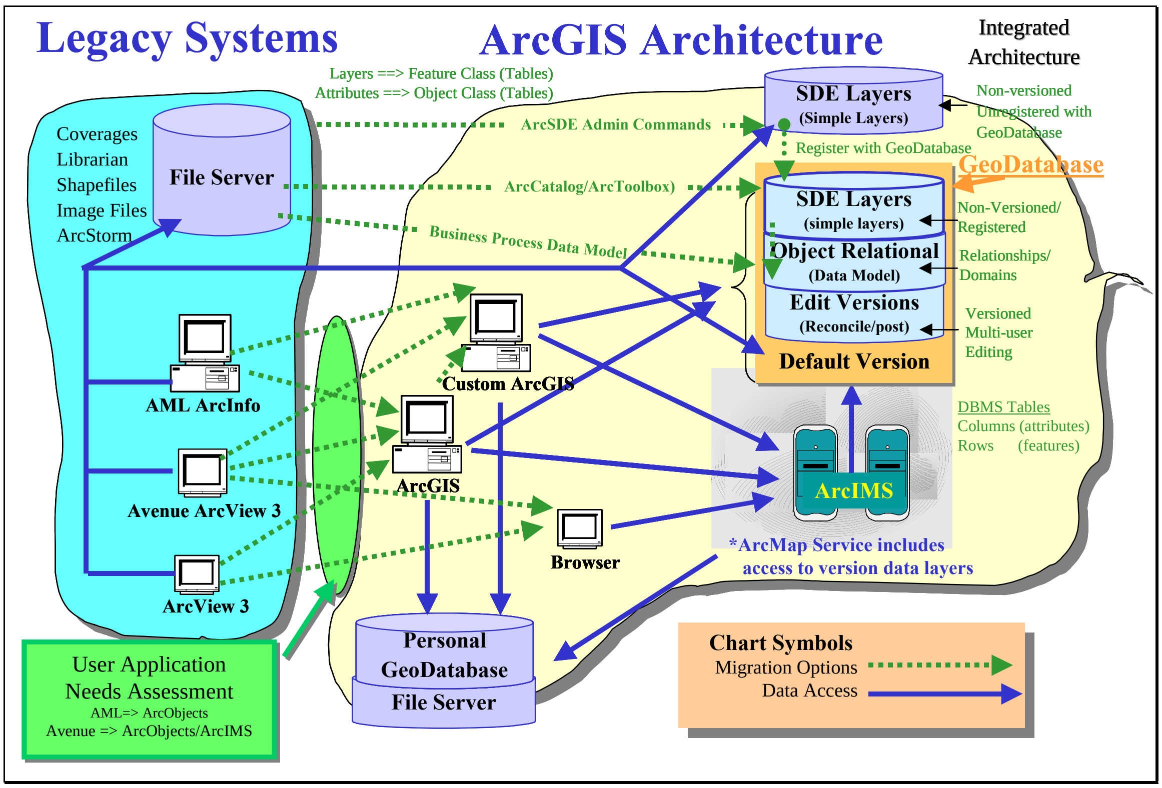
Power User Migration. Power users include GIS specialists who are trained in GIS analysis and technology. Many of their current tasks are undertaken on an ad hoc basis and do not require custom applications. Many power users should be able to migrate directly to the standard ArcGIS desktop product without custom development. The ArcGIS desktop provides access to ArcIMS data sources and to versions and object relationships in the ArcSDE geodatabase.

Operational User Migration. Some customization may be required to support migration of standard desktop operations that currently are supported by custom ArcInfo applications. Many of the basic edit operations may be supported directly with the standard ArcEditor desktop.

There may also exist ArcView applications that can be supported with the ArcIMS technology for query and analysis.

Figure 2-11 provides an application migration roadmap from legacy applications that use AML, Avenue, and COTS ArcView 3.x technology.

Figure 2-11
Application Migration Road Map



Note that the migration path from each of the existing platforms has a path from the existing implementation directly into ArcGIS without requiring any customization. It should also be noted that some ArcView 3 users might be able to perform their query and analysis functions through a thin browser client connected to an ArcIMS service. During the transition from the existing environment to the ArcGIS environment, there may be a need for continued use of existing AML applications. Workstation ArcInfo provides this capability, though the data accessed by existing AMLs would need to remain in coverage format until the existing code is updated to work with ArcSDE data or users become familiar with the ArcGIS Desktop tools.

3 Network Communications

Network communications provide the required connectivity to support distributed computer processing. Network products support a stable and dependable communication protocol for distributed data transport. A variety of communication protocols support distributed applications and data resources located at sites throughout an organization.

For several years, network technology was a relatively static environment while computer performance was increasing at an accelerating rate. Recent advances in communication technology support a dramatic shift in network solutions, introducing worldwide communications over the Internet and bringing information from millions of sources directly to the desktop in real time.

3.1 Desktop Workstation Environment

GIS applications rate among the heavy users of network traffic, along with document management and video conferencing. GIS technology provides a visual display environment to the user supporting very quick analysis of large amounts of graphic data. Access to distributed data sources for real-time display and analysis puts large demands on network communications. Data must be transported across the network to where the program is executed in order to display the information.

Figure 3-1
GIS Applications Network Impact

What GIS Does ...

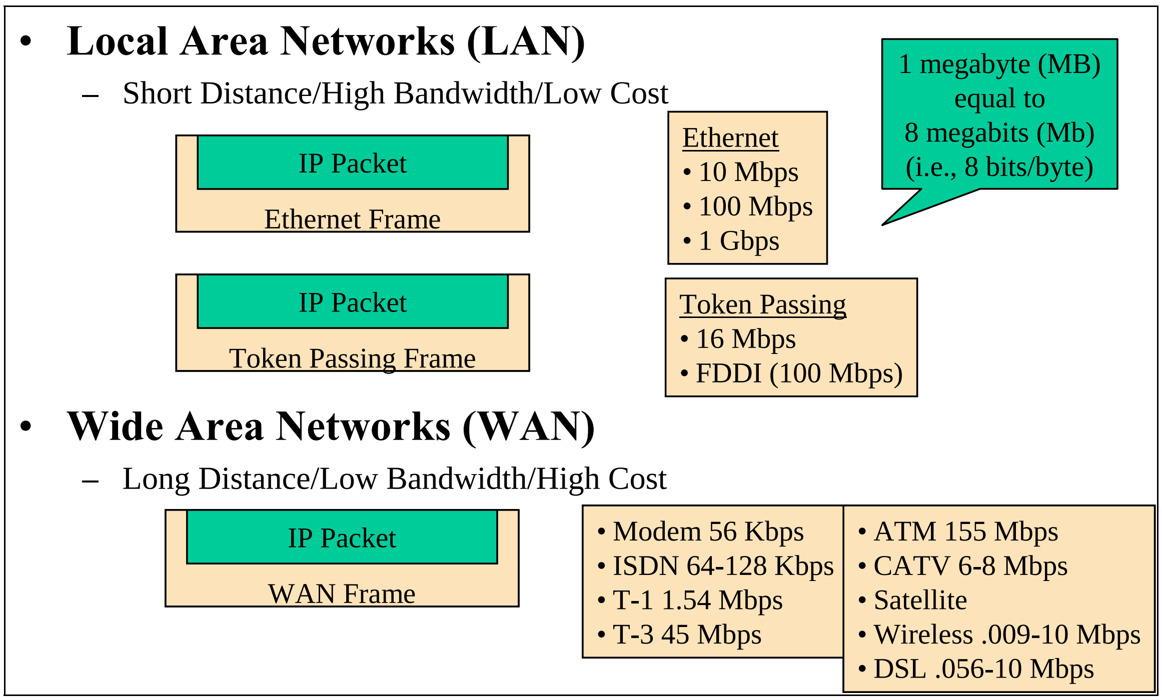
- Graphic Data Representation (Maps)
- Large Quantity of Data Analysis
- Lots of Network Traffic

Data is a collection of digital computer information stored in media that has the capability to record and retain the data structure. These data are represented by little pieces of information called bits. Each bit takes up the same space on a storage or transmission media. For convenience, these little bits can be grouped into bytes of information with each byte containing eight bits. Data can be transported from one location to another within packets that protect the integrity of these data.

Data are typically transported from one storage location to another over copper-wire or glass-fiber physical networks. Other types of transport media include microwave, radio wave, and satellite digital transmissions. Each network protocol has limits to its supported rate of data transport based on the technology used to support the transmission.

Network transport solutions can be grouped into two general technology classes. These classes include local area networks (LANs) and wide area networks (WANs). The volume of data (measured in bits) that can be transported per second represents the transport rate (capacity) of a specific network segment. This capacity is called network bandwidth and is typically measured in millions of bits (megabits) or billions of bits (gigabits) per second.

Figure 3-2
Types of Networks



- **Local Area Networks (LANs).** Local area networks support high-bandwidth communication for short distances. This environment supports local operating environments (usually within a building or local campus environment). Data transport over a single technology is single-threaded, which means only one data transmission can be supported on a single LAN segment at any one time. The cost for LAN environments is inexpensive relative to other hardware costs supporting the system environment.

- **Wide Area Networks (WANs).** Wide area networks support communication between remote locations. Technology supports much lower bandwidth than LAN environments, but transmission is possible over long distances. This is a data transport environment, which means data is packaged in a series of additional packets and transported as a stream of data along the transmission media. The cost for WAN connections is relatively high compared to LAN environments.

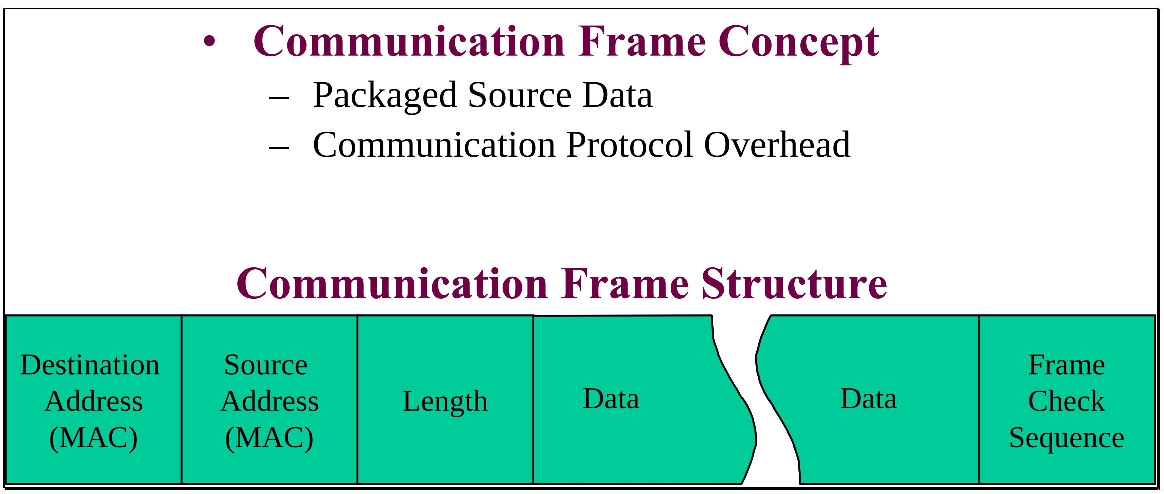
- **Data Units**. Data capacity is measured in terms of megabytes or gigabytes when stored on computer disk. Megabytes (MB) are abbreviated using a large “B” while megabits (Mb) are abbreviated using a small “b.” One must remember 1 MB = 8 Mb when converting data volume from disk storage to network traffic.

3.2 Client/Server Communication Concept

Applications move data over the network through proprietary client/server communication protocols. Communication processes located on the client and server platforms define the communication format and address information. Data are packaged within communication packets, which contain communication control information required to transport the data from its source client process to the destination server process.

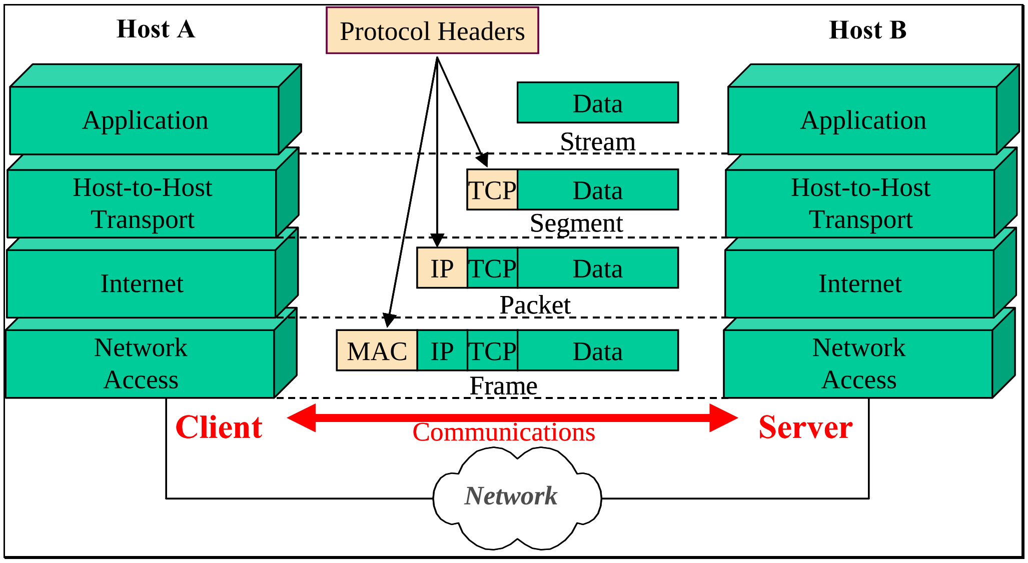
- **Communication Packet Structure.** The basic Internet packet structure includes destination and source addresses, and a series of control information in addition to the data structure. This information supports delivery of the packet across the network medium. The IP packet size will vary depending on the amount of data. The largest IP packet is around 65 Kilobytes (KB). Ethernet frames are limited to 1.5 KB. Data can be distributed across several packets to support a single data transfer.

Figure 3-3
Communication Packet Structure



- **Network Transport Protocol.** The communication packet is constructed at different layers during the transmission process. A data stream from the Host A application is sent through the protocol layers to establish a data frame for network transmission. The Transmission Control Protocol (TCP) header packages the data at the transport layer, the Internet Protocol (IP) header is added at the Internet layer, and the Media Access Control (MAC) address information is included at the physical network layer. The data frame is then transmitted across the network to Host B where the reverse process moves the data to the host application. A single data transfer can include several communications back and forth between the host applications.

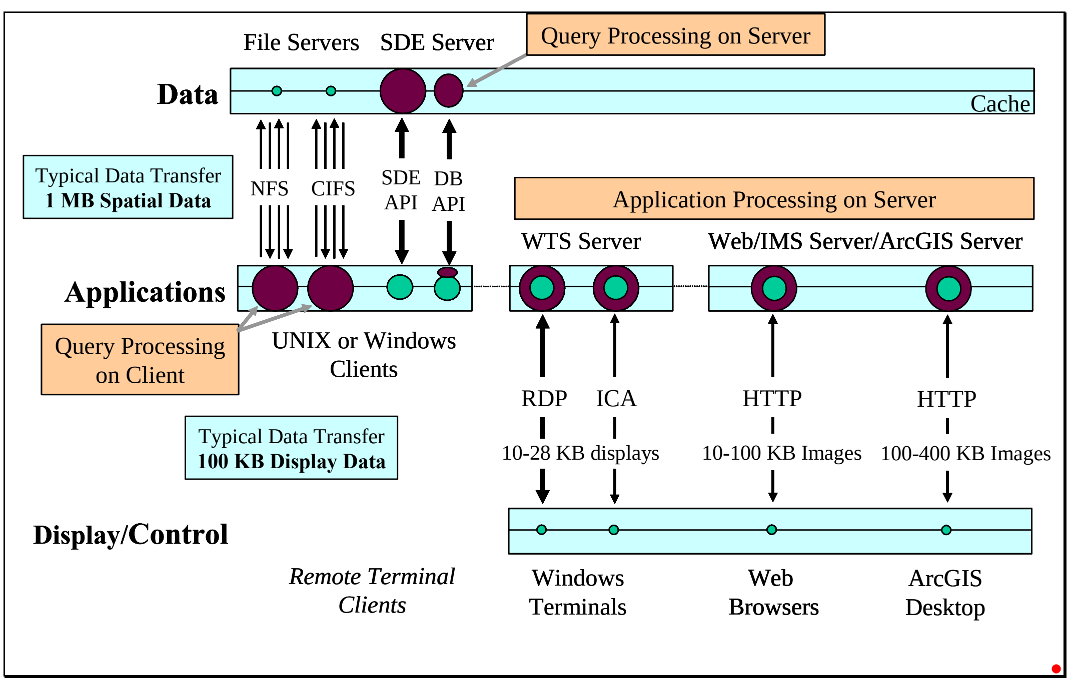
Figure 3-4
Network Transport Protocol



3.3 Client/Server Communications

Several client/server communication solutions are available to support network data transfer. Each solution includes a client and server component to support data delivery. The client process prepares the data for transmission and the server process delivers the data to the application environment. Primary protocols used by GIS solutions include the following.

Figure 3-5
Client/Server Communications



- **NFS (UNIX) and CIFS (Windows) Protocol.** Supports remote disk mounting enabling a client application to access data from a distributed server platform. All query intelligence is resident with the client application, directing access to data located on the server platform. Data must be transferred to the client application to support analysis and display.

- **ArcSDE API.** ArcSDE includes client and server communication components. The server component includes intelligence to support query processing. Data are compressed during transfer and uncompressed by the client application. Data must be transferred to the client application to support analysis and display.

  An alternative ArcSDE client direct connect option is available that connects with a DBMS client API on the desktop. The ArcSDE middleware functions are supported on the client platform, and the DBMS network client supports data transmission to the server. Query processing remains on the DBMS server.

- **ICA and RDP Protocol.** Supports remote terminal display and control of applications supported by a host Windows Terminal Server. Transmits display and control information to terminal client. Both ICA and RDP protocols compresses data for transmission.

- **HTTP Protocol.** Standard Web transmission protocol. Transaction-based environment, with product selection and display controlled by the browser client. Data is compressed for transmission. ArcGIS desktop applications can also access ArcIMS as a data source. Traffic for the ArcGIS desktop is higher due to the larger image transfers. Image size is directly proportional to the physical screen display size, thus larger image displays can result to much higher traffic.

3.4 Client/Server Network Performance

The data transfer volume and the network bandwidth can be used to establish expected user response times. A typical GIS application requires up to 1 MB of data to generate a new map display. A typical terminal environment requires 100 KB of data to support the display environment.

Figure 3-6
Client/Server Performance

Client/Server Communications	**Network Traffic Transport Time**				
	56 Kbps	**1.54 Mbps**	**10 Mbps**	**100 Mbps**	**1 Gbps**
File Server to Workstation Client (NFS) •1 MB => 10 Mb + 40 Mb = 50 Mb	893-Sec	32-Sec	5-Sec	0.5-Sec	0.05-Sec
SDE Server to Workstation Client •1 MB => 10 Mb >> 5 Mb	89-Sec	3.2-Sec	0.5-Sec	0.05-Sec	0.005-Sec
Windows Terminal Server to Terminal Client (ICA) •100 KB => 1 Mb >> 280 Kb	5-Sec	0.18-Sec	0.03-Sec	0.003-Sec	0.0003-Sec
Web Server to Browser Client (HTTP) •50 KB => 500 Kb	9 Sec	0.3 Sec	0.05 Sec	0.005 Sec	0.0005-Sec
Web Server to ArcGIS Desktop Client (HTTP) •200 KB => 2 Mb	36-Sec	1.2-Sec	0.20-Sec	0.02-Sec	0.002-Sec

Best Practices

The chart above takes the data transfer requirements in megabytes (MB), converts this to megabits (Mb) for transmission, includes any compression of these data performed by the communication protocol, and calculates the total volume of data in megabits (Mb) that must be transmitted (protocol overhead may be greater than what was used in this sample conversion). The transport time required to transfer these data are calculated for four standard bandwidth solutions. This simple illustration identifies the primary cause for remote client performance problems. Sufficient bandwidth is essential to support user performance requirements.

File server configurations support query from the client applications. When selecting data from a file (coverage or shapefile), the total file must be delivered to the client for processing. Data not required by the application is then rejected at the client location. This accounts for the considerable amount of network overhead experienced by these communications.

ArcSDE client/server configurations support query processing on the server platform. The query processing includes locating the requested data and filtering that data so only the specific data extent requested by the client is returned over the network. If the client limits requests to a small volume of data (i.e., point data or a single parcel in a parcel layer), the resulting data transfer can be very small and network transport performance would improve accordingly.

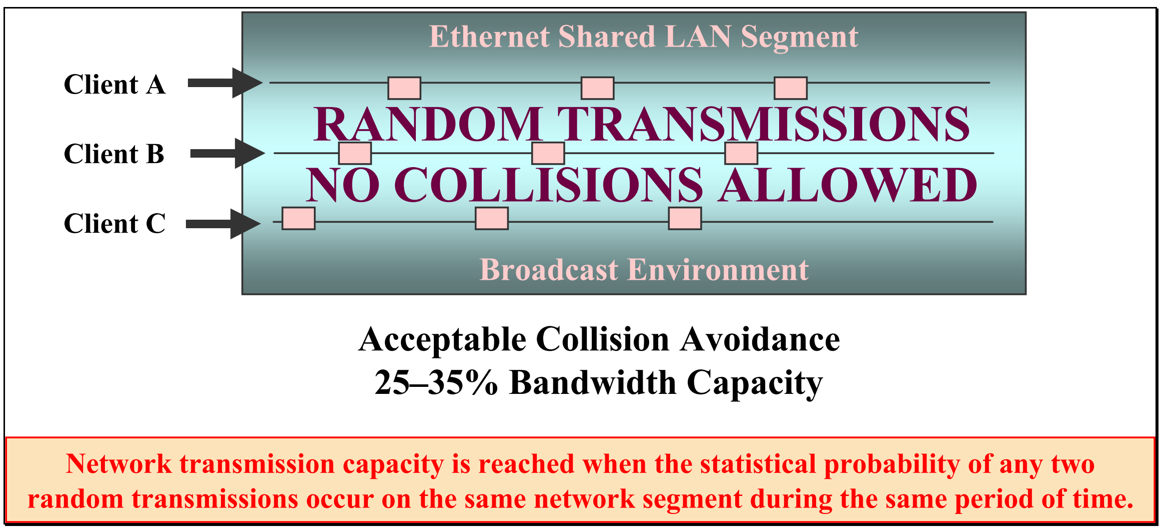
Best practices are established for network configuration alternatives. Distributed client/server application environments generally perform better in a local area network environment.

Transaction-based services, or persistent Windows Terminal Server connections, provide stable processing environments for processing over less stable wide area network connections.

3.5 Shared Network Capacity

The total number of clients on a single network segment is a function of network traffic transport time (size of data transfer and network bandwidth) and the total number of concurrent clients. Only one client data frame can be transmitted over a shared network segment at one point in time. Multiple transmissions on the same Ethernet network segment will result in collisions, which will require another transmission to complete data frame delivery. Ethernet segments fail rapidly during saturation due to the rapidly increasing number of transmissions.

Figure 3-7
Shared Network Capacity



Token-passing environments operate somewhat differently. Concurrent transactions must wait for a token to support data frame delivery, resulting in transmission delays. Delays will increase as the network reaches saturation. Failure mode is much more graceful than Ethernet, supporting a higher acceptable bandwidth utilization.

3.6 Typical 1-MB Map Display

A GIS application may require 1 MB of spatial data, or up to 10 Mb of network traffic, to support a single map display. Applications can be tuned to prevent display of specific layers when the map extent exceeds defined thresholds. Only the appropriate data should be displayed for each map extent (i.e., it may not be appropriate to display individual parcel layers in a map showing the full extent of San Diego, CA). Proper tuning of the application can reduce network traffic and improve performance.

Figure 3-8
Typical 1-MB Map Display
(1:3,000 Scale (Feet), Average Features = 250)

3.7 Network Configuration Guidelines

Standard published guidelines are used for configuring network communication environments. These standards are application-specific and based on typical user environment needs. Communication environments are statistical in nature, since only a percentage of user processing time requires transmission over the network. Network data transfer time is a small fraction of the GIS users total response time (on properly configured networks). Network data transfer time can dominate response time when bandwidth is too small or when too many clients are on the same shared network segment.

Figure 3-9
Network Configuration Guidelines

- **Network Design Standards**
  - Current User Environment Needs
  - Addresses Statistical Application Use
  - Provides Basis for Initial System Design
- **Network Management**
  - Ongoing Traffic Management Task
  - Hardware, Application, and User Dependent
  - Strongly Affected by Work Environment and Changes in Computer Technology

The network must be designed to support peak traffic demands and is a function of the types of applications and user work patterns. Standard guidelines provide a place to start configuring a network environment. Once the network is operational, network traffic demands should be monitored and necessary adjustments made to support user requirements.

3.8 Shared Network Configuration Standards

Figure 3-10 provides recommended design guidelines for network environments. These guidelines establish a baseline for configuring distributed LAN environments. Five separate client/server environments are included for each network bandwidth. The number of recommended clients is based on experience with actual system implementations and does not represent worst-case environments. Networks should be configured with the flexibility to provide special support to power users whose data transfer needs exceed typical GIS user bandwidth requirements.

Figure 3-10
Network Design Guidelines

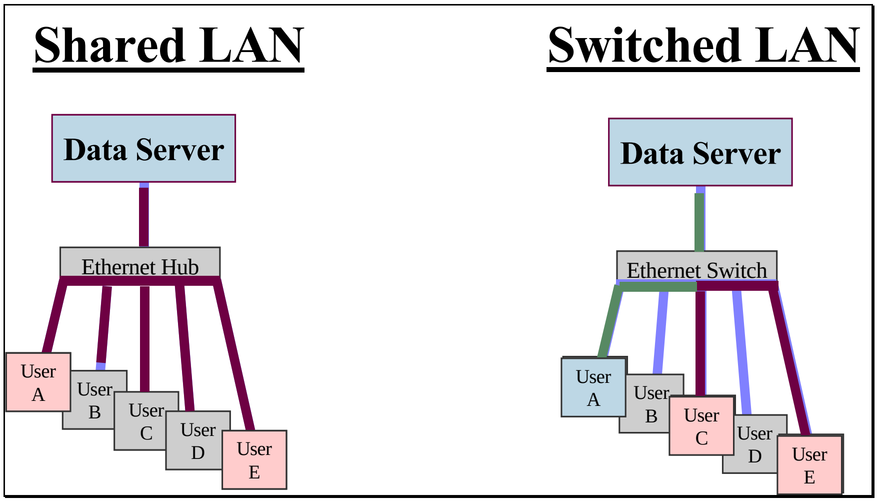
Local Area Networks Bandwidth	Concurrent Client Loads File Servers	SDE Servers	Windows Terminals	Web Products
10 Mbps LAN	2-4	10-20	350-700	150-300
16 Mbps LAN	3-6	16-32	550-1100	250-500
100 Mbps LAN	20-40	100-200	3,500-7,000	1,500-3,000
1 Gbps LAN	200-400	1,000-2,000	35,000-70,000	15,000-30,000
Wide Area Networks Bandwidth	**Concurrent Client Loads File Servers**	**SDE Servers**	**Windows Terminals**	**Web Products**
56 Kbps Modem	NR	NR	2-4	1-2
128 Kbps ISDN	NR	NR	5-10	2-4
256 Kbps DSL	NR	NR	10-20	5-10
512 Kbps	NR	NR	20-40	10-20
1.54 Mbps T-1	NR	1-2	50-100	25-50
2 Mbps E-1	NR	1-3	75-150	40-80
6.16 Mbps T-2	1-2	6-12	200-400	100-200
45 Mbps T-3	10-20	50-100	1,500-3,000	700-1500
155 Mbps ATM	30-60	150-300	5,000-10,000	2,500-5,000

3.9 Local Area Network Component Configuration

Local area networks are generally constructed with wiring closets at different locations throughout the building (i.e., closet on each floor) with twisted-pair wiring from the wiring closet to each user desktop. Each user desktop computer is connected to a port on an Ethernet or token-ring hub located in the wiring closet. The hubs within the wiring closets are connected to the computer room over a glass-fiber or twisted-pair copper-wire backbone. The data servers located in the computer room are also connected to the network backbone. Network bandwidth capacity is a function of the computer network interface card and the port on the hub in the wiring closet.

There are two types of basic hubs supporting most network environments. The initial hub technology supported a shared network. This worked fine for sharing data between local area network clients. Distributed client/server processing configurations required much more bandwidth. A new switched hub technology was introduced to support the growing traffic demands.

Figure 3-11
Shared LAN



- **Shared Ethernet Hubs.** A broadcast protocol is used to support Ethernet communications. A standard Ethernet hub provides the backbone for the Ethernet LAN. Each user workstation and the data server is connected to a port in the Ethernet hub.

  When User A communicates with the data server, the communication will broadcast over all LAN segments connected to the shared hub. Any other transmission attempted during this same period will result in a collision, delay for a random period of time, and then retransmit. As more users attempt to broadcast at the same time, collisions increase and the number of transmissions (and resulting collisions) grows exponentially until network traffic is saturated.

  The maximum recommended communication rates for LAN environments are 25- to 35-percent utilization (depending on the total number of users). The probability of any two users initiating a transmission at the same time contributes to the total traffic supported by the network (higher utilization rates can be achieved with fewer users on the network).

  Increasing bandwidth (100 Mbps versus 10 Mbps) can reduce data transport time (faster data transfer) and lower the probability of transmission collisions (each transmission spends less time on the network). A 100BaseT network can handle roughly ten times the number of clients as a 10BaseT network.

- **Switched Ethernet.** An Ethernet switched hub maps each user workstation address to the switch backplane, and transmissions are sent down the user LAN segment only when they are addressed to that user. The Ethernet backplane has a high bandwidth (gigabit range), so multiple transmissions can share access to the backplane, providing higher bandwidth to each user.

  Uplinks to common network locations (central data server or network backbone) should include higher bandwidth. Several users can access the server virtually at the same time due to variation in network capacity. Example: A switched Ethernet network with five 10BaseT segments and one 100BaseT segment (for the data server) can support the cumulative equivalent of 50-Mbps bandwidth to the server.

Some Ethernet switches support single-user segments configured in duplex mode, which allows the segment to send and receive messages at the same time (each using one of the twisted-pair lines). The switch includes a buffer cache, which prevents collisions over the duplex connections. A duplex connection on a 100-Mbps port can provide up to 200-Mbps bandwidth (100 Mbps in each direction). Full duplex connections can support higher transmission loads, since they protect against collisions and retransmissions during peak traffic conditions.

Network technology has improved significantly over the past several years. Many switches today include support for a variety of network functions, including protocol conversion and communication routing. Introduction of switched gigabit Ethernet has enabled many organizations to replace expensive network backbones with switched gigabit Ethernet, with significant cost and performance benefits. Network components are becoming a commodity, with technology improving and costs going down. The Internet technology has significantly expanded the network communication marketplace, encouraging new and faster network technology.

3.10 Web Services Configuration Guidelines

Implementation of ArcIMS Web mapping services places additional demands on the network infrastructure. The amount of system impact is related to the complexity of the published mapping services. Map services with small (less than 10 KB) or a limited number of complex images will have little impact on network traffic. Large images (greater than 100 KB) can have significant impact on network performance.

Figure 3-12 provides an overview of network performance characteristics that should be considered when deploying a Web mapping solution. The top chart shows the maximum number of requests that can be supported over various WAN bandwidths based on average map image size. The bottom chart shows the optimum transmission time for the various size map images. Web information products should be designed to support user performance needs, which may be dominated by available bandwidth. Standard ArcIMS map services should produce images from 30 KB to 50 KB in size, in order to minimize network transport time to standard ArcIMS client browsers (50-KB image requires over 17 seconds of network transport time for 28-Kbps modem clients, limiting site capacity to a maximum of 7,400 requests per hour over a single T-1 Internet Service Provider connection). ArcGIS desktop users may access ArcIMS images from 200 KB to 400 KB in size. Users generally demand reasonable performance, or they will not be satisfied. Proper infrastructure bandwidth and careful map information product design are required to support high-performance Web solutions.

Figure 3-12
ArcIMS Network Performance

Wide Area Network Bandwidth	Peak ArcIMS Requests/Hour (based on Average Image Size)					
	10 KB	30 KB	50 KB	75 KB	100 KB	400 KB
56 Kbps Modem	2,016	672	403	269	202	50
1.54 Mbps T-1	55,440	18,480	11,088	7,392	5,544	1,386
6.16 Mbps T-2	221,760	73,920	44,352	29,568	22,176	5,544
45 Mbps T-3	1,620,000	540,000	324,000	216,000	162,000	40,500
155 Mbps ATM	5,580,000	1,860,000	1,116,000	744,000	558,000	139,500
Note: 1 KB = 10 Kb HTTP traffic						

Wide Area Network Bandwidth	Image Transfer Time (sec) based on Average Image Size					
	10 KB	30 KB	50 KB	75 KB	100 KB	400 KB
19 Kbps Modem	5.3	15.8	26.3	39.5	52.6	210.5
28 Kbps Modem	3.6	10.7	17.9	26.8	35.7	142.9
56 Kbps Modem	1.8	5.4	8.9	13.4	17.9	71.4
256 Kbps	0.4	1.2	2.0	2.9	3.9	15.6
512 Kbps	0.2	0.6	1.0	1.5	2.0	7.8
1.54 Mbps T-1	0.1	0.2	0.3	0.5	0.6	2.6
6.16 Mbps T-2	0.0	0.0	0.1	0.1	0.2	0.6
45 Mbps T-3	0.0	0.0	0.0	0.0	0.0	0.1
155 Mbps ATM	0.0	0.0	0.0	0.0	0.0	0.0

ArcIMS includes an Extract Service that will support data downloads to Web clients over the Internet. The ArcIMS Extract Service extracts data layers from ArcSDE based on identified extent, zips the data into a compressed file, and downloads the data to client. Figure 3-13 identifies minimum download times based on available bandwidth and the size of compressed data packages. Data downloads should be restricted to protect Web site Internet service bandwidth. Data downloads can very easily dominate available bandwidth and impact performance to other Web mapping clients.

Figure 3-13
Data Download Performance

Wide Area Network Bandwidth	Peak FTP Downloads/Hour (based on Average File Size)				
	1 MB	5 MB	10 MB	20 MB	50 MB
56 Kbps Modem	17	3	2	1	0
1.54 Mbps T-1	462	92	46	23	9
6.16 Mbps T-2	1,848	370	185	92	37
45 Mbps T-3	13,500	2,700	1,350	675	270
155 Mbps ATM	46,500	9,300	4,650	2,325	930
Note: 1 KB = 10 Kb FTP traffic					
Wide Area Network Bandwidth	File Transfer Time (sec) based on Average File Size				
	1 MB	5 MB	10 MB	20 MB	50 MB
19 Kbps Modem	526	2,632	5,263	10,526	26,316
28 Kbps Modem	357	1,786	3,571	7,143	17,857
56 Kbps Modem	179	893	1,786	3,571	8,929
128 Kbps	78	391	781	1,563	3,906
256 Kbps	39	195	391	781	1,953
1.54 Mbps T-1	6	32	65	130	325
6.16 Mbps T-2	2	8	16	32	81
45 Mbps T-3	0	1	2	4	11
155 Mbps ATM	0	0	1	1	3

Many network administrators establish and maintain metrics on network utilization, which help them estimate increased network demands when planning for future user deployments. Figure 3-14 provides standard network design planning factors for typical GIS clients, based on their target data source. These numbers will be used in the following chapters to project network bandwidth requirements to support planned GIS user deployments.

Figure 3-14
Network Design Planning Factors

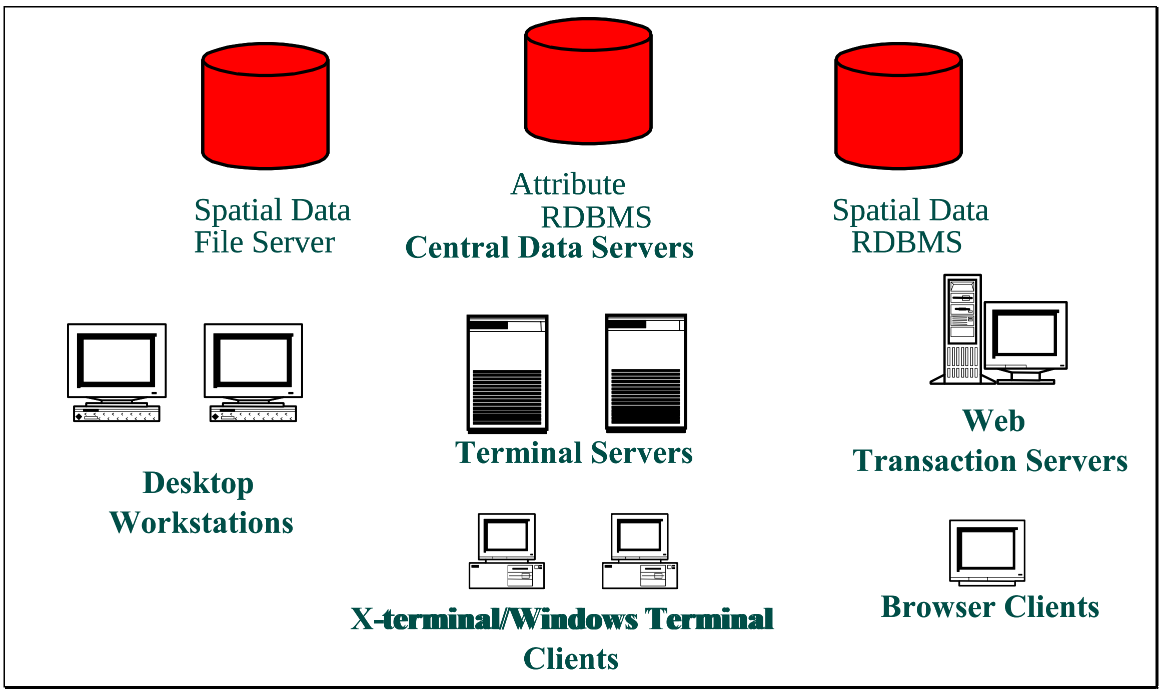
Client Platform	Data per Query		Traffic per query	Bandwidth per user
	KBpq	Compressed KBpq	Kbpq	Kbps
ArcSDE Client	1,000	500	5,000	500
File Server Client	1,000	5,000	50,000	5,000
Terminal Client	100	28	280	28
ArcIMS Browser Client	50	50	500	50
ArcIMS ArcMap client	200	200	2000	200

4 GIS Product Architecture

This section provides a basis for understanding components involved in distributed GIS applications. Understanding basic application architecture, relationships between commercial products and custom applications, and the component interfaces required to support GIS solutions provides a foundation for understanding distributed GIS design principles.

Enterprise-level GIS applications support a variety of users throughout an organization, all requiring access to shared common spatial and attribute data. System hardware and software environments for distributed GIS applications are supported by multi-tier client/server architecture. An overview of this architecture is presented in Figure 4-1.

Figure 4-1
GIS Multi-tier Architecture



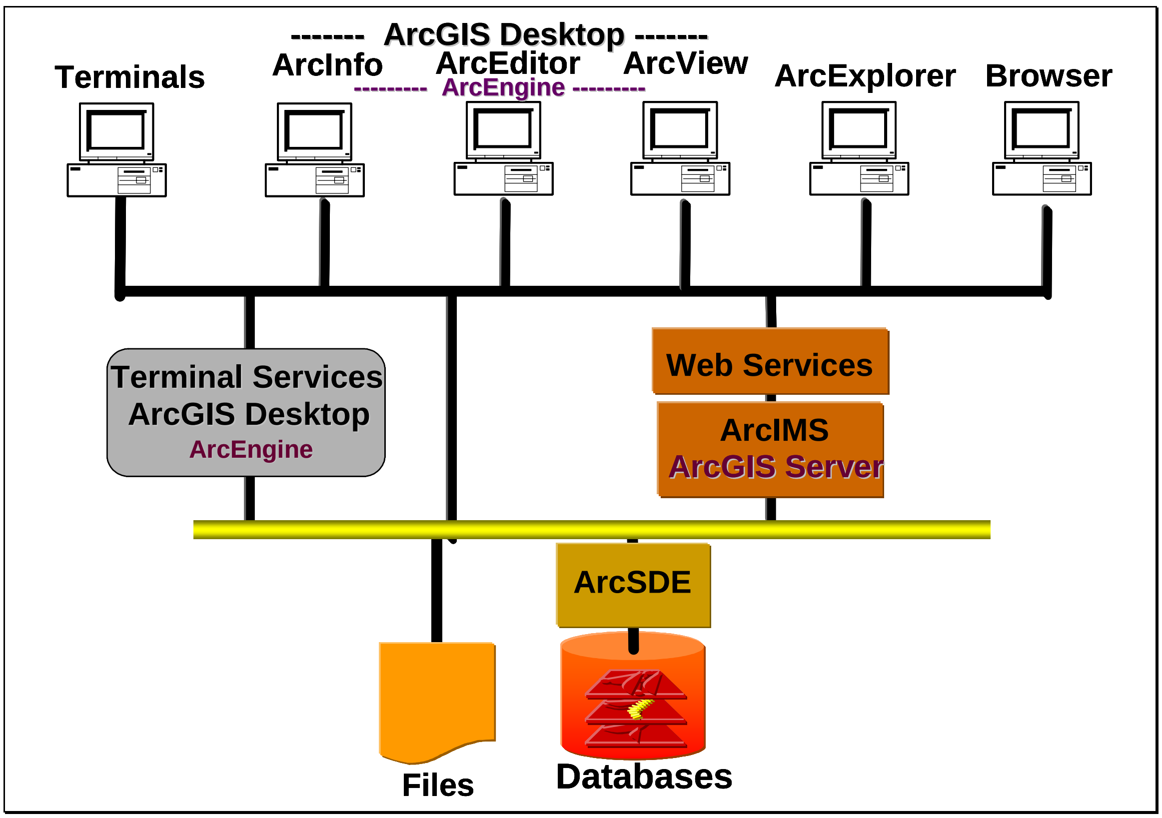
- **Central Data Servers.** Shared spatial and tabular database management systems provide central data repositories for shared geographic data. These database management systems can be located on separate data servers or on the same central server platform.
- **Application Compute Servers.** GIS applications are supported within the distributed configuration by hardware platforms that execute the GIS functions. In a centralized solution, application compute servers can be UNIX or Microsoft Windows platforms that provide host compute services to a number of GIS clients. These platforms include terminal servers and Web transaction servers (map servers). In smaller configurations, the application compute server and central data server may be on the same platform.
- **Desktop Workstations.** Display and control of application processes are provided by desktop workstations which, in many cases, are PCs running X-emulation software,

Windows terminal clients, or Web browser clients. In many GIS solutions, the client application server and desktop user workstation may be the same platform.

4.1 ArcGIS System Software Architecture

ArcGIS is a collective name representing the combined ESRI GIS technology. This technology includes a mix of ArcGIS desktop applications and ArcGIS server-based services. Figure 4-2 provides an overview of the ArcGIS system environment.

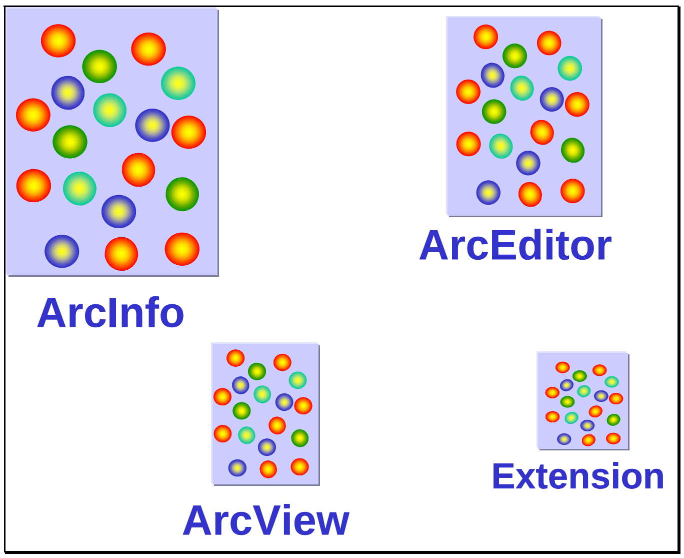
Figure 4-2
ESRI ArcGIS Software



4.2 ArcGIS Desktop Software Architecture

ArcGIS desktop applications include ArcInfo, ArcEditor, and ArcView licensing options. These applications are supported by a common set of ArcObjects developed using COM programming technology. ArcGIS desktop software is supported on the Microsoft Windows operating system. The ArcGIS desktop technology presents an object-oriented user-friendly interface along with a variety of GIS functionality. Figure 4-3 provides an overview of the ArcGIS desktop software.

Figure 4-3
ArcGIS Desktop Software



The ArcGIS 9 release includes two new ArcObjects developer environments (ArcEngine and ArcGIS Server). ArcEngine supports development of lightweight custom desktop applications, while ArcGIS server support development of custom Web geoprocessing services. A complete set of ArcObjects are exposed for each development environment.

An overview of ESRI commercial GIS software is provided in Figure 4-4. These include GIS applications (UNIX and Windows), data management solutions (GIS file server, ArcStorm, and ArcSDE), and remote access client solutions (Windows terminals and browsers).

Figure 4-4
ESRI Software Environments

- **GIS Applications**
  - GIS for UNIX Product Architecture
  - GIS for Windows Product Architecture
- **Data Management Solutions**
  - GIS File Server (coverages, shapefiles, LIBRARIAN, ArcStorm)
  - Spatial Database Engine (client/server data management)
- **Remote Access Client Solutions**
  - Windows Clients with Microsoft Terminal Servers
  - Browser Clients with ArcIMS
  - Browser Clients with ArcGIS Server
  - GIS Desktop applications with AGS Services

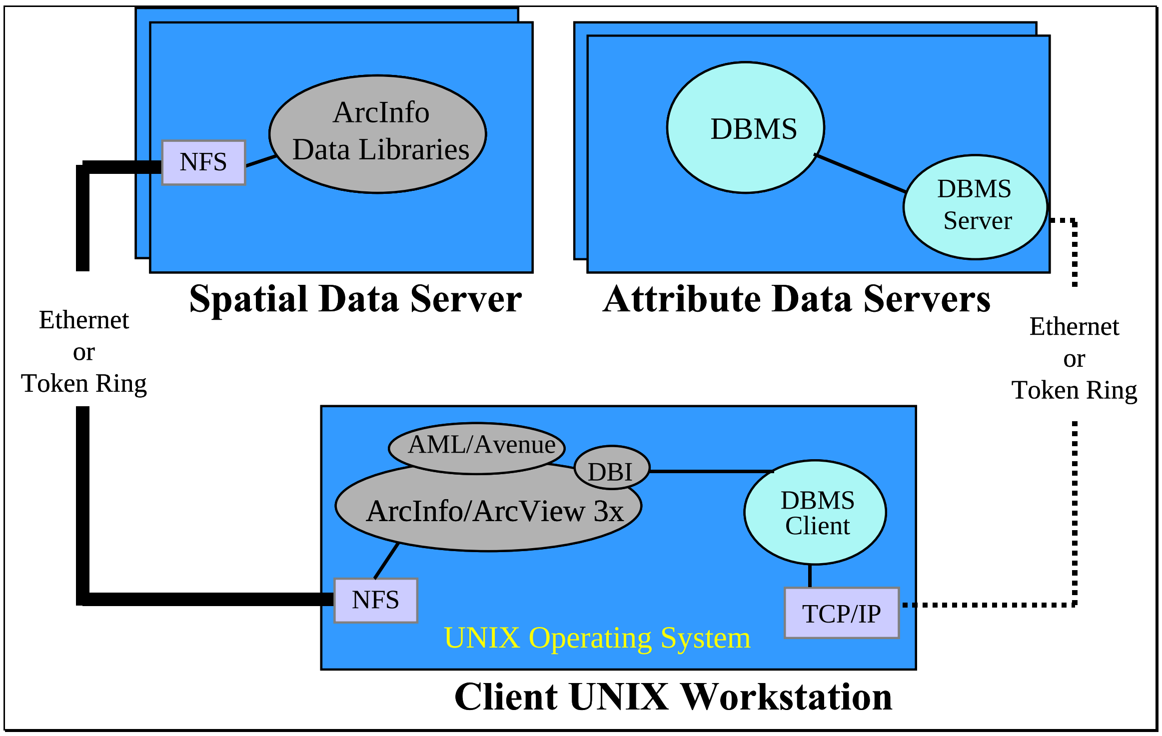
ESRI commercial software performance and associated system interface specifications provide a baseline for system design. Custom GIS application solutions require system resources to support the basic underlying commercial software functions.

GIS applications are supported by an open systems architecture. This architecture combines a variety of closely integrated commercial products to establish a fully supported system solution. Commercial software supports evolving communication interface standards to enable system integration with minimum customization. The importance of selecting well established software solutions cannot be over-emphasized, since all parts of the distributed configuration are critical in supporting overall system performance.

4.3 GIS for UNIX

Primary components supporting distributed ArcInfo for UNIX solutions are identified in Figure 4-5.

Figure 4-5
GIS for UNIX Product Architecture
(UNIX File Server Spatial Data Source)



GIS application functions are executed within the UNIX workstation operating system environment. File-based spatial data management solutions (including spatial coverages, shapefiles, and ArcInfo LIBRARIAN) are supported entirely from the client workstation. The DBMS vendor software operates within the system environment provided by the attribute data server. Network file servers (NFS), provided with the UNIX operating system, mounts files located on the spatial data server to the client workstation, making them appear as if on local disks. Spatial data located on the GIS data server appear as local data to the GIS application.

A Database Integrator module is included with ArcInfo and ArcView GIS that translates communication from the GIS application to the DBMS client module located on the client workstation. DBMS client and server components handle network communication between the client workstation and the DBMS data server using appropriate network communication protocol. ArcInfo AML or other standard programming tools such as Visual Basic, Delphi, PowerBuilder, C, C++, Tcl/Tk, and/or Motif can be used to establish a custom user interface to ArcInfo application environments. Avenue macro language supports customized ArcView application environments.

Communications between GIS workstation applications and spatial data located on a separate file server require a significant amount of network traffic overhead due to the connection-oriented protocol supporting NFS communications. Single-threaded application processes that function in memory on the client workstation execute program calls against the central database. Each line of code must receive a response over the network connection before the next line of code can be executed. Several transmissions are required to locate each source of required data. This type of communication generates lots of extra network traffic.

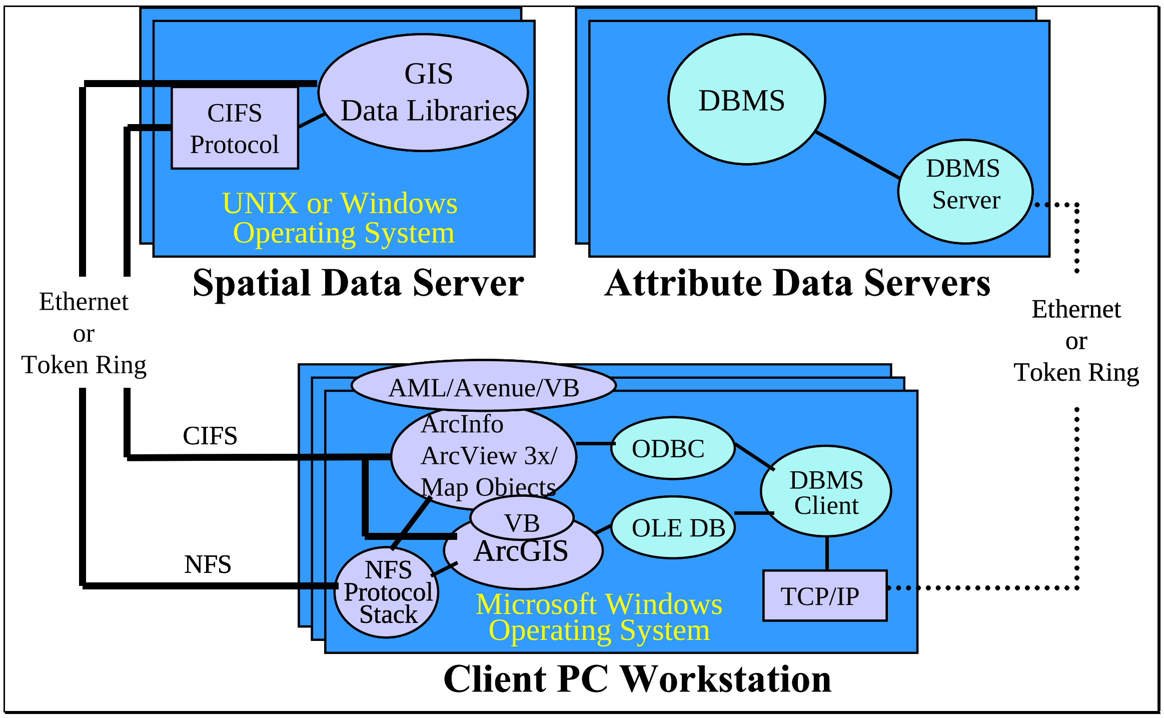
Communication between GIS workstation applications and remote attribute data requires very little network traffic. Queries to the central tabular DBMS are packaged in a single client request and sent as a message to the server for processing. The request is handled by a separate server process, which compiles the answer to the query and sends the response back to the client application for further processing. There are two reasons this is much more efficient than accessing spatial data—one is the use of message-oriented communication protocol (data processing is supported by a local server process); the other reason is the limited size of tabular data files, which are much smaller than spatial graphical files.

All of the ArcInfo functionality represented in the ArcInfo Workstation legacy software has been rewritten and deployed in the ArcGIS desktop software. The modern software takes advantage of object technology to accelerate software development and enhance GIS software functionality. The ArcGIS desktop environment supports a much more friendly user interface and powerful GIS functionality than was possible with the legacy ArcInfo Workstation software.

4.4 GIS for Windows

In 1996, ESRI ported the ArcInfo UNIX workstation application to the Windows platform, positioning ESRI to take advantage of the Microsoft Windows environment and the lower cost of PC hardware. ArcView GIS applications were also deployed on Windows workstations. Critical components supporting distributed GIS for Windows solutions are identified in Figure 4-6.

Figure 4-6
GIS for Windows Product Architecture
(File Server Spatial Data Source)



GIS application executables execute within the operating system environment provided by the Windows platform. Microsoft Common Internet File Services (CIFS) protocols included with Windows operating system support sharing of server disk resources to PC clients. Remote data servers appear as local disk drives to the client Windows workstation, and GIS applications access to spatial data is provided from the client workstation. The GIS Windows applications were developed to an Open Database Connectivity standard (ODBC-compliant) communication interface. The ODBC interface provides access to PC-based attribute data sources including Microsoft SQL Server and Microsoft Access. An ODBC driver must be obtained to complete the interface between GIS applications and each specific attribute database. AMLs developed in the UNIX environment will continue to perform with Workstation ArcInfo for Windows. Avenue scripts supporting custom ArcView GIS UNIX applications are supported by ArcView GIS for Windows software. Software are available to support conversion of UNIX system calls to Windows commands and may be required to support some custom code. ArcGIS desktop clients use an OLE-DB interface to the DBMS client.

Communication between GIS applications and spatial data located on a separate data server (using CIFS protocol) requires network traffic overhead similar to UNIX NFS communications. Accessing remote data sources may take twice as long as accessing the same data on local disk, depending on the data storage technology.

Initially, Windows data servers supported department-level work groups. Server configurations capable of supporting enterprise-level GIS operations were not available. PC vendors (along with Intel) have made significant progress toward supporting enterprise server requirements. Windows multi-processor servers can be configured for up to eight processors. Microsoft provides a cluster fail-over solution for Windows operating systems that supports server failover requirements.

Several solutions are available to support mixed Windows and UNIX environments. Software products are available to enable UNIX platforms to directly share disks to PC clients. Gateway products are available for Novell and Windows servers that support mapping of UNIX server disks to their supported PC work groups. PC client NFS products are available to support mounting of the UNIX server disk. In all these solutions, the server disk is mapped to the client workstation to allow ArcInfo access to the remote server data as if it were on a local PC drive.

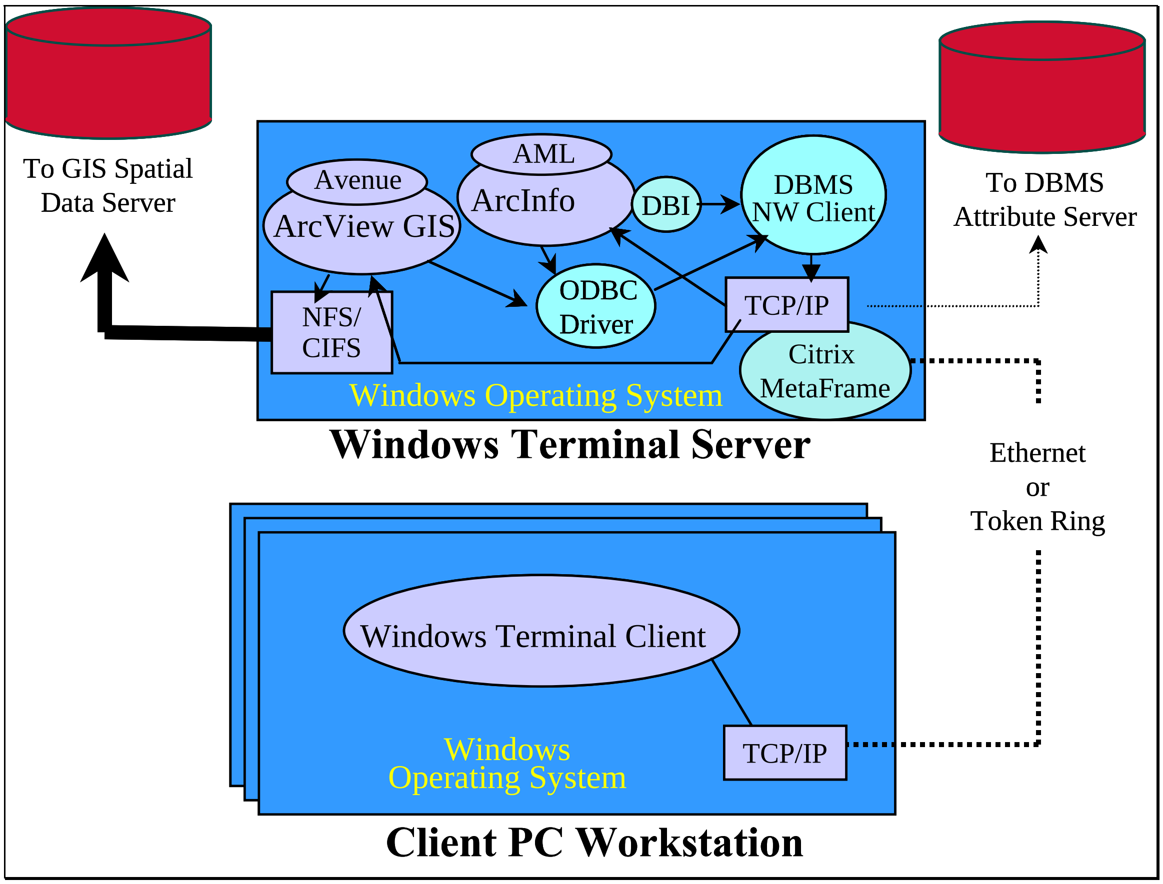
4.5 Microsoft Windows Terminal Server

The Microsoft Windows Terminal Server product establishes a multi-host environment on a Windows server. A Windows Terminal client provides display and control of applications executed on the Windows Terminal Server. Microsoft uses a standard remote desktop protocol (RDP) to support communication between the terminal server and client Windows platforms.

Citrix provides a MetaFrame extension product that provides a more efficient independent computing architecture (ICA) communication protocol to support communications between the terminal server and client Windows platform. The ICA protocol requires less than 28-Kbps bandwidth (rendering vector data information products) to support full Windows display and control of GIS applications supported on a Windows Terminal Server. The MetaFrame product also includes client software for UNIX, Macintosh, and imbedded Web client applications.

Figure 4-7 provides an overview of the Windows Terminal Server communication architecture.

Figure 4-7
Windows Terminal Server Product Architecture

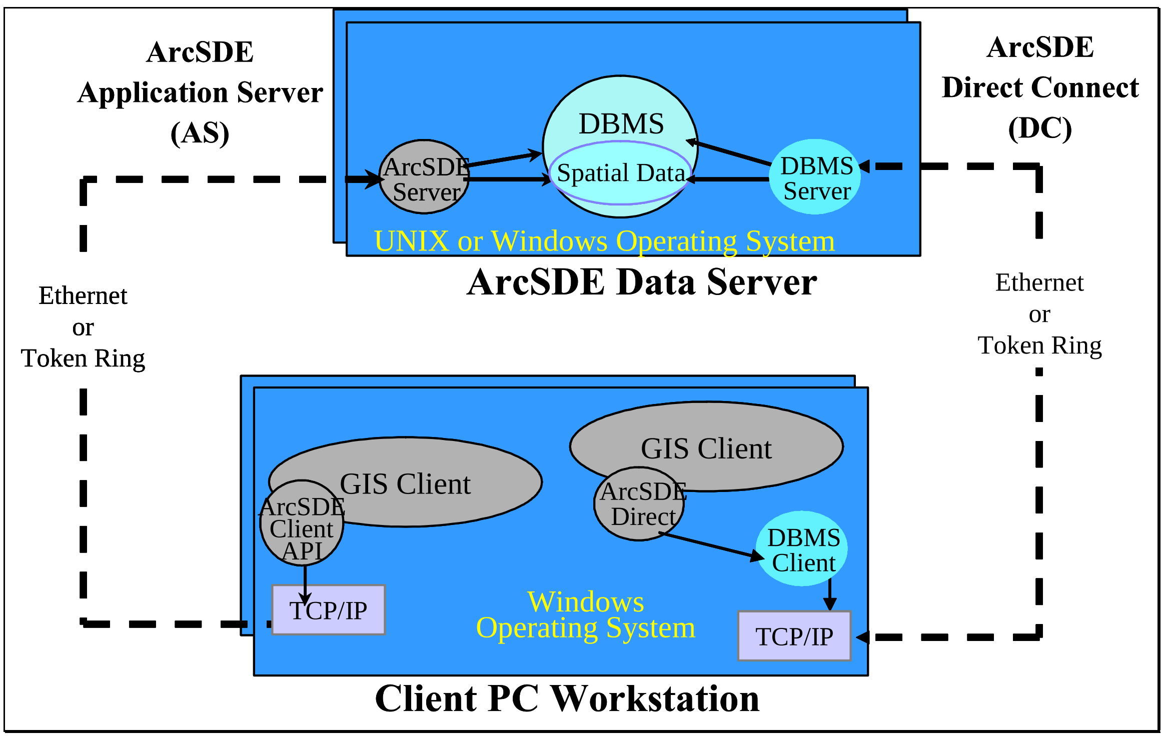


The Windows Terminal client communicates with the Windows Terminal Server through a compressed message-oriented communication protocol. The Windows environment display must be provided over the network to the client workstation, but this requires much less data than that required for spatial data processing by the terminal server or a workstation client. The terminal display traffic requirements are very small, supporting full server application performance over 28-Kbps modem dial-up connections (displays with an image backdrop may require more bandwidth).

4.6 Spatial Database Engine (ArcSDE)

The Spatial Database Engine supports storage of spatial data within standard commercial DBMS applications. Integration of GIS spatial data with the enterprise-level DBMS environment provides a powerful enterprise-level data storage solution for large data stores and/or solutions supporting a high number of GIS clients. A variety of data performance and administration tools are provided with the associated DBMS solutions. Critical components associated with ArcSDE communication architecture are identified in Figure 4-8.

Figure 4-8
ArcSDE Data Server Product Architecture



The ArcSDE solution combines spatial and attribute data into a single GIS database. Query processing is supported by the ArcSDE DBMS server. A transaction request is prepared by the GIS application client and sent to the ArcSDE server for processing. The ArcSDE server process completes the transaction query and returns the response back to the client for processing. There is no requirement in this configuration to map the data server disk to the GIS client. Application processes located on the ArcSDE data server process all spatial and attribute data requests received from the GIS client application.

ArcInfo, ArcView GIS, MapObjects, ArcEngine, ArcIMS and ArcGIS Server applications include ArcSDE client APIs that support direct access to central SDE server data. Also, both ArcSDE and ArcInfo support direct conversion of ArcInfo coverages to ArcSDE layers. An additional ArcSDE CAD client API is available to support storage of MicroStation and AutoCAD data in ArcSDE.

ArcSDE 8 supports the traditional georelational database and a new geodatabase-relational data model. This version also introduces the concept of a versioned database, and supports native data maintenance operations from the desktop ArcInfo 8 platform in the form of a versioned database.

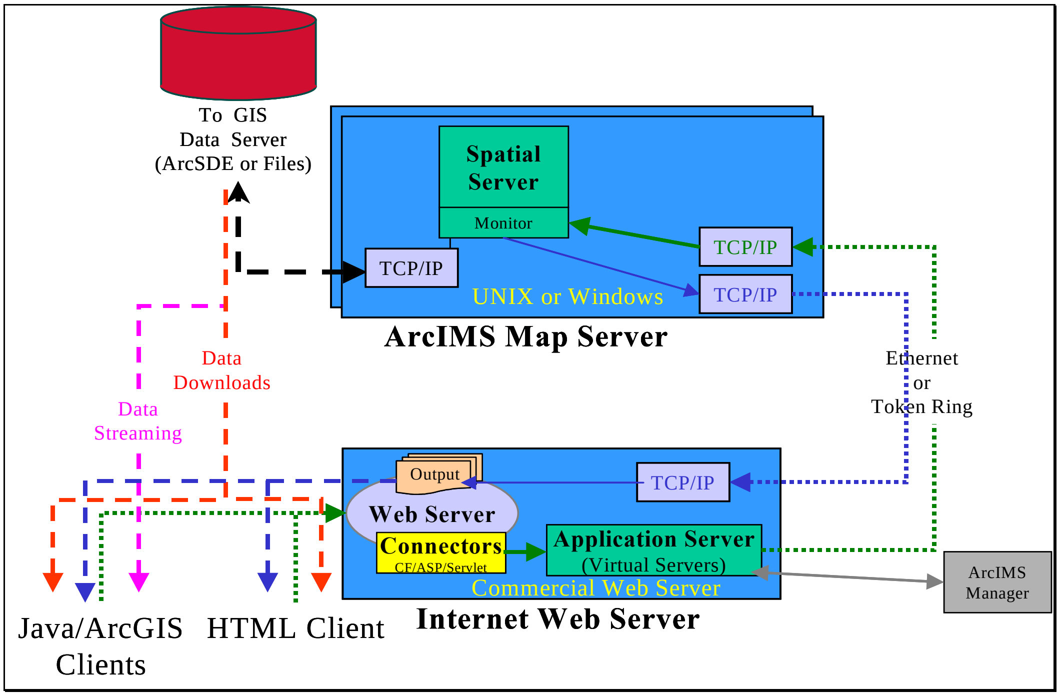
Standard DBMS client/server communications can be used with ArcSDE but are not required for ArcSDE queries. When used, they can provide standard access to attribute data through the DBMS client communication interface.

The ArcGIS 8.1 release includes a direct connect ArcSDE client access option for Microsoft SQL2000 and Oracle database solutions. The ArcSDE Direct option for Oracle will connect to the Oracle network client. The Oracle network client will communicate ArcSDE query calls to the server. The ArcSDE Direct option for SQL2000 will support direct communications to the server. Query processing will be supported by the DBMS functions on the server platform. To upgrade existing ArcSDE client applications, the ArcSDE Direct Connect API is available for download. A mix of direct-connect and ArcSDE server-connect clients can be supported the same geodatabase environment.

4.7 Arc Internet Map Server (ArcIMS)

Arc Internet Map Server (ArcIMS) introduces a modern approach to serving map products over the Internet. ArcIMS has a Java-based application management environment that includes mapping services and map design tools to support a variety of Internet map services. Critical components associated with the ArcIMS communication architecture are identified in Figure 4-9.

Figure 4-9
ArcIMS Web Services Product Architecture

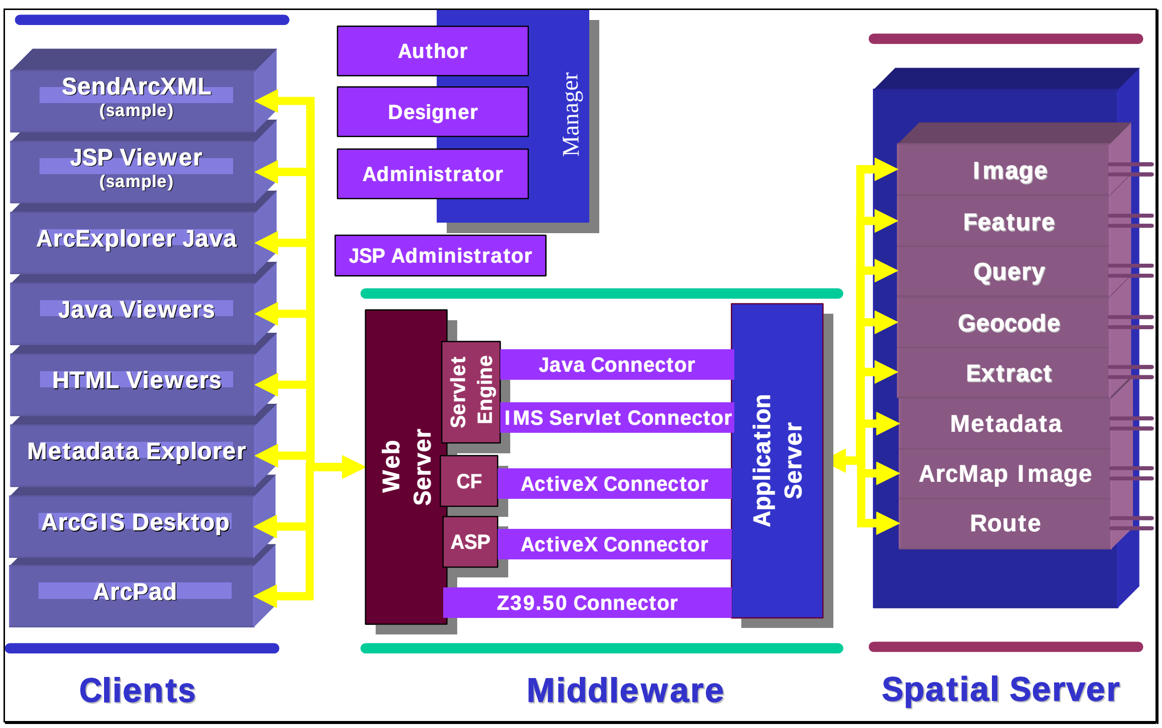


ArcIMS includes a Java Web servlet that supports Web map-publishing services. The standard product includes an ArcIMS manager and map development wizards that support design and authoring of most standard map products without special programming. ArcIMS also includes a Java client that supports standard Web products, data streaming, and data downloads. The Java client also supports integration of local vector data with map images obtained from the Web. ArcIMS Web services can also be used as a data source for ArcGIS desktop clients.

The map server platform supports the primary ArcIMS Web services. Map services are developed by the ArcIMS Manager design and authoring tools producing templates on the application server that manage the map service and performance as a service queue. Additional programming tools (Cold Fusion [CF] and Active Server Pages [ASP]) can be used on the Web server to enhance functionality of thin HTML clients.

Figure 4-10 provides an overview of the ArcIMS 4 component architecture.

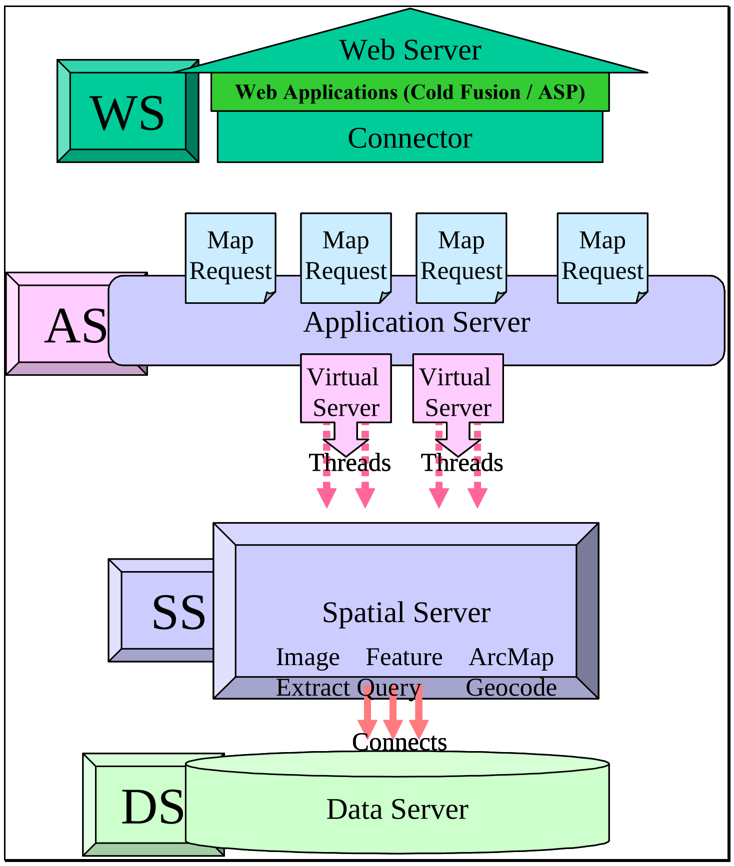
Figure 4-10
ArcIMS 4 Architecture



4.7.1 ArcIMS Platform Configuration Alternatives

There are several ways to configure an ArcIMS site. Figure 4-11 provides an overview of the ArcIMS components and their locations.

Figure 4-11
ArcIMS Component Architecture



The location of the ArcIMS components and their configuration can directly impact the Web site capacity, reliability of the site, and overall output performance. The ArcIMS components can be divided into the following categories.

- **Web Server and Connectors (WS).** The Web server component supports communication between the ArcIMS map services and the Web client applications. The connectors on the Web server translate Web HTTP traffic to communication understood by the ArcIMS Web services. A very limited amount of processing is required to support this server.

- **ArcIMS Application Server (AS).** The ArcIMS application server component provides an application layer that supports the inbound map service request queues (virtual servers) and registered connects to the ArcIMS public service engines (Image, ArcMap, Feature, Extract). Inbound requests are routed to available service instances for processing. Roughly 10 percent of the ArcIMS processing load is required to support the application server functions.

- **Spatial Server (SS).** The ArcIMS spatial server includes the service engines (Image, Feature, Extract, Query, ArcMap Image, Geocode, and Route) that service the map requests. The spatial server also includes a metadata search engine. The spatial server scripts (engines) represent most of the ArcIMS processing requirements. ArcIMS monitor is another term used for spatial server in the ArcIMS documentation.

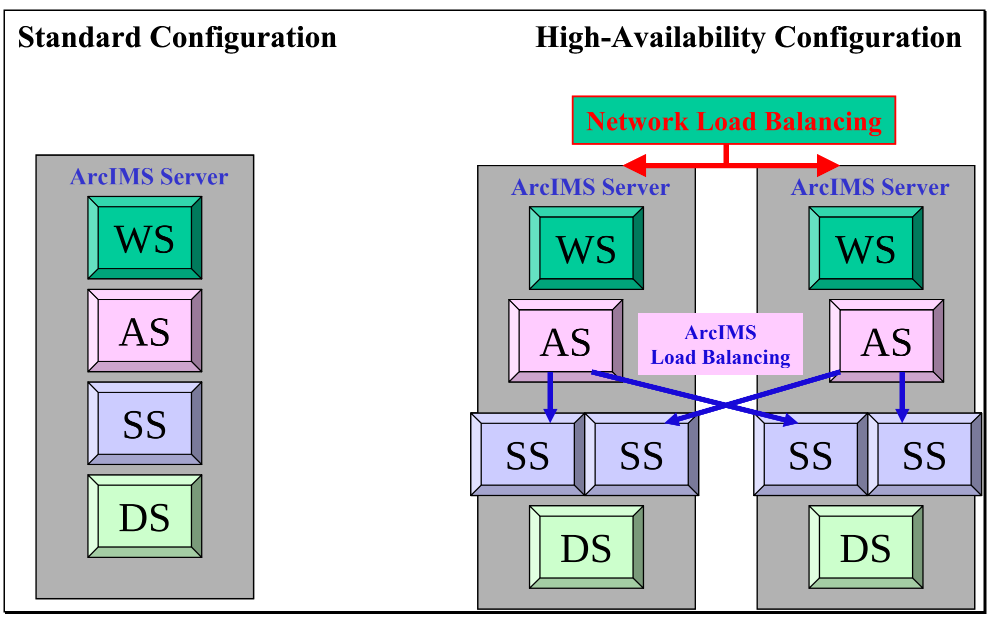
- **Data Server (DS).** The data server (GIS data source) is where the GIS data is stored. An ArcSDE data source supports the query processing functions, roughly 20 percent of typical Web services processing load. Standard GIS image or file data sources are also represented at this level.

A minimum ArcIMS site can be configured with as few as one platform or as many as six platforms, depending on site requirements. Alternatives can be divided into single-tier, two-tier, and three-tier platform configurations. Simple configurations are easier to maintain and support. The more complex configurations support higher capacity sites and higher availability.

4.7.1.1 Single-tier Platform Configuration

Figure 4-12 provides an overview of some example single-tier platform configurations. Single-tier configurations provide one or two platforms capable of supporting all the ArcIMS components. Most initial deployments can be supported by a single-tier architecture.

Figure 4-12
Single-tier Platform Configuration



- **Standard Configuration.** A complete ArcIMS site can be configured on a single hardware platform. This configuration is appropriate for map service development, sites with a limited number of service requests, and initial prototype deployments.

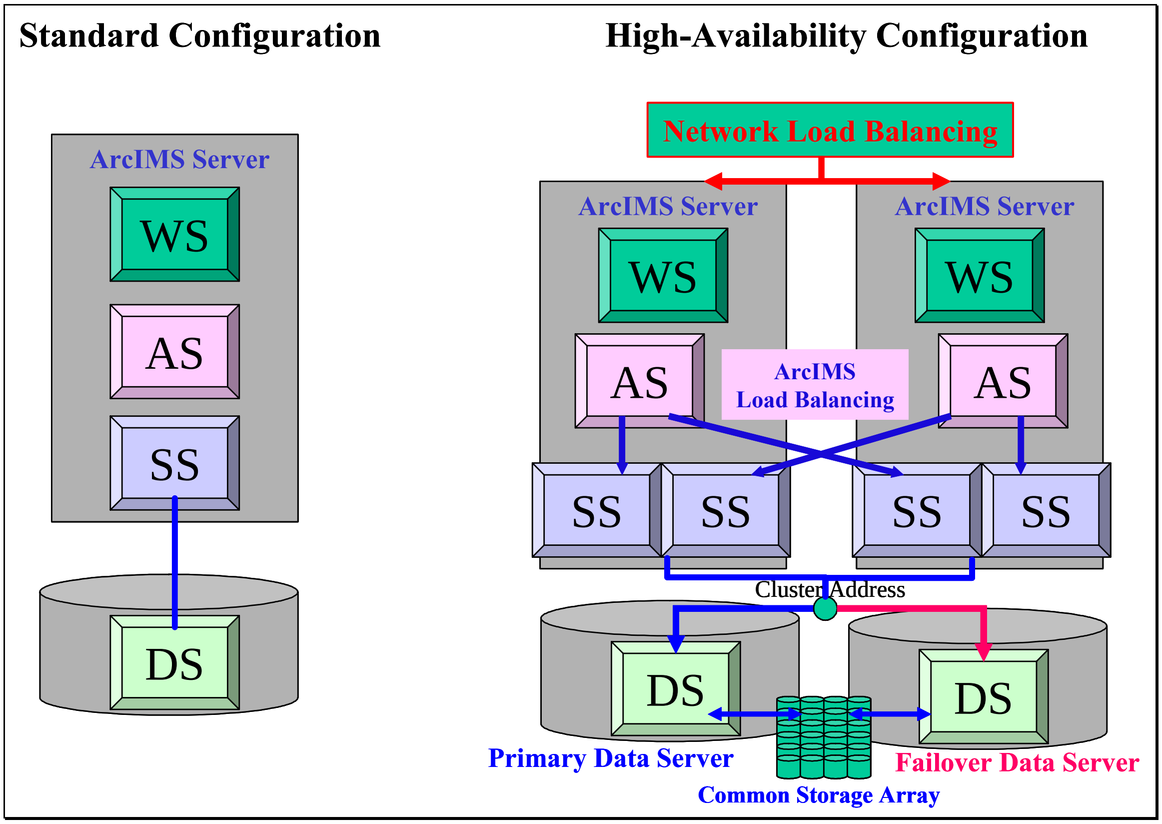
- **High-Availability Configuration.** Most ArcIMS production operations require redundant server solutions, configured so the site remains operational in the event of a single platform failure. This configuration will continue to support production operations during single platform maintenance and upgrade. This configuration includes: (1) network load balancing to route the traffic to each of the servers during normal operations, and only to the active server if one of the servers fails; (2) ArcIMS load balancing to distribute spatial server processing load between the two platforms to avoid having requests backup on one server when extra processing resources are available on the other server; two spatial servers are required on each platform to support this configuration; and (3) each server will require a complete copy of the data.

4.7.1.2 Two-tier Platform Configuration

There are several different options for supporting a two-tier platform architecture. The two-tier options support different ArcIMS components on the two layers of physical platform environments.

The two-tier architecture in Figure 4-13 includes ArcIMS and data server platforms. The Web server and ArcIMS components are located on the ArcIMS platform, and the data server is located on a separate data server platform. This is a popular initial configuration for sites with large volumes of data resources or existing data servers. A single copy of the data can support multiple server components in conjunction with other enterprise GIS data clients.

Figure 4-13
Two-tier Platform Configuration
(separate data servers)

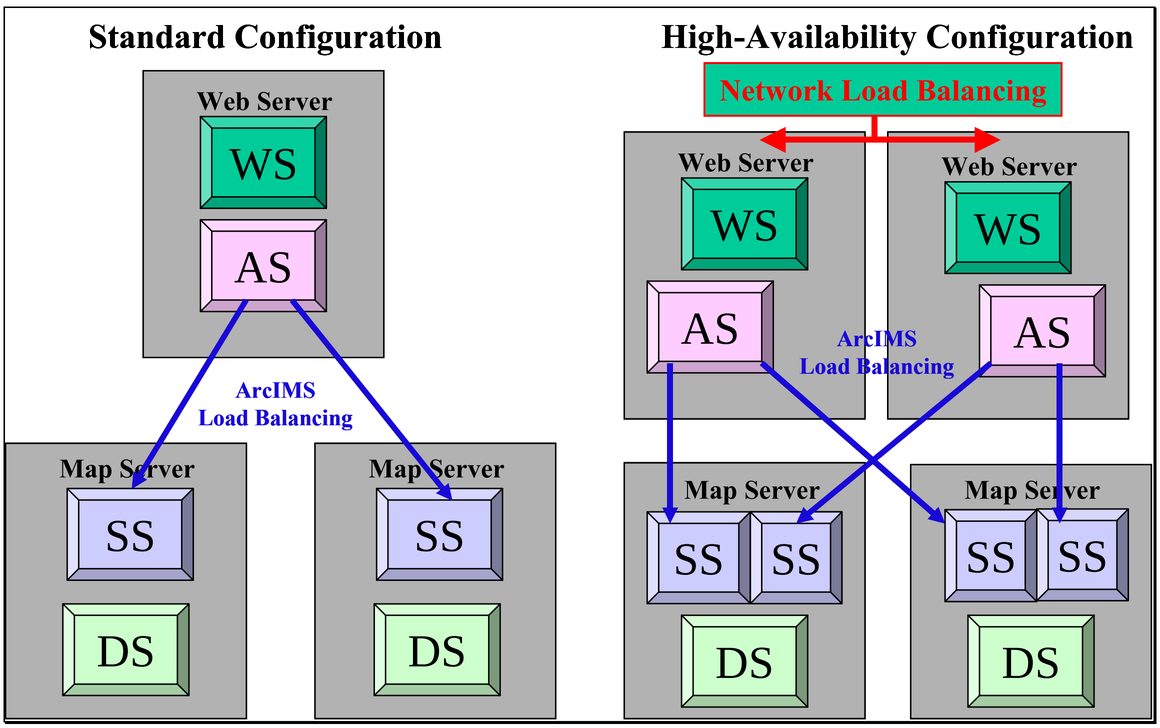


- **Standard Configuration.** The standard configuration includes one or multiple ArcIMS servers with a separate single data server platform. The Web server is installed on the ArcIMS server. The ArcIMS server layer can be a single platform, or can be expanded to support two platforms, depending on the required site capacity. ArcIMS load balancing is provided by the application server.

- **High-Availability Configuration.** High-availability operations require redundant server solutions, configured so the site remains operational in the event of any single platform failure. This configuration includes: (1) network load balancing to route the traffic to each of the Web servers during normal operations, and only to the active Web server if one of the servers fails; (2) ArcIMS load balancing to distribute spatial server processing load between the two ArcIMS server platforms to avoid having requests back-up on one server when extra processing resources are available on the other server; two spatial servers are required on each ArcIMS server platform to support this configuration; and (3) two data servers are clustered and connected to a common storage array data source. The primary data server supports query services during normal operations, and the secondary data server takes over query services when the primary server fails.

The two-tier architecture in Figure 4-14 includes Web server and Map server platforms. The Web and application server components are located on the Web server platform, and the spatial and data server components are located on the map server platform. A separate copy of the data must be provided on each map server to support this configuration. This configuration is only practical for small data sources.

Figure 4-14
Two-tier Platform Configuration
(separate map servers)

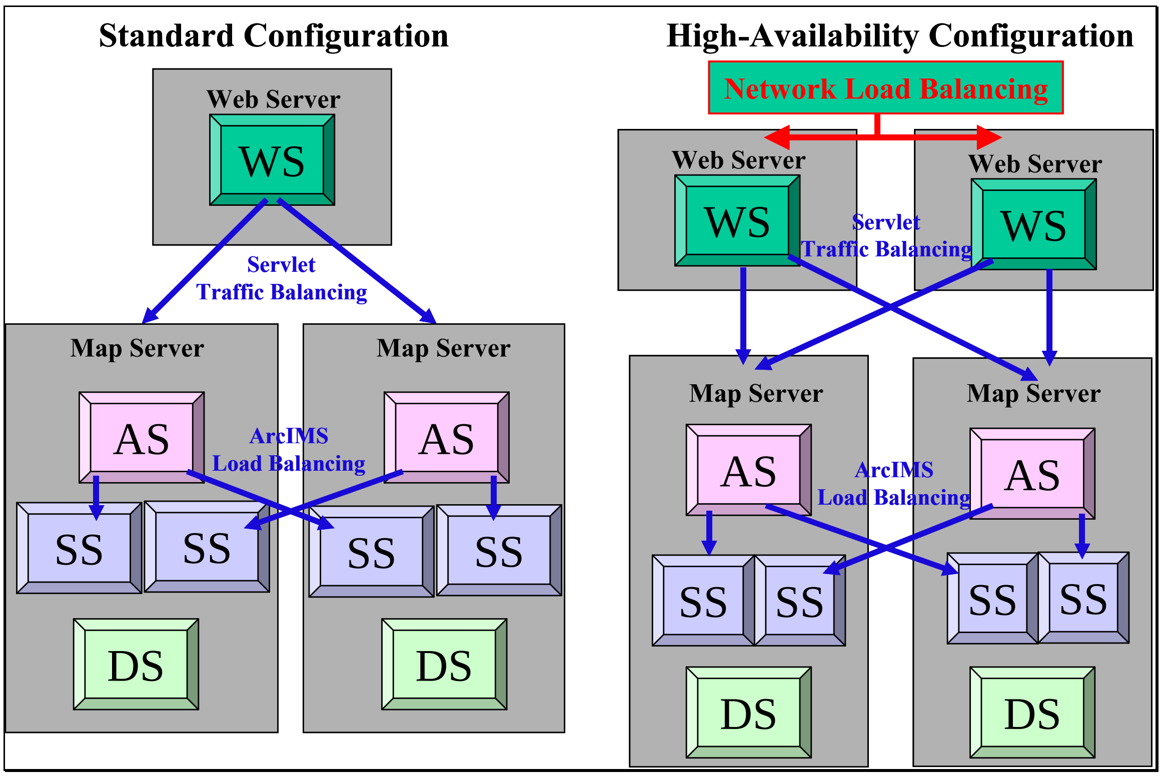


- **Standard Configuration.** The standard configuration includes a single Web server with a separate map server layer. The map server layer can be a single platform, or can be expanded to support several platforms, depending on the required site capacity. ArcIMS load balancing is provided by the ArcIMS application server.

- **High-Availability Configuration.** High-availability operations require redundant server solutions, configured so the site remains operational in the event of any single platform failure. This configuration includes: (1) network load balancing to route the traffic to each of the Web servers during normal operations, and only to the active Web server if one of the servers fails; (2) ArcIMS load balancing to distribute spatial server processing load between the two map server platforms to avoid having requests back-up on one server when extra processing resources are available on the other server; two spatial servers are required on each map server platform to support this configuration; and (3) each map server will require a complete copy of the data.

The two-tier architecture in Figure 4-15 includes Web server and map server platforms. The Web server and ArcIMS connectors are located on the Web server platform, and the ArcIMS application, spatial, and data server components are located on the map server platform. A separate copy of the data must be provided on each map server to support this configuration. This configuration is only practical for small data sources.

Figure 4-15
Two-tier Platform Configuration
(separate Web servers)



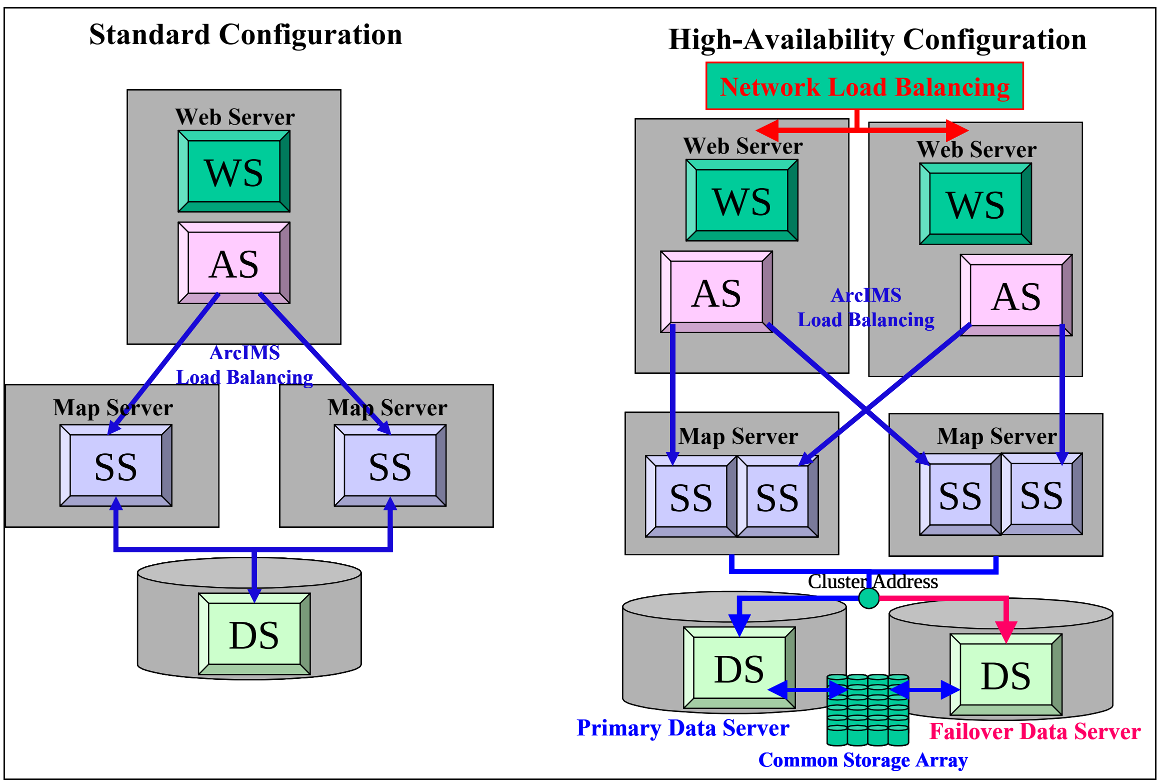
- **Standard Configuration.** The standard configuration includes a single Web server with a separate map server layer. The map server layer can be a single platform, or can be expanded to support several platforms, depending on the required site capacity. Web traffic balancing is supported by the ArcIMS connectors. ArcIMS load balancing is provided by the ArcIMS application server. Multiple spatial servers must be configured on the map servers to support load balancing of multiple platforms. Administration of this architecture becomes increasingly complex as additional map servers are deployed.

- **High-Availability Configuration.** High-availability operations require redundant server solutions, configured so the site remains operational in the event of any single platform failure. This configuration includes: (1) network load balancing to route the traffic to each of the Web servers during normal operations, and only to the active Web server if one of the servers fail; (2) ArcIMS load balancing to distribute spatial server processing load between the two map server platforms to avoid having requests back up on one server when extra processing resources are available on the other server; two spatial servers are required on each map server platform to support this configuration; and (3) each map server will require a complete copy of the data. Administration of this architecture becomes increasingly complex as additional map servers are deployed.

4.7.1.3 Three-tier Platform Configuration

Figure 4-16 provides an overview of some example three-tier platform configurations. The three-tier configuration includes a Web server, a map server, and a data server tier with the application server located on the Web server.

Figure 4-16
Three-tier Platform Configuration



- **Standard Configuration.** The standard three-tier configuration includes a single Web server with a separate map server and data server tier. The map server tier can be a single platform or expanded to support several platforms, depending on the required site capacity. ArcIMS load balancing is provided by the application server. Both map servers use a common data source.

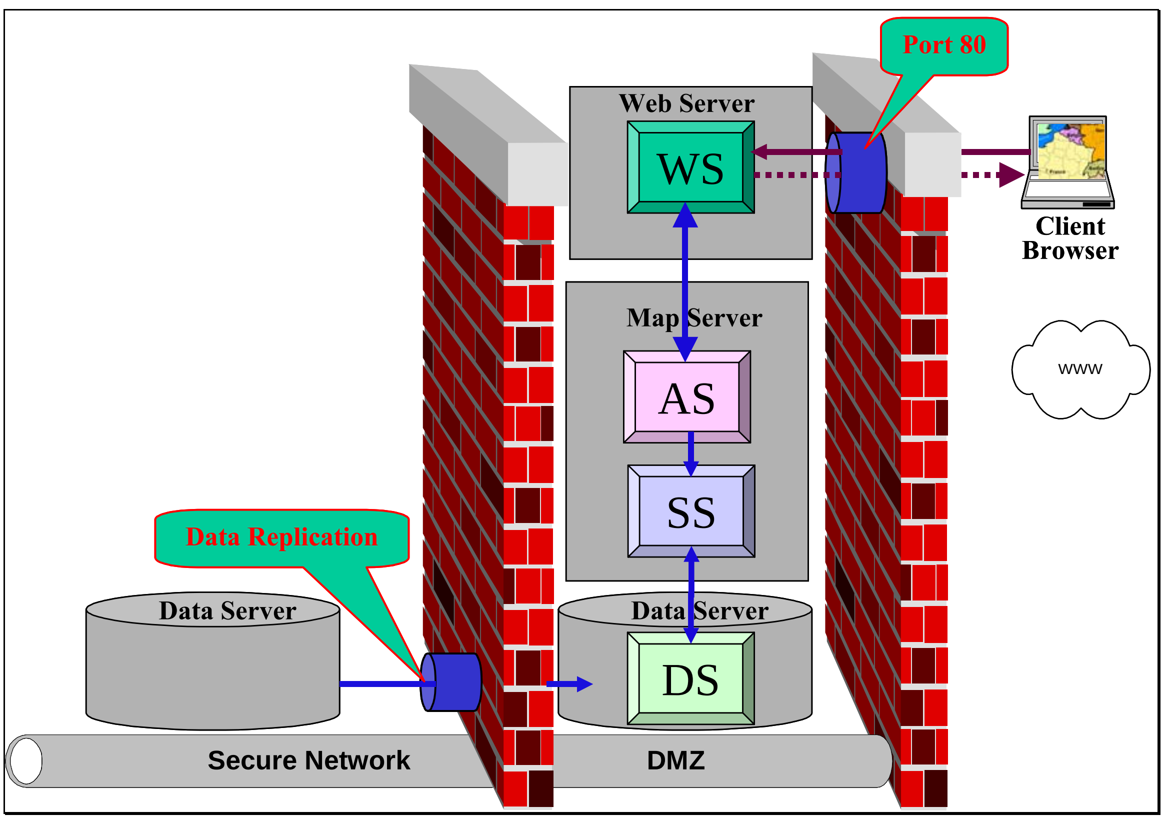
- **High-Availability Configuration.** This configuration includes two Web servers, two map servers, and two data servers. This solution includes: (1) Network load balancing is provided to route the traffic to each of the Web servers during normal operations, and only to the active Web server if one of the servers fail; (2) ArcIMS load balancing distributes the spatial server processing load between the two map server platforms to avoid having requests backup on one server when extra processing resources are available on the other server; two spatial servers are required on each map server platform to support this configuration; and (3) two data servers are clustered and connected to a common storage array data source. The primary data server supports query services during normal operations, and the secondary data server takes over query services when the primary server fails.

4.7.2 ArcIMS Firewall Configuration Alternatives

An ESRI white paper, Security and ArcIMS, addresses configuration options for secure ArcIMS environments. This paper is available on the ESRI Web site at the following URL: http://www.esri.com/library/whitepapers/pdfs/SecurityArcIMS.pdf. Firewall configurations are provided to support various levels of security. A number of security options are identified here, based on the location of the ArcIMS software components.

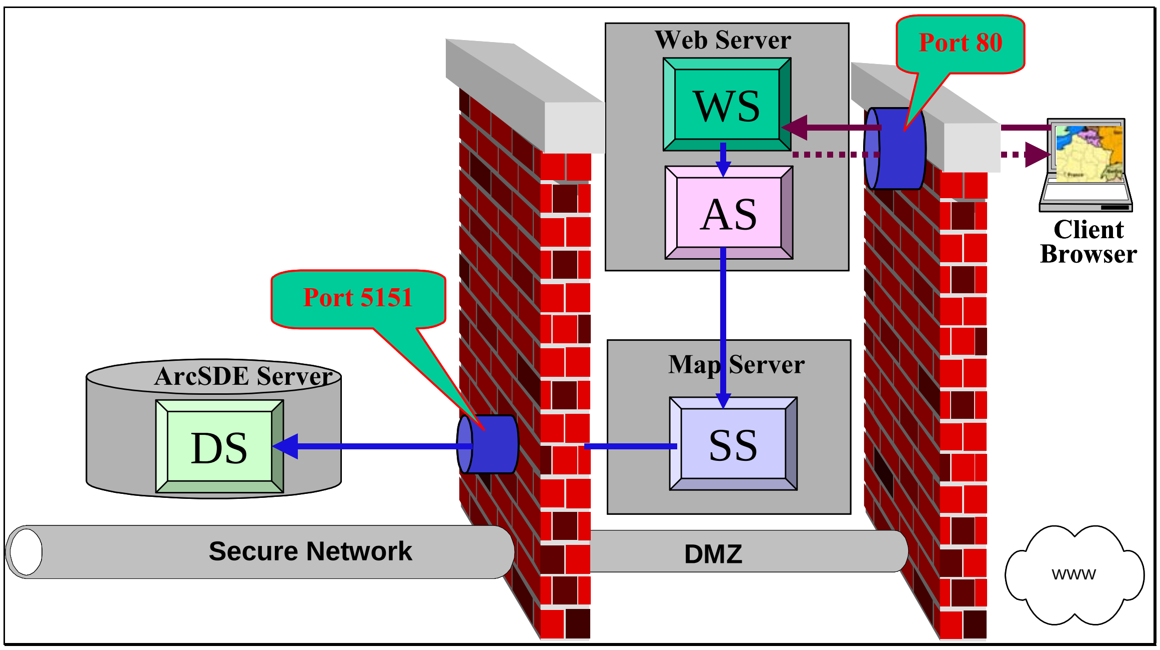
- **All ArcIMS Components in DMZ**. The most secure solution provides physical separation of the secure network from all of the ArcIMS software components. Figure 4-17 shows the Web server, application server, spatial server and data server, are all located outside the secure network firewall within the DMZ. This configuration requires maintenance of duplicate copies of the GIS data. Data must be replicated from the internal GIS data server to the external data server supporting the ArcIMS services.

Figure 4-17
All ArcIMS Components in DMZ



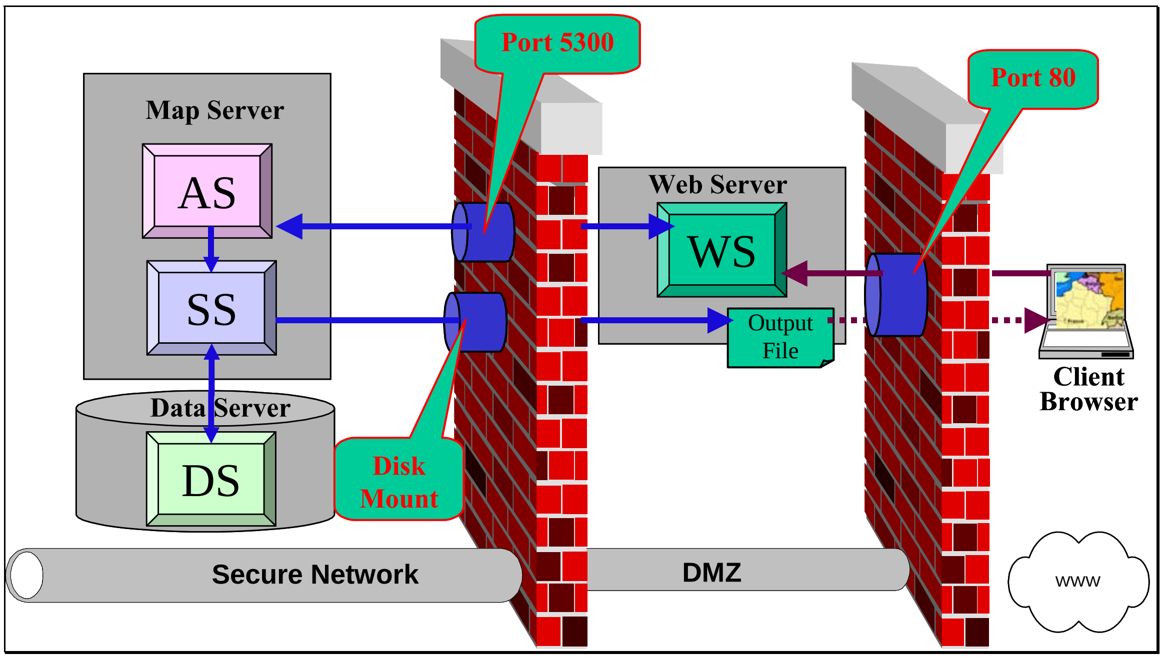
■ **All ArcIMS Components in DMZ except Data Server.** Figure 4-18 shows the Web server, application server, and spatial server located in the DMZ, accessing the internal ArcSDE data server located on the secure network. Port 5151 access through the secure firewall will allow limited access to the ArcSDE DBMS data server. Security is provided through the ArcIMS services and the DBMS security. Firewall prevents traffic from any other source to access the internal secure network.

Figure 4-18
All ArcIMS Components in DMZ except Data Server



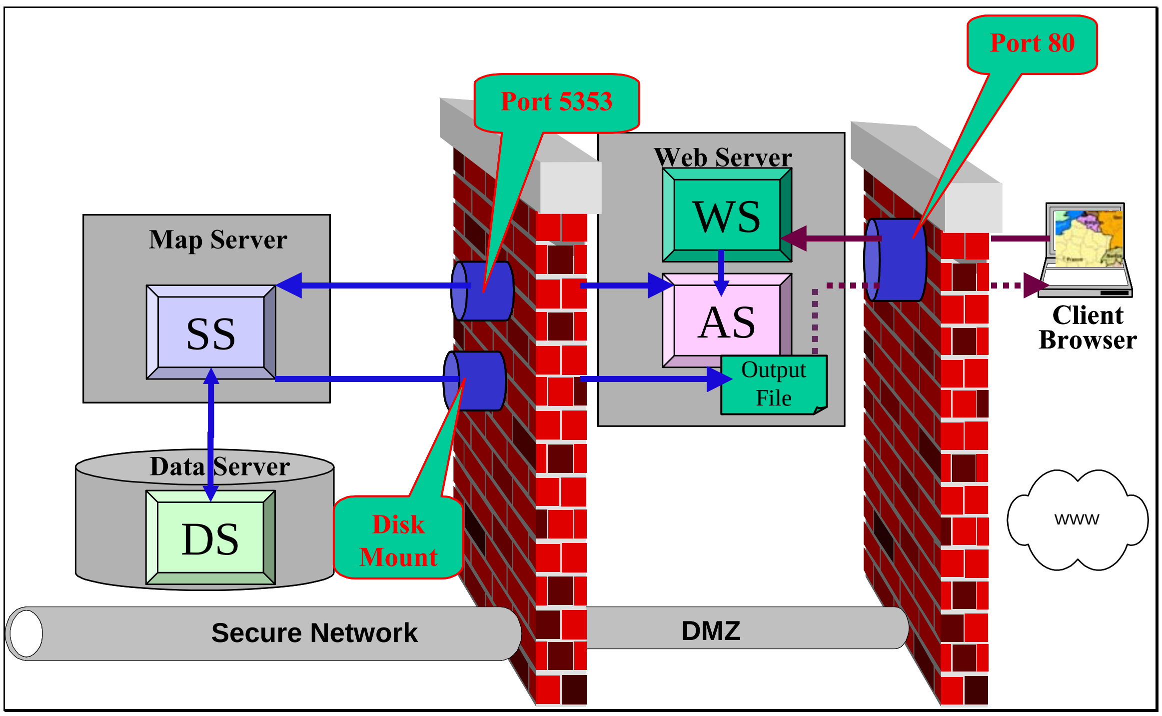
- **Web Server in the DMZ, Remainder of the ArcIMS Components on the Secure Network.** Figure 4-19 shows the Web server located in the DMZ, with the map server and data server located on the secure network. The application server and spatial server must be located on the internal network for this configuration to be acceptable. The output file, located on the Web server, must be shared to the map server. This disk mount will support one-way access from the map server through the firewall to the Web server.

Figure 4-19
Web Server in DMZ, Remainder of Configuration on Secure Network



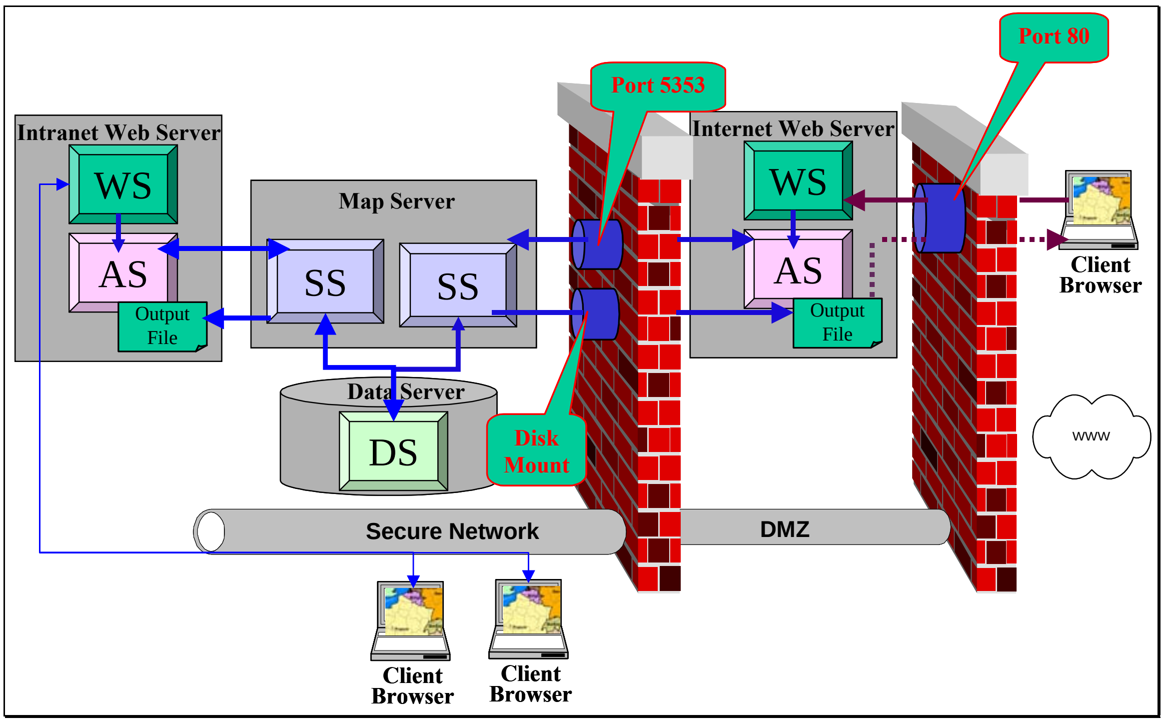
- **Web Server and Application Server in the DMZ, Remainder of the ArcIMS—Components on the Secure Network.** Figure 4-20 shows the Web server and application server located in the DMZ, with the map server and data server located on the secure network. The output file, located on the Web server, must be shared to the map server. This disk mount will support one-way access from the map server through the firewall to the Web server.

Figure 4-20
Web and Application Server in DMZ, Remainder on Secure Network



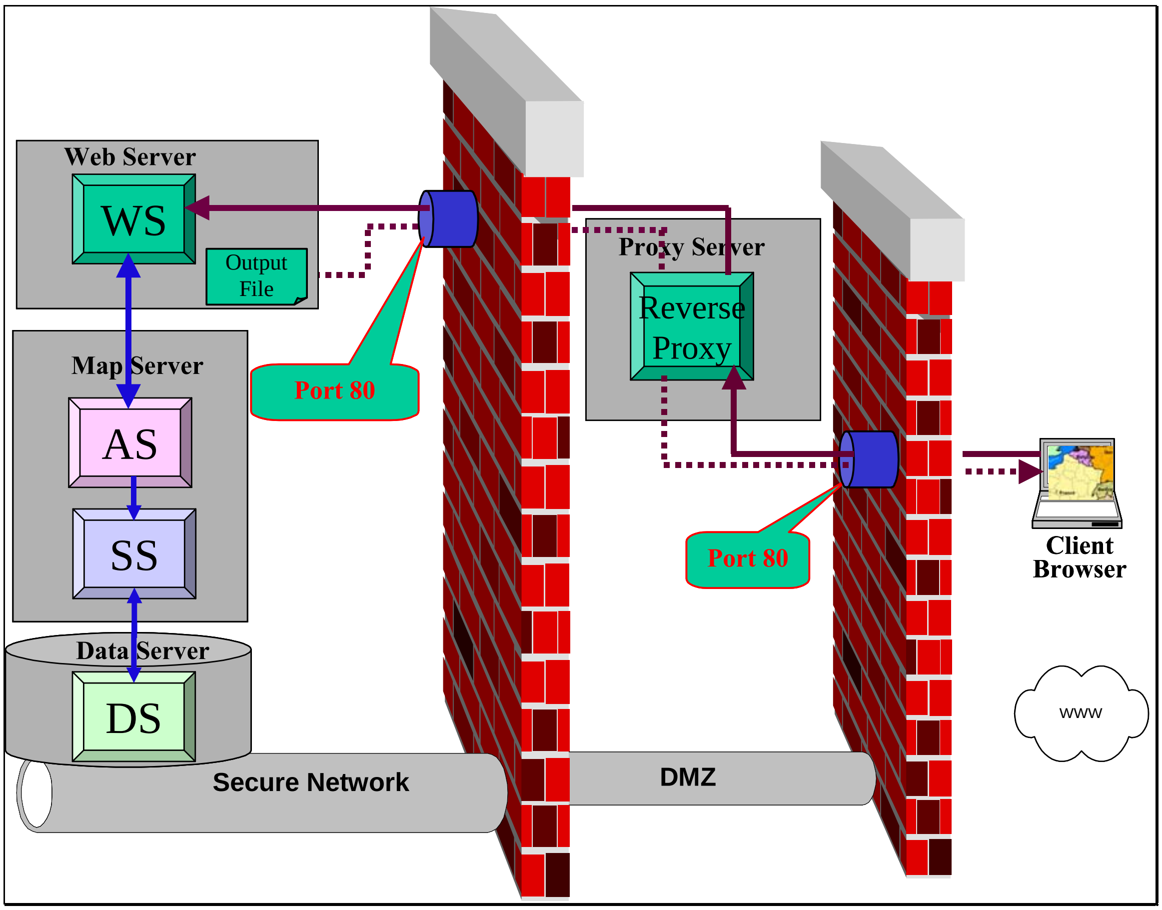
- **Multiple Web Server Configuration.** Figure 4-21 shows a multiple Web server solution, providing separate access security to Intranet and Internet browser clients. This hybrid solution provides shared use of a central map server compute environment while supporting separate user access security requirements. Separate map services can be deployed on the two Web servers, providing secure access to separate user communities from the same ArcIMS site.

Figure 4-21
Multiple Web Server Configuration



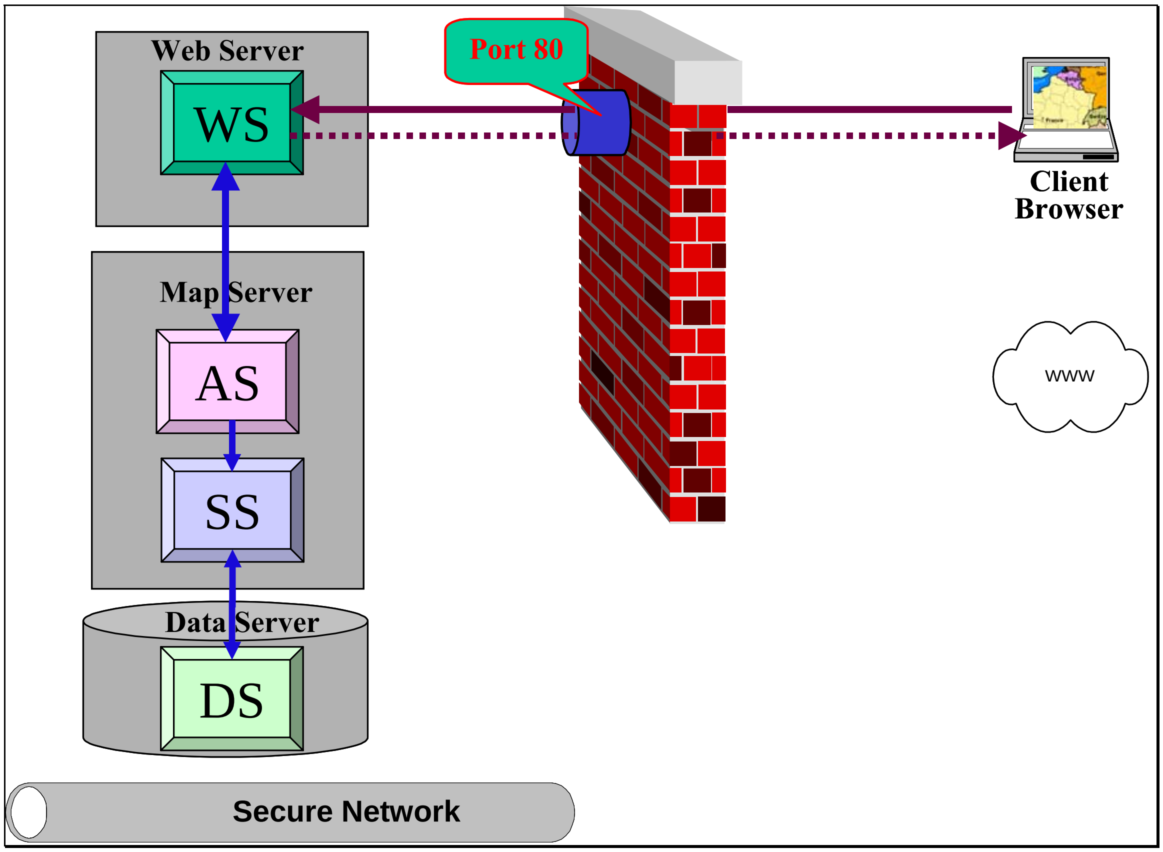
■ **Web Services with Proxy Server.** Figure 4-22 shows interface with intranet Web Server configuration supported by a proxy server. This solution provides private network security through a proxy server, and supports the complete Web configuration on the private network. This configuration enables full management of the Web site on the private network.

Figure 4-22
Web Services with Proxy Server



- **All of the ArcIMS Components on the Secure Network.** Figure 4-23 shows the Web server, map server, and data server components all inside the firewall on the secure network. Port 80 must be open to allow HTTP traffic to pass through the firewall. Many organizations are not comforable with this level of security.

Figure 4-23
All ArcIMS Components on Secure Network



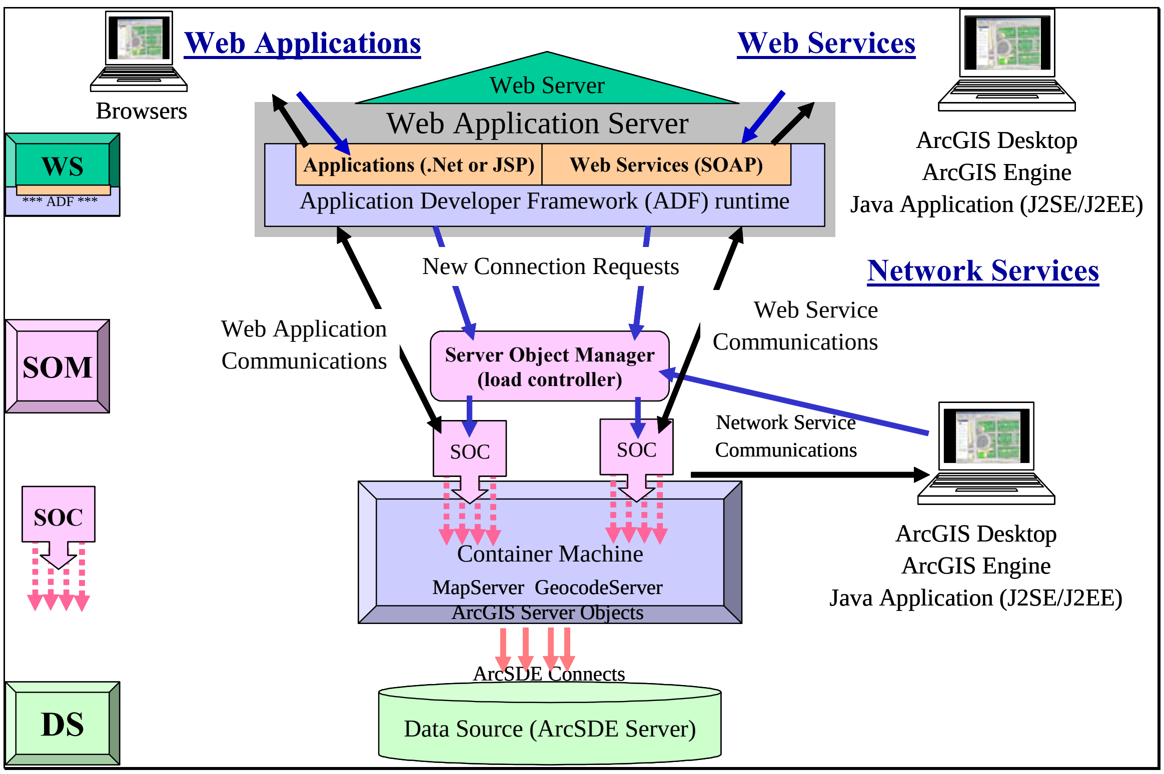
4.8 ArcGIS Server

ArcGIS Server (AGS) provides a standard component server deployment of the full ArcObjects GIS technology. AGS technology was deployed with the ArcGIS 9 release to support a full range of network services to support both Web- and network-based application environments.

4.8.1 ArcGIS Server Architecture

Critical components associated with the AGS communication architecture are identified in Figure 4-24.

Figure 4-24
ArcGIS Server Component Architecture



The ArcGIS Server components include a Server Object Container (SOC), Server Object Manager, and Application Developer Framework. These software components work in conjunction with third party Web Application Server technology to support Web clients. The ArcGIS Server includes an ArcSDE Direct Connect (DC) and Application Server Connect (ASC) integration with supported ArcSDE database environments.

- **Network Services.** The ArcGIS Server can provide services to GIS applications with local network access. The SOM makes the initial SOC assignment, after which the SOC communicates directly with the local application interface to complete the transaction.

- **Web Services.** The ArcGIS Server can provide services to GIS applications with access through the Web server. These services are provided using standard SOAP protocol. The initial connection is provided through a Web services application (Web Services Catalog template is included with the ArcGIS Server software). The SOM provides the Web services application the initial SOC assignment, after which the SOC communicates directly with the Web Services application to complete the transaction.
- **Web Applications.** The ArcGIS Server can provide services to a Web application supporting a standard client browser display with access through the Web server. The Web Applications are developed within the Web application server using standard .NET or J2EE programming environments.

ArcSDE is the ArcGIS Server preferred spatial data source. The ArcSDE database is normally supported on a separate hardware platform for optimum performance.

4.8.2 ArcGIS Server Load Balancing

There are three types of load balancing supported by the ArcGIS Server. Load balancing is provided to establish the SOC instances during SOM startup, on initial application connection to existing SOC instances when supporting a client service transaction, and for instance creation when the number of concurrent service requests exceed deployed service configuration instances.

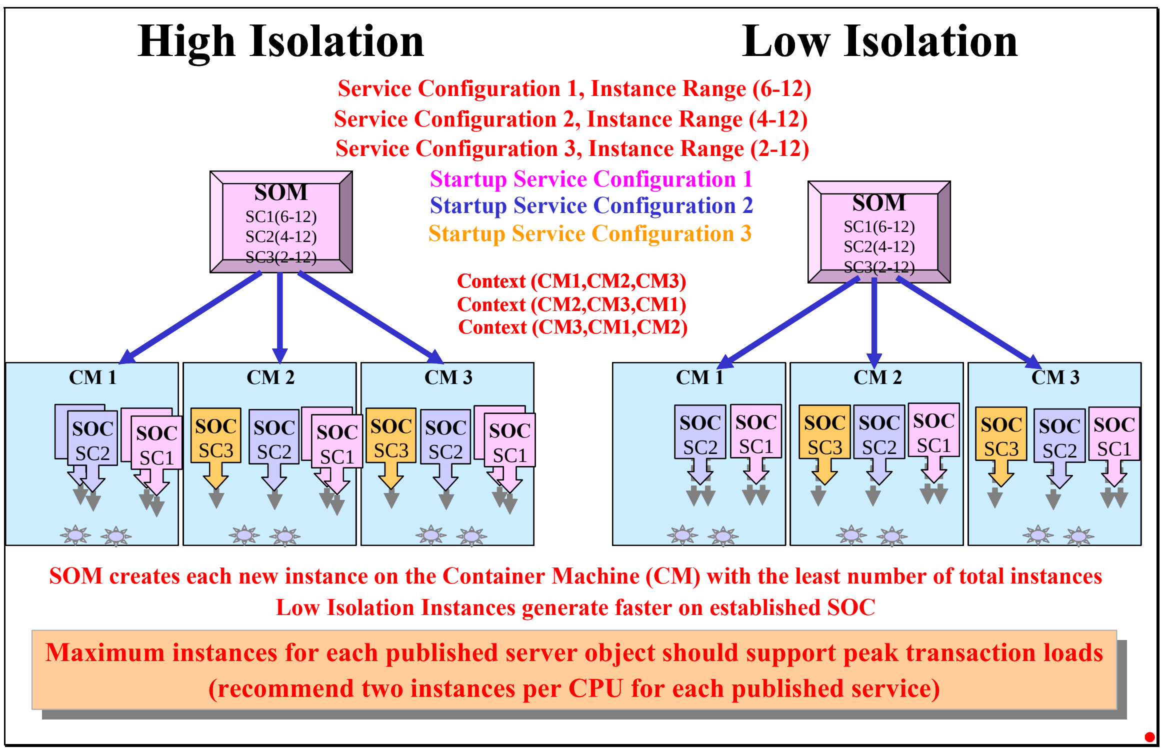
The ArcGIS Server SOM software manages deployment of SOC instances based on ‘service configurations’ established by the system administrator. The SOC instances are deployed on ‘container machines’ (CM) that support AGS server object code execution. The published service configurations specify the range (minimum, maximum) of SOC instances that can be deployed on the available container machines to support anticipated peak service transaction rates. The SOM maintains an ordered list of the deployed container machines (referred to as the CM context) which is used by the load balancing algorithms. The ‘context’ list of container machines is rotated with each SOC instance assignment. Each published service configuration is supported by dedicated SOC instances created during SOM startup or during instance creation.

The SOC executables are multi-threaded, and are configured to support from one to four concurrent SOC instances. Each service configuration will specify whether the SOC instances should be deployed as a ‘high isolation’ or ‘low isolation’ environment. High isolation environments support one instance per SOC executable, while low isolation environments support up to four instances per SOC executable.

SOM Startup. The initial ArcGIS Server configuration is established during SOM startup. The SOM assigns the first SOC instance to the first CM provided on the context list, the following instance is assigned to the next machine in the context list, and so on until the minimum number of SOC instances identified in the published service configuration are deployed. The SOM startup is complete once SOC instances for all published service configurations are deployed in a balanced configuration across the available container machines, based on the minimum specified for each service configuration instance range.

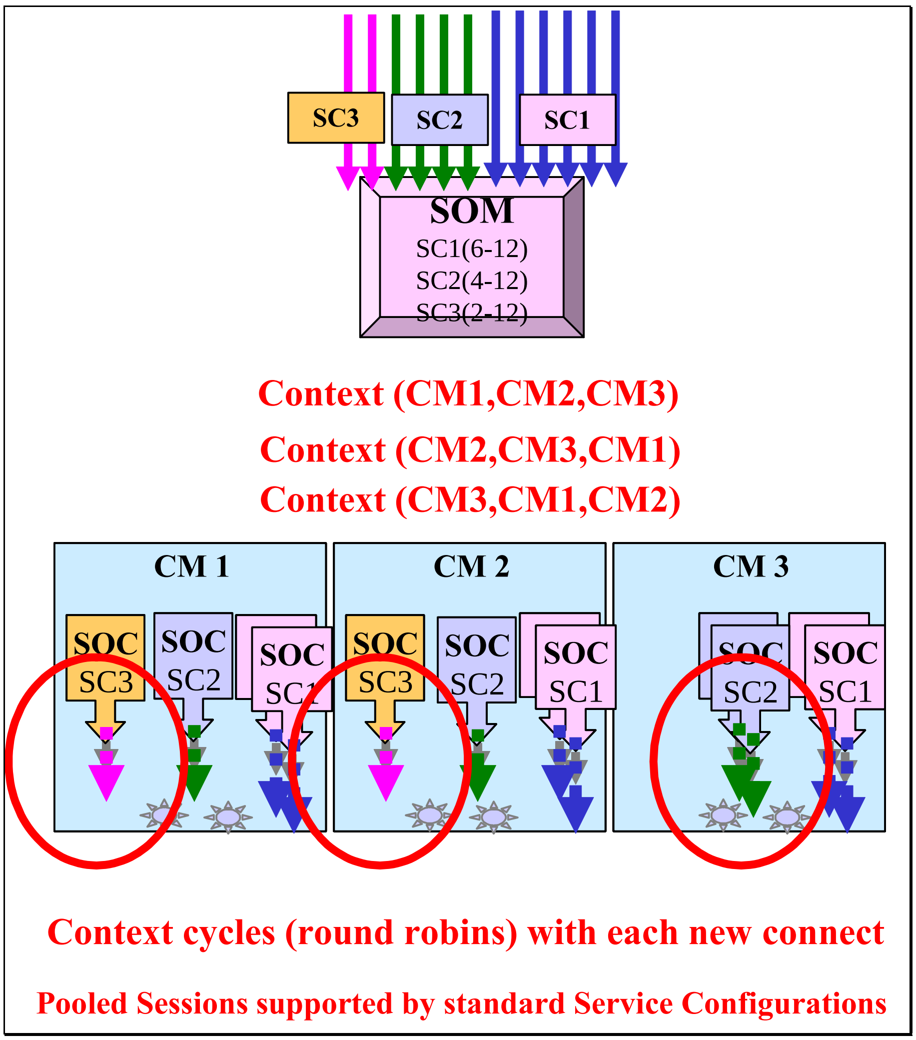
The resulting ArcGIS Server startup configuration is provided in Figure 4-25, based on three published service configurations each with different specified minimum instance range.

Figure 4-25
ArcGIS Service Startup



SOM Instance Assignment. Instance assignment load balancing is performed by the SOM on initial application connection. The SOM assigns each inbound service request to the first available service configuration SOC instance, based on the current CM context. If a required service configuration instance is not available on the first CM in the current context, assignment will move to the next CM in the context list until an available instance is found. The context is rotated one machine following each instance assignment. An example of instance assignment load balancing is provided in Figure 4-26.

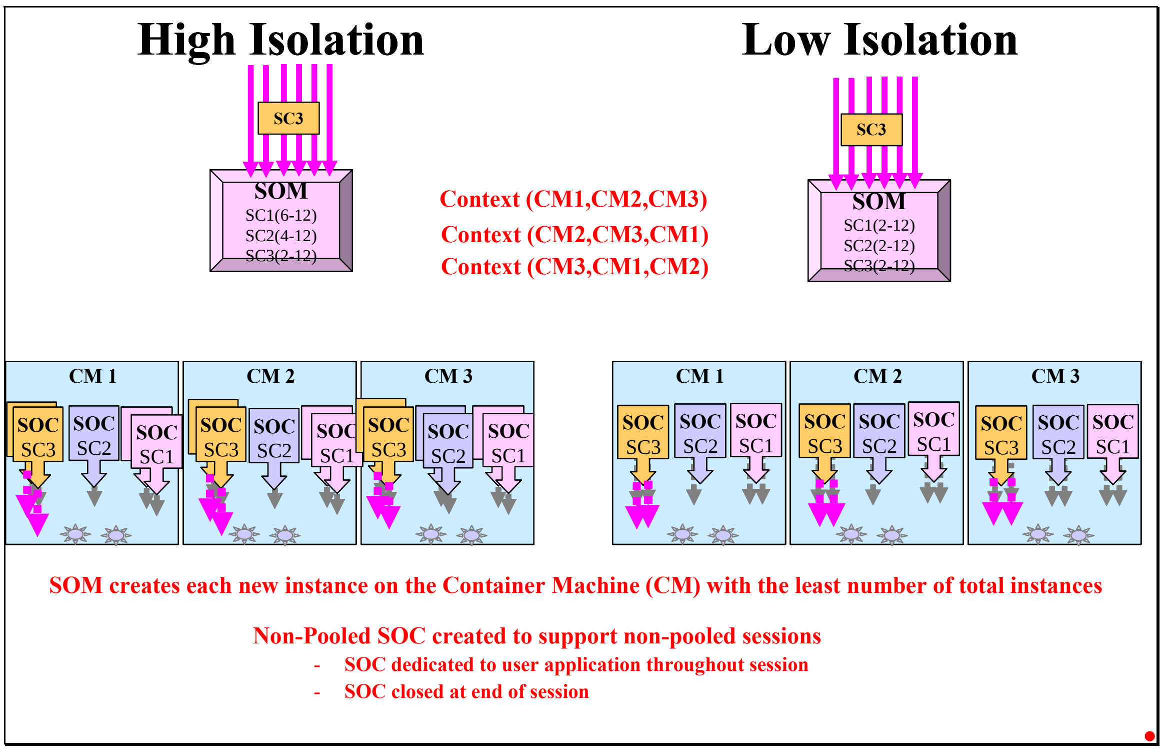
Figure 4-26
ArcGIS Server Instance Assignment Load Balancing



All created instances are active as long as the SOM that created the instance is alive.

SOM Instance Creation. Instance creation load balancing is performed by the SOM when the total number of concurrent service connections exceed the number of deployed SOC instances for the requested service configuration. The SOM deploys an additional SOC instance for the requested service configuration on the CM with the least number of existing SOM instances. If the same number of instances was already assigned to each CM, the SOM would deploy the new SOM instance based on the current CM context. SOM instances can be created up to the maximum service configuration instance range. Concurrent service requests exceeding the maximum instance range will be held by the SOM in a service queue awaiting the next available SOM instance. All created instances are retained as long as the SOM is alive, and will end if the SOM connection is lost. The context is rotated by one machine following each instance creation or assignment. An example of instance creation load balancing is provided in Figure 4-27.

Figure 4-27
ArcGIS Server Instance Creation Load Balancing



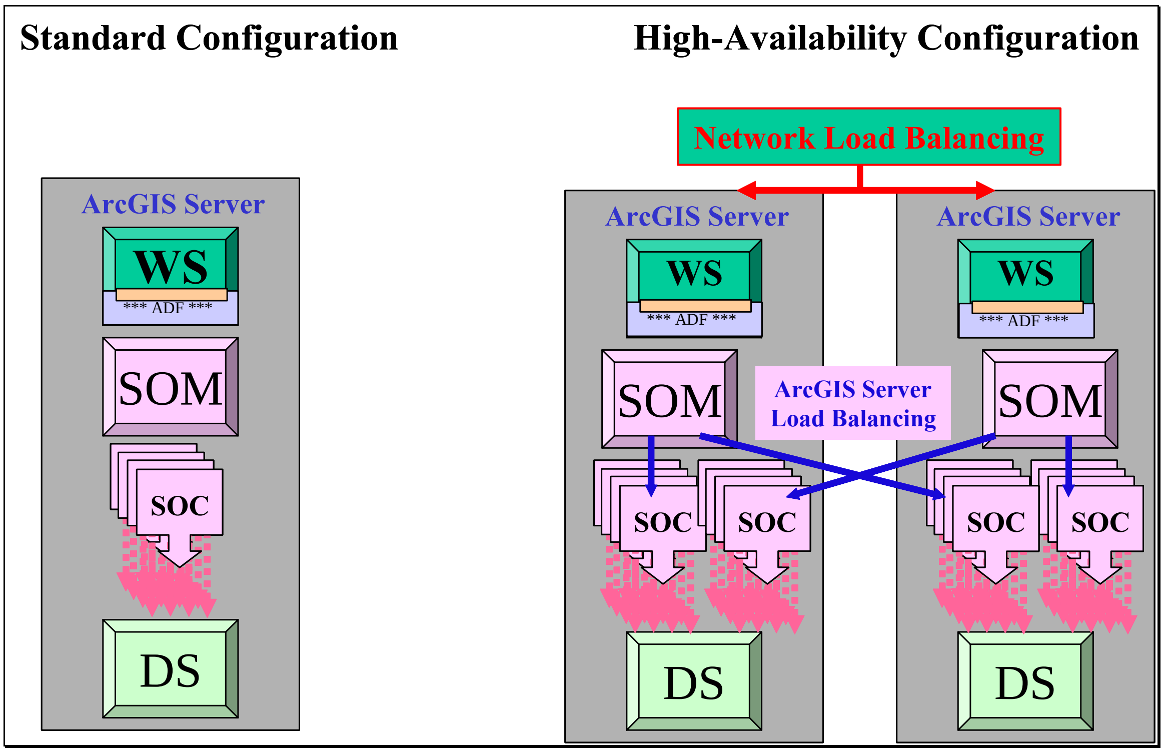
ArcGIS server supports both pooled and non-pooled user sessions. Pooled sessions are supported by deployed SOC instances and all state changes are maintained at the application level.

Non-pooled user sessions are supported by dedicated SOC instances, and are required for all applications that may generate state changes within the assigned SOC instance. Instance creation load balancing is used to establish a non-pooled user session. The non-pooled SOC instance ends once the user session is closed.

4.8.2.1 ArcGIS Server Single-tier Platform Configuration

Figure 4-28 provides an overview of some example single-tier platform configurations. Single-tier configurations provide one or two platforms capable of supporting all ArcGIS Server components. Most prototype deployments can be supported by a single-tier architecture.

Figure 4-28
ArcGIS Server Single-tier Platform Configuration



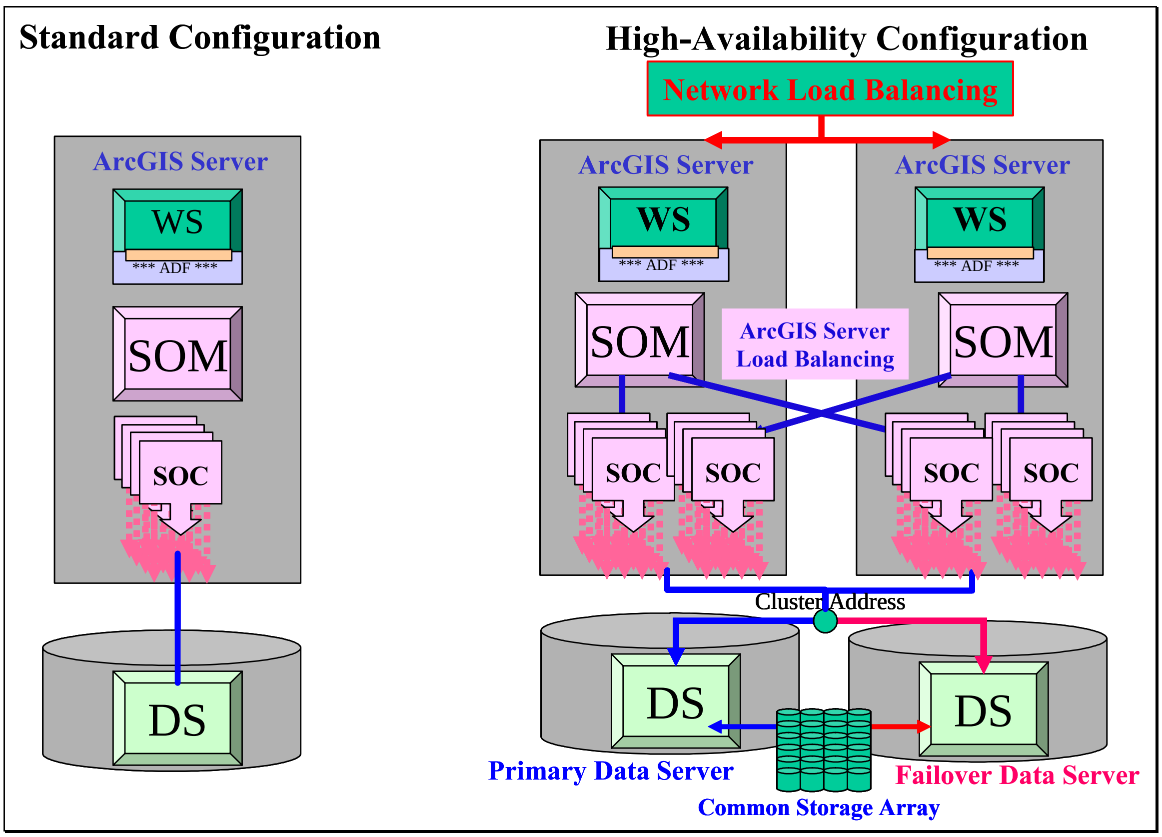
- **Standard Configuration.** A complete ArcGIS Server site can be configured on a single hardware platform. This configuration is appropriate for initial ArcGIS Server application development, sites with a limited number of service requests, and initial prototype deployments.

- **High-Availability Configuration.** Most ArcGIS Server production operations require redundant server environments, configured so the site remains operational in the event of a single platform failure. This configuration will continue to support production operations during single platform maintenance and upgrade. This configuration includes: (1) network load balancing to route the traffic to each of the servers during normal operations, and only to the active server if one of the servers fails; (2) mirrored AGS SOM configurations each load balancing to distribute SOC processing load between the two platforms and continue support in the event of one server failure; and (3) each server will require a complete copy of the data.

4.8.2.2 ArcGIS Server Two-tier Platform Configuration

The two-tier architecture in Figure 4-29 includes ArcGIS Server and data server platforms. The Web application server and AGS components are located on the ArcGIS Server container machine, and the data server is located on a separate data server platform. This is the most common configuration for small to medium sites with an ArcSDE database or existing data servers. A single copy of the data can support multiple AGS container machines in conjunction with other enterprise GIS data clients.

Figure 4-29
ArcGIS Server Two-tier Platform Configuration
(separate data servers)



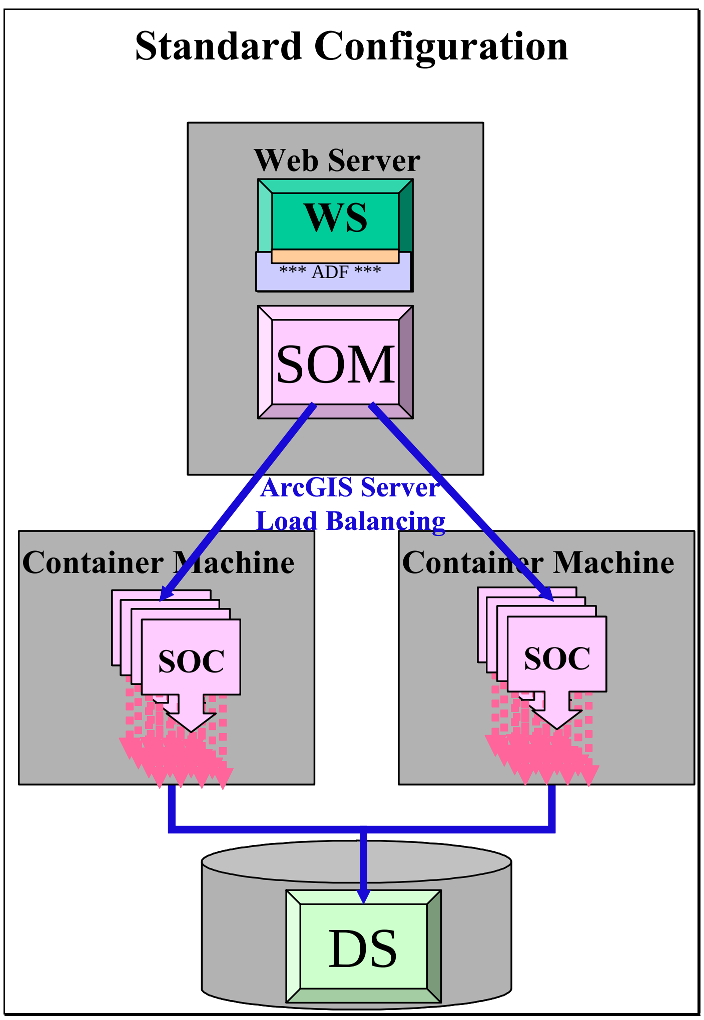
- **Standard Configuration.** The standard configuration includes one or multiple ArcGIS Server container machines with a separate single ArcSDE data server platform. The Web application server is installed on the ArcGIS Server container machine. The ArcGIS Server layer can be a single container machine, or can be expanded to support two container machines, depending on the required site capacity. ArcGIS Server load balancing is supported by a mirrored AGS SOM configuration.

- **High-Availability Configuration.** High-availability operations require redundant server solutions, configured so the site remains operational in the event of any single platform failure. This configuration includes: (1) network load balancing to route the traffic to each of the Web servers during normal operations, and only to the active Web server if one of the servers fails; (2) two ArcGIS Server container machines with mirrored SOM load balancing to distribute processing load between the two container machines; and (3) two ArcSDE data servers clustered in a failover configuration and connected to a common storage array data source. The primary data server supports query services during normal operations, and the secondary data server takes over query services when the primary server fails.

4.8.2.3 ArcGIS Server Three-tier Platform Configuration

Figure 4-30 provides an overview of a standard three-tier ArcGIS Server configuration. The three-tier configuration includes Web server, container machine, and a data server tiers with the SOM located on the Web server.

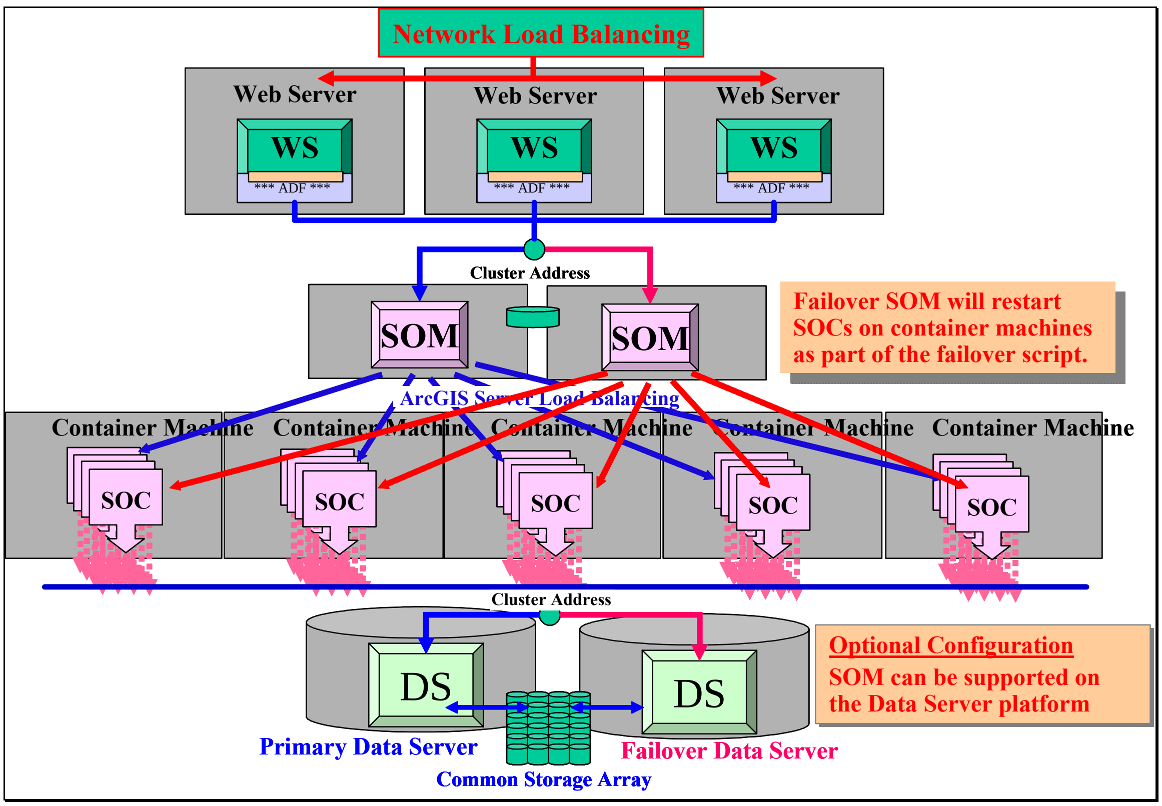
Figure 4-30
Three-tier Platform Standard Configuration



- **Standard Configuration.** The standard three-tier configuration includes a single Web server with separate container machine and data server tiers. The container machine tier can be a single platform or expanded to support several platforms, depending on the required site capacity. ArcGIS Server load balancing is provided by the SOM located on the Web server. All SOC instances use a common data source.

Figure 4-31 provides an overview of a high-availability three-tier ArcGIS Server configuration. The three-tier configuration includes multiple Web servers, container machines, and two ArcSDE data servers. A mirror set of SOM are provided either on a separate clustered tier or supported on the ArcSDE data server cluster.

Figure 4-31
Three-tier Platform High-Availability Configuration



- **High-Availability Configuration.** The high-availability three-tier configuration may include several Web servers, several container machines supporting the SOC instances, and two ArcSDE data servers. Network load balancing is used to route inbound traffic to the available Web servers; affinity is used to retain user connection with the initial Web server assignment. Web servers must be configured to support peak Web application processing loads. Web applications must be assigned to an SOM during initial site configuration.

  Two SOM configurations must be provided for high availability, and can be established in a fail-over configuration. Primary SOM will support the initial deployment, and the secondary SOM will start-up a new set of SOC instances during a cluster failover in the event of loss of the primary server. The clustered SOM environment can be supported on the same platforms as the clustered ArcSDE database servers.

5 Data Administration

Data management is a primary consideration when developing enterprise GIS architectures. Enterprise GIS normally benefits from efforts to consolidate agency GIS data resources. There are several reasons for supporting data consolidation. These reasons include improving user access to data resources, providing better data protection, and enhancing the quality of the data. Consolidation of IT support resources also reduces hardware cost and the overall cost of system administration.

The simplest and most cost-effective way to manage data resources is to keep one copy of the data in a central data repository, and provide required user access to these data to support data maintenance and operational GIS query and analysis needs. This is not always practical, and many system solutions require that organizations maintain distributed copies of the data. There are significant compromises that may be required to support distributed data architectures.

This chapter provides an overview of data management technology. Several basic data management tasks will be identified, along with the current state of the technology in supporting these tasks. These data management tasks include the following:

- Ways to protect spatial data
- Ways to backup spatial data
- Ways to move spatial data
- New ways to access spatial data

5.1 Ways to Protect Spatial Data

Enterprise GIS environments depend heavily on GIS data to support a variety of critical business processes. Data is one of the most valuable resources of a GIS, and protecting data is fundamental to supporting critical business operations.

The primary data protection line of defense is provided by the storage solutions. Most storage vendors have standardized on RAID (redundant array of independent disks) storage solutions for data protection. A brief overview of basic storage protection alternatives includes the following:

- **JBOD (Just a bunch of disks).** A disk volume with no RAID protection is referred to as a JBOD configuration, or just a bunch of disks. This represents a configuration of disks with no protection and no performance optimization.
- **RAID 0.** A disk volume in a RAID 0 configuration provides striping of data across several disks in the storage array. Striping supports parallel disk controller access to data across several disks reducing time required to locate and transfer the requested data. Data is transferred to array cache once it is found on each disk. RAID 0 striping provides optimum data access performance with no data protection. 100 percent of the disk volume is available for data storage.
- **RAID 1.** A disk volume in a RAID 1 configuration provides mirror copies of the data on disk pairs within the array. If one disk in a pair fails, data can be accessed from the

remaining disk copy. The failed disk can be replaced and data restored automatically from the mirror copy without bringing the storage array down for maintenance. RAID 1 provides optimum data protection with minimum performance gain. Available data storage is limited to 50 percent of the total disk volume, since a mirror disk copy is maintained for every data disk in the array.

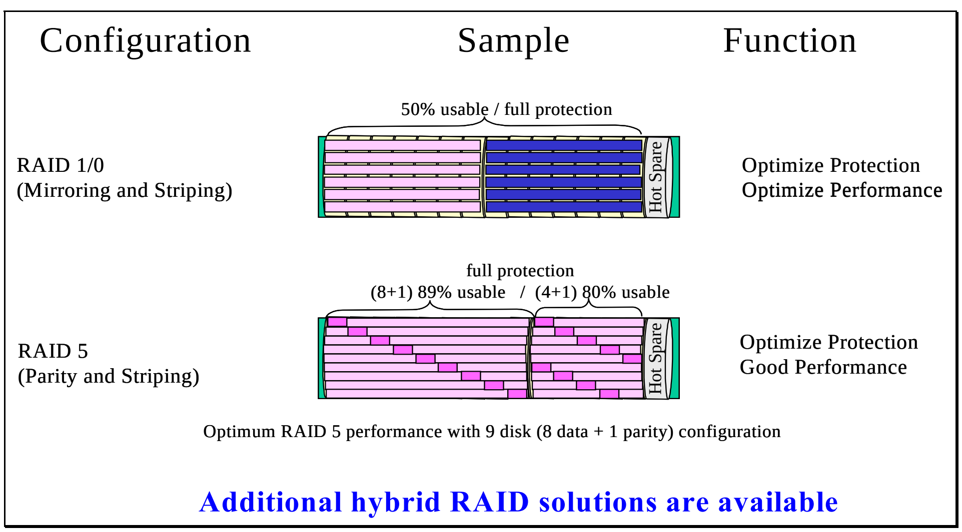
- **RAID 3 and 4.** A disk volume in a RAID 3 or RAID 4 configuration supports striping of data across all disks in the array except for one parity disk. A parity bit is calculated for each data stripe and stored on the parity disk. If one of the disks fails, the parity bit can be used to recalculate and restore the missing data. RAID 3 provides good protection of the data and allows optimum use of the storage volume. All but one parity disk can be used for data storage, optimizing use of the available disk volume for data storage capacity.

There are some technical differences between RAID 3 and RAID 4 which, for our purposes, are at a level beyond our current discussion. Both of these storage configurations have potential performance disadvantages. The common parity disk must be accessed for each write, which can result in disk contention under heavy peak user loads. Performance may also suffer due to requirements to calculate and store the parity bit for each write. Write performance issues are normally resolved through array cache algorithms on most high-performance disk storage solutions.

5.2 Popular RAID Configurations

The following RAID configurations are the most common used to support ArcSDE storage solutions. These solutions represent RAID combinations that best support data protection and performance goals. Figure 5-1 provides an overview of the most popular composite RAID configuration strategies.

Figure 5-1
Ways to Store Spatial Data
(Standard RAID configurations)



- **RAID 1/0.** RAID1/0 is a composite solution including RAID 0 striping and RAID 1 mirroring. This is the optimum solution for high performance and data protection. This is also the highest cost solution. Available data storage is limited to 50 percent of the total disk volume, since a mirror disk copy is maintained for every data disk in the array.

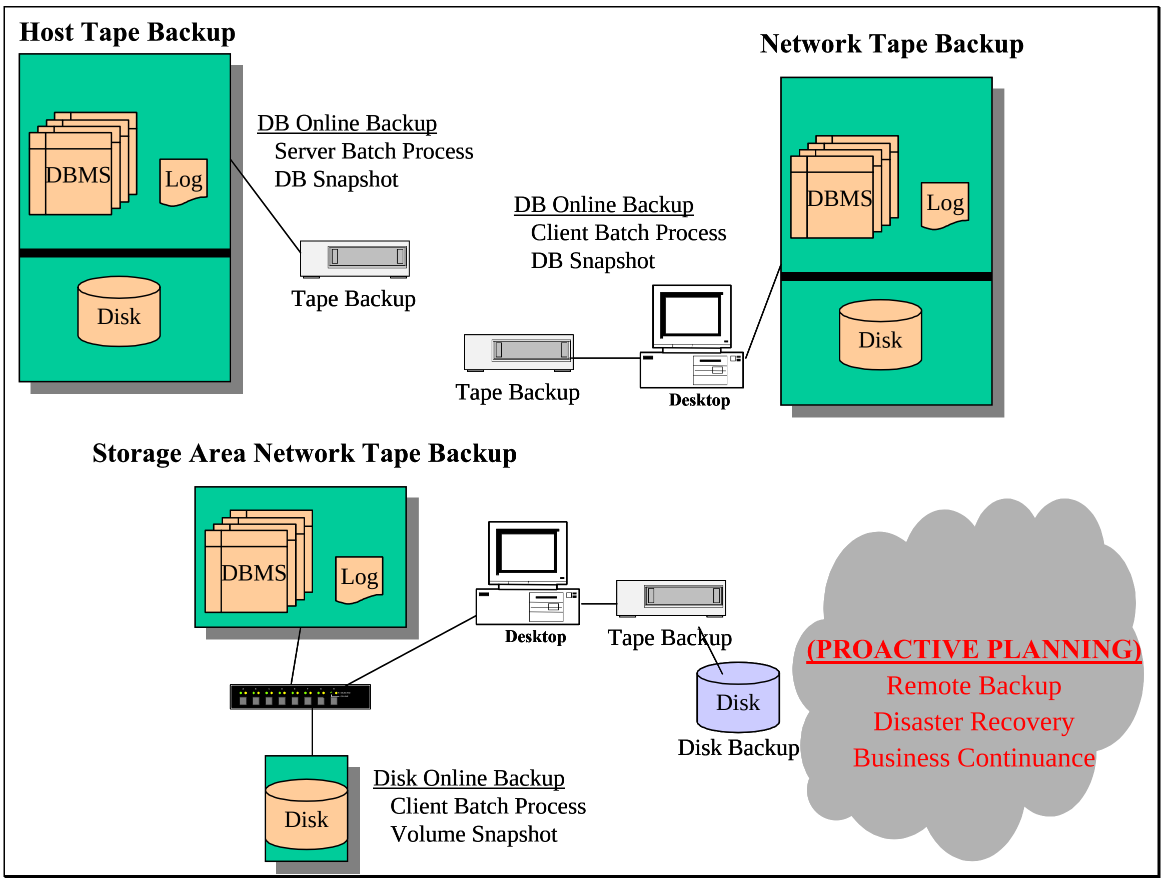
- **RAID 5.** RAID 5 includes the striping and parity of the RAID 3 solution, and includes distribution of the parity volumes for each stripe across the array to avoid parity disk contention performance bottlenecks. This improved parity solution provides optimum disk utilization and near optimum performance, supporting disk storage on all but one parity disk volume.
- **Hybrid Solutions.** Some vendors provide alternative proprietary RAID strategies to enhance their storage solution. New ways to store data on disk can improve performance and protection, and may simplify other data management needs. Each hybrid solution should be evaluated to determine if and how it may support specific data storage needs.

5.3 Ways to Backup Spatial Data

Data protection at the disk level will minimize the need for system recovery in the event of a single disk failure, but will not protect against a variety of other data failure scenarios. It is always important to keep a current backup copy of critical data resources at a safe known location away from the primary site.

Data backups typically provide the last line of defense for protecting our data investments. Careful planning and attention to storage backup procedures are important factors of a successful backup strategy. Data loss can result from many types of situations, with some of the most probable situations being administrative or user error. Figure 5-2 provides an overview of the different ways to backup spatial data.

Figure 5-2
Ways to Backup Spatial Data



- **Host Tape Backup.** Traditional server backup solutions use lower-cost tape storage for backup. Data must be converted to a tape storage format and stored in a linear tape medium. Backups can be a long drawn-out process taking considerable server processing resource (typically consume a CPU during the backup process) and requiring special data management for operational environments.

For database environments, these backups must occur based on a single point in time to maintain database continuity. Database vendors support online back-up requirements by establishing a procedural snapshot of the database. A copy of the protected snapshot data are retained in a snapshot table when changes are made to the database, supporting point-in-time backup of the database and potential database recovery back to the time of the snapshot.

Host processors can be used to support backup operations during off-peak hours. If backups are required during peak-use periods, backups can impact server performance.

- **Network Client Tape Backup.** The traditional online backup can often be supported over the LAN with the primary batch back-up process running on a separate client platform. DBMS snapshot may still be used to support point-in-time backups for online database environments. Client back-up processes can contribute to potential network performance bottlenecks between the server and the client machine due to the high data transfer rates during the backup process.
- **Storage Area Network Client Tape Backup.** Some backup solutions support direct disk storage access without impacting the host DBMS server environment. Storage backup is performed over the SAN or through a separate fiber channel access to the disk array with batch process running on a separate client platform. A disk-level storage array snapshot is used to support point-in-time backups for online database environments. Host platform processing loads and LAN performance bottlenecks can be avoided with disk-level backup solutions.
- **Disk Copy Backups**. The size of databases has increased dramatically in recent years, growing from 10s of Gigabytes to 100s of Gigabytes and, in many cases, Terabytes of data. Recovery of large databases from tape backups is very slow, taking days to recover large spatial database environments. At the same time, the cost of disk storage has decreased dramatically providing disk copy solutions for large database environments competitive in price to tape storage solutions. A copy of the database on local disk, or a copy of these disks to a remote recovery site, can support immediate restart of the DBMS following a storage failure simply by restarting the DBMS with the backup disk copy.

5.4 Ways to Move Spatial Data

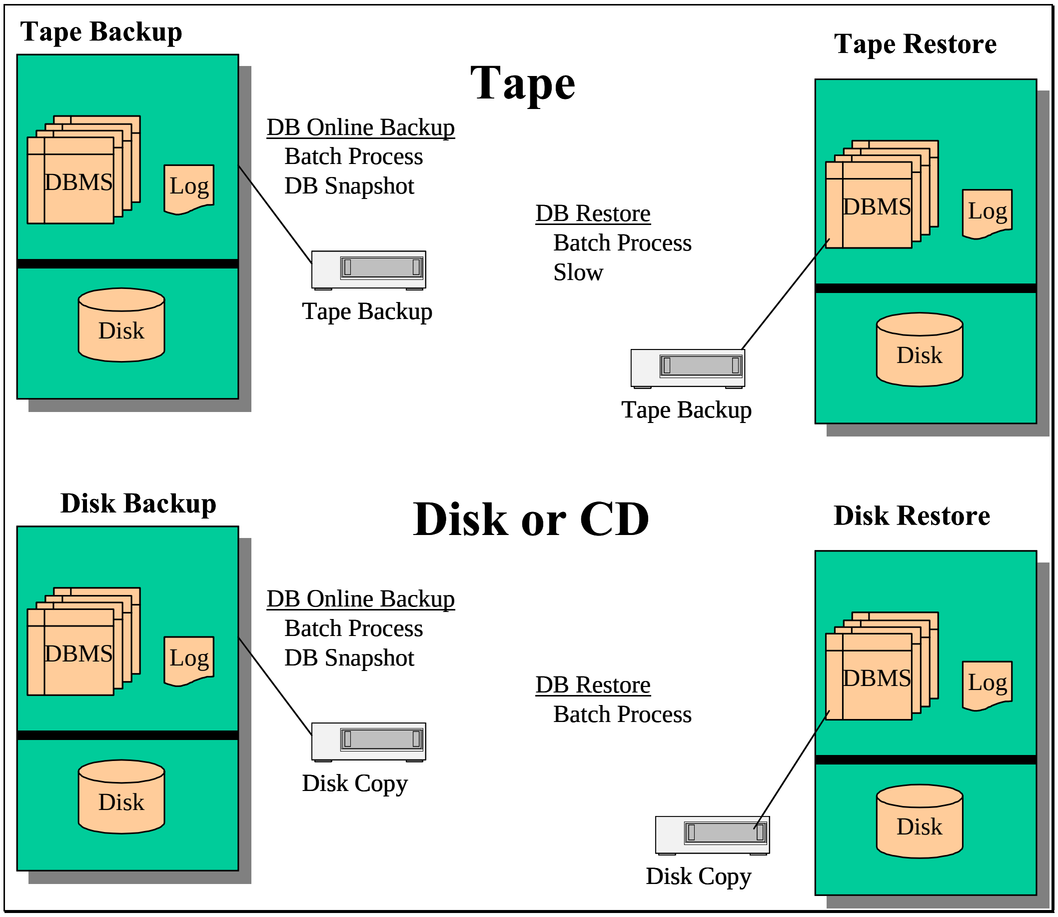
Many enterprise GIS solutions require continued maintenance of distributed copies of the GIS data resources, typically replicated from a central GIS data repository or enterprise database environment. Organizations with a single enterprise database solution still have a need to protect data resources in the event of an emergency such as fire, flood, accidents, or other natural disasters. Many organizations have recently reviewed their business practices, and updated their plans for business continuance in the event of a major loss of data resources. The tragic events of September 11, 2001 demonstrated the value of such plans, and increased interest and awareness of the need for this type of protection.

This section reviews the various ways organizations move spatial data. Traditional methods copy data on tape or disk and physically deliver these data to the remote site through standard transportation modes. Once at the remote site, data is reinstalled on the remote server environment. Technology has evolved to provide more efficient alternatives for maintaining distributed data sources. Understanding the available options and risks involved in moving data will be important in defining an optimum enterprise GIS architecture.

5.4.1 Traditional Data Transfer Methods

Figure 5-3 identifies traditional methods for moving a copy of data to a remote location.

Figure 5-3
Ways to Move Spatial Data
(Traditional Tape Backup/Disk Copy)



Traditional methods include backup and recovery of data using standard tape or disk transfer media. Moving data using these types of procedures are commonly called "sneaker net" and provide a way to transfer data without the support of a physical network.

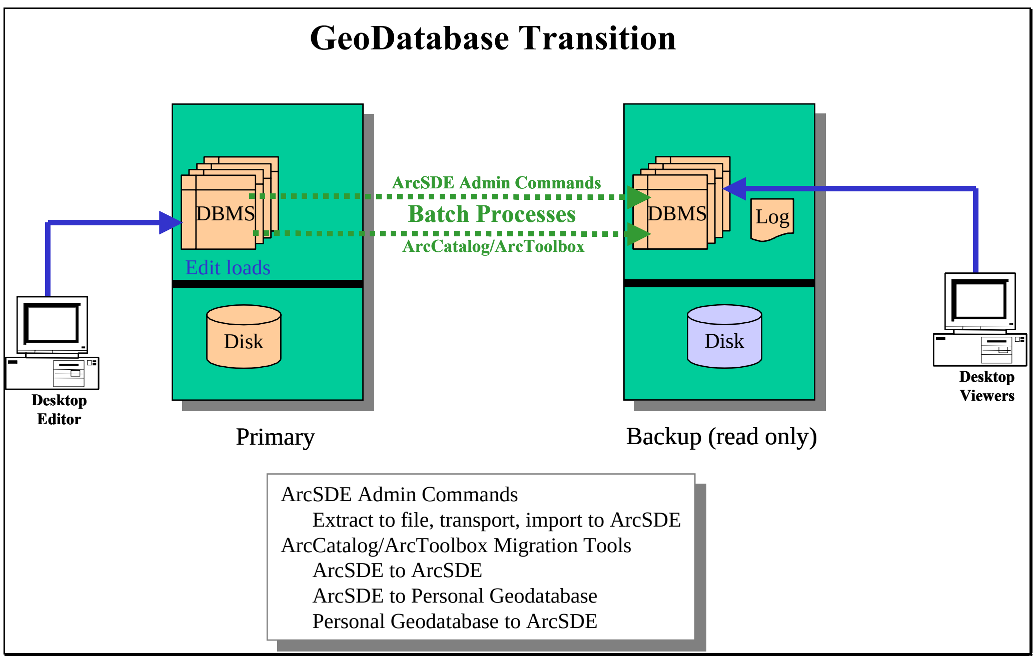
- **Tape Backup.** Tape backup solutions can be used to move data to a separate server environment. Tape transfers are normally very slow. The reduced cost of disk storage has made disk copy a much more feasible option.

- **Disk Copy.** A replicated copy of the database on disk storage can support rapid restore at a separate site. The database can be restarted with the new data copy and online with a very short recovery time.

5.4.2 ArcGIS Database Transition

Moving subsets of a single database cannot normally be supported with standard backup strategies. Data must be extracted from the primary database and imported into the remote database to support the data transfer. Database transition can be supported using standard ArcGIS export/import functions. These tools can be used as a method for establishing and maintaining a copy of the database at a separate location. Figure 5-4 identifies ways to move spatial data using ArcGIS data transition functions.

Figure 5-4
Ways to Move Spatial Data
(Database Transition)



- **ArcSDE Admin Commands.** Batch process can be used with ArcSDE admin commands to support export and import of an ArcSDE database. Moving data using these commands is most practical when completely replacing the data layers. These commands are not optimum solutions when transferring data to a complex ArcSDE geodatabase environment.

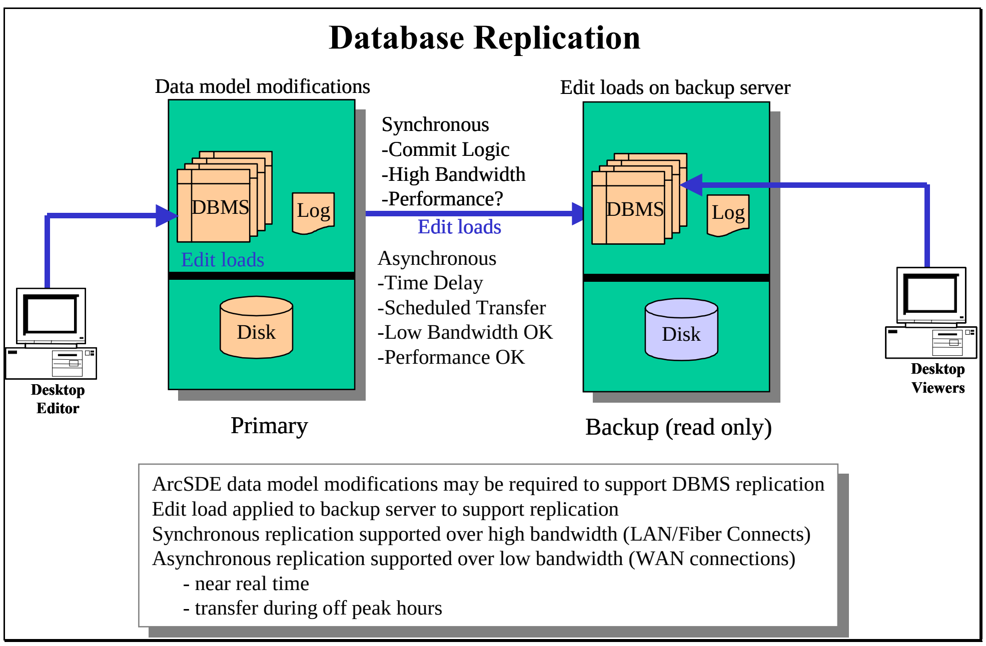
- **ArcCatalog/ArcToolbox Commands.** ArcCatalog supports migration of data between ArcSDE geodatabase environments, extracts to a personal geodatabase, and imports from a personal geodatabase to an ArcSDE environment.

5.4.3 Database Replication

Customers have experienced a variety of technical challenges when configuring DBMS spatial data replication solutions. ArcSDE data model modifications may be required to support DBMS replication solutions. Edit loads will be applied to both server environments, contributing to potential performance or server sizing impacts. Data changes must be transmitted over network connections between the two servers, causing potential communication bottlenecks. These challenges must be overcome to support a successful DBMS replication solution.

Customers have indicated that DBMS replication solutions can work but require a considerable amount of patience and implementation risk. Acceptable solutions are available by some DBMS vendors to support replication to a read-only back-up database server. Dual master server configuration strategies significantly increase the complexity of an already complex replication solution. Figure 5-5 presents the different ways to move spatial data using database replication.

Figure 5-5
Ways to Move Spatial Data
(Database Replication)



- **Synchronous Replication.** Real-time replication requires commitment of data transfer to the replicated server before releasing the client application on the primary server. Edit operations with this configuration would normally result in performance delays due to the typical heavy volume of spatial data transfers and the required client interaction times. High-bandwidth fiber connectivity (1000-Mbps bandwidth) is recommended between the primary server and the replicated back-up server to minimize performance delays.
- **Asynchronous Replication.** Near real-time database replication strategies decouple the primary server from the data transfer transaction to the secondary server environment. Asynchronous replication can be supported over WAN connections, since the slow

transmission times are isolated from primary server performance. Data transfers (updates) can be delayed to off-peak periods if WAN bandwidth limitations dictate, supporting periodic updates of the secondary server environment at a frequency supporting operational requirements.

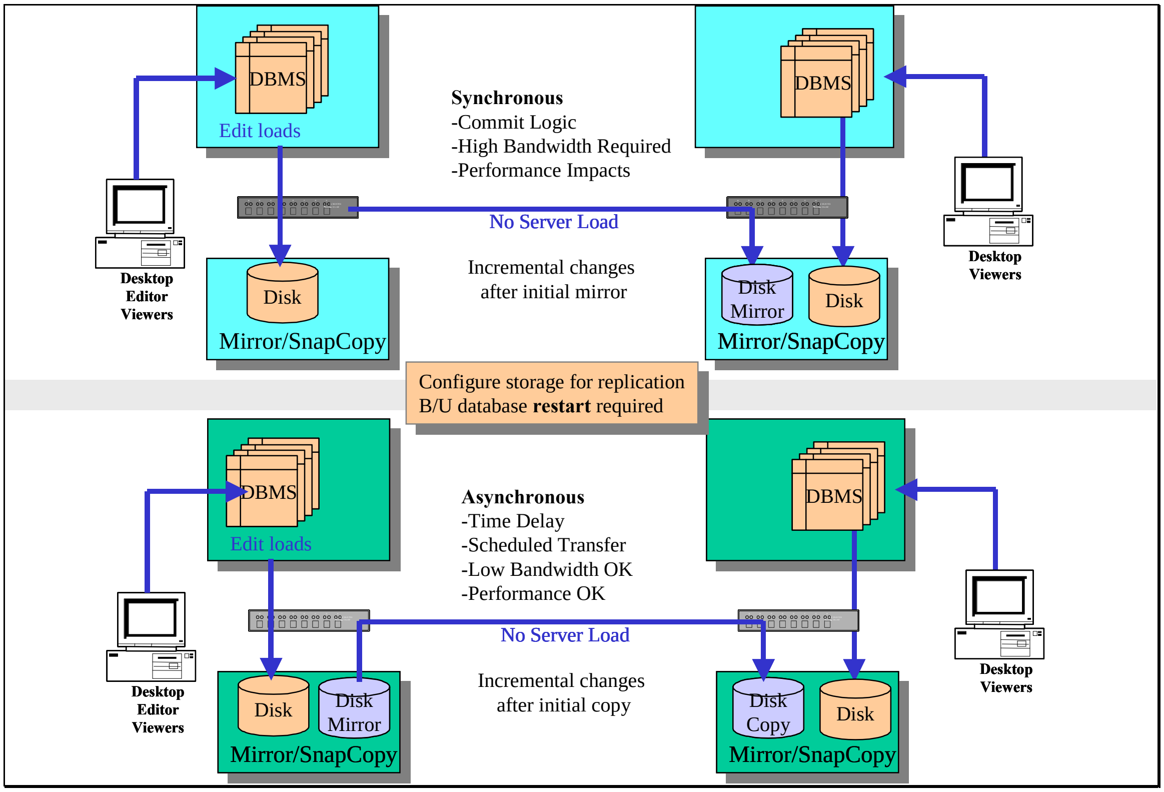
5.4.4 Disk-level Replication (Synchronous)

Disk-level replication is a well established technology, supporting global replication of critical data for many types of industry solutions. Spatial data is stored on disk sectors very similar to any other data storage and, as such, does not require special attention beyond what might be required for other data types. Disk volume configurations (data location on disk and what volumes are transferred to the remote site) may be critical to ensure database integrity. Mirror copies are refreshed based on point-in-time snapshot functions supported by the storage vendor solution.

Disk-level replication provides transfer of block-level data changes on disk to a mirror disk volume located at a remote location. Transfer can be supported with active online transactions with minimum impact on DBMS server performance capacity. Secondary DBMS applications must be restarted to refresh DBMS cache and processing environment to the point-in-time of the replicated disk volume.

Figure 5-6 presents the different ways to move spatial data using disk-level replication.

Figure 5-6
Ways to Move Spatial Data
(Disk-level Replication)



- **Synchronous Replication.** Real-time replication requires commitment of data transfer to the replicated storage array before releasing the DBMS application on the primary server. High-bandwidth fiber connectivity (1000-Mbps bandwidth) is recommended between the primary server and the replicated backup server to avoid performance delays.
- **Asynchronous Replication.** Near real-time disk-level replication strategies decouple the primary disk array from the commit transaction of changes to the secondary storage array environment. Asynchronous replication can be supported over WAN connections, since the slow transmission times are isolated from primary DBMS server performance. Disk block changes can be stored and data transfers delayed to off-peak periods if WAN bandwidth limitations dictate, supporting periodic updates of the secondary disk storage volumes to meet operational requirements.

5.4.5 New Ways to Access Spatial Data

The ArcGIS 8.3 release supports a disconnected editing solution. This solution supports a registered geodatabase version extract to a personal geodatabase or separate database instance for disconnected editing purposes. The version adds/deletes will be collected by the disconnected editor, and on reconnecting to the parent server, can be uploaded to the central ArcSDE database as a version update.

Figure 5-7 presents an overview of the ArcGIS 8.3 disconnected editing with check-out to a personal geodatabase. The ArcGIS 8.3 release is restricted to a single check-out/check-in transaction for each client edit session.

Figure 5-7
ArcGIS 8.3 Disconnected Editing Personal Geodatabase

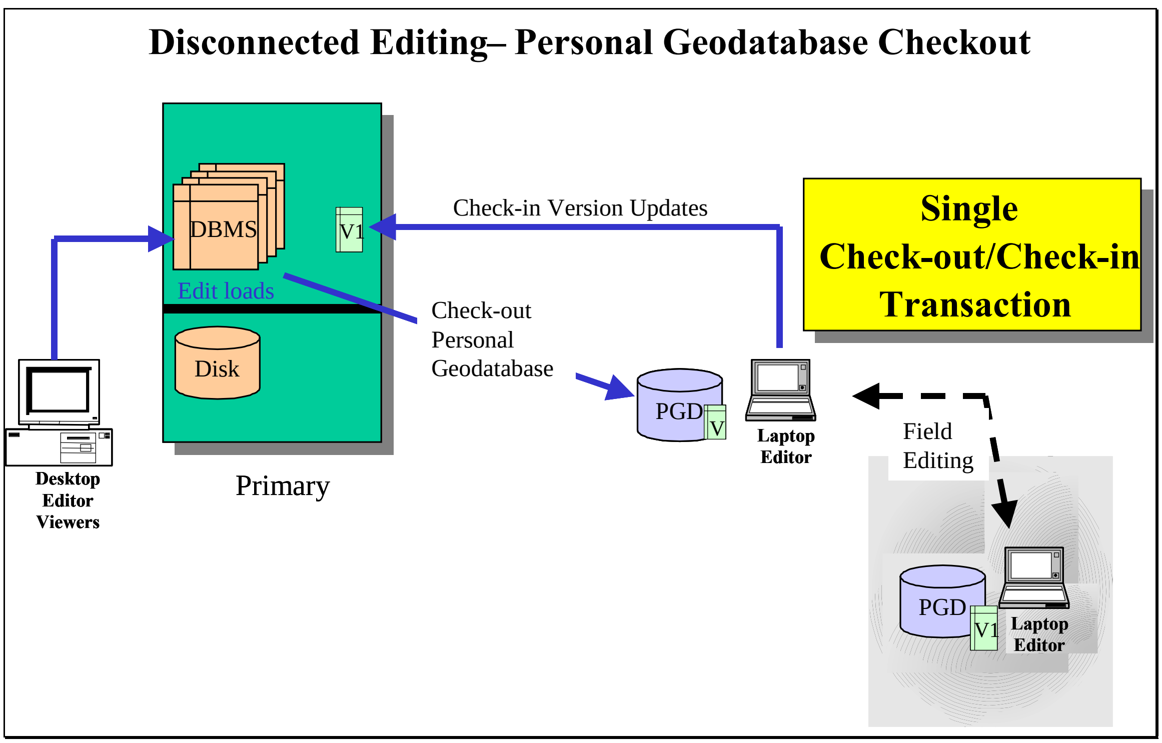
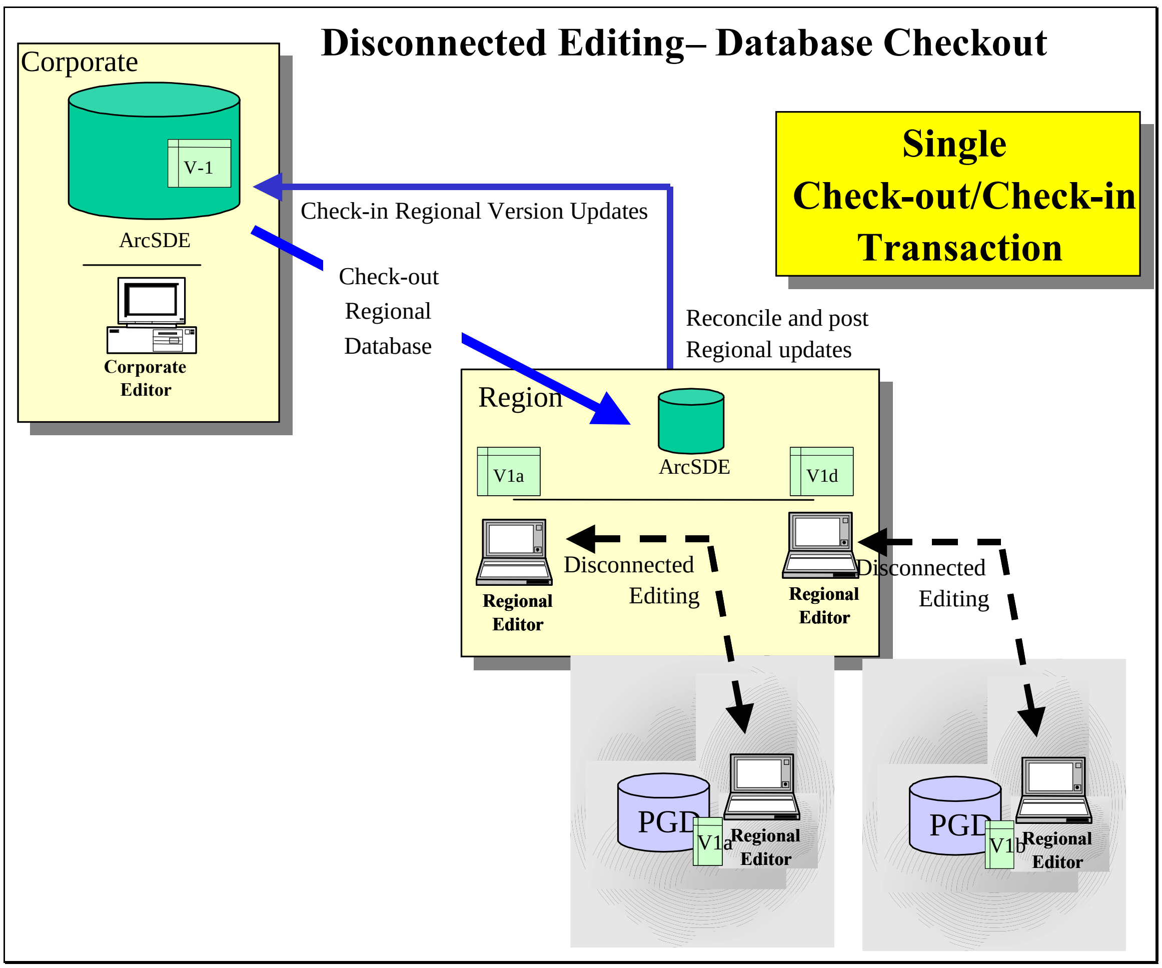


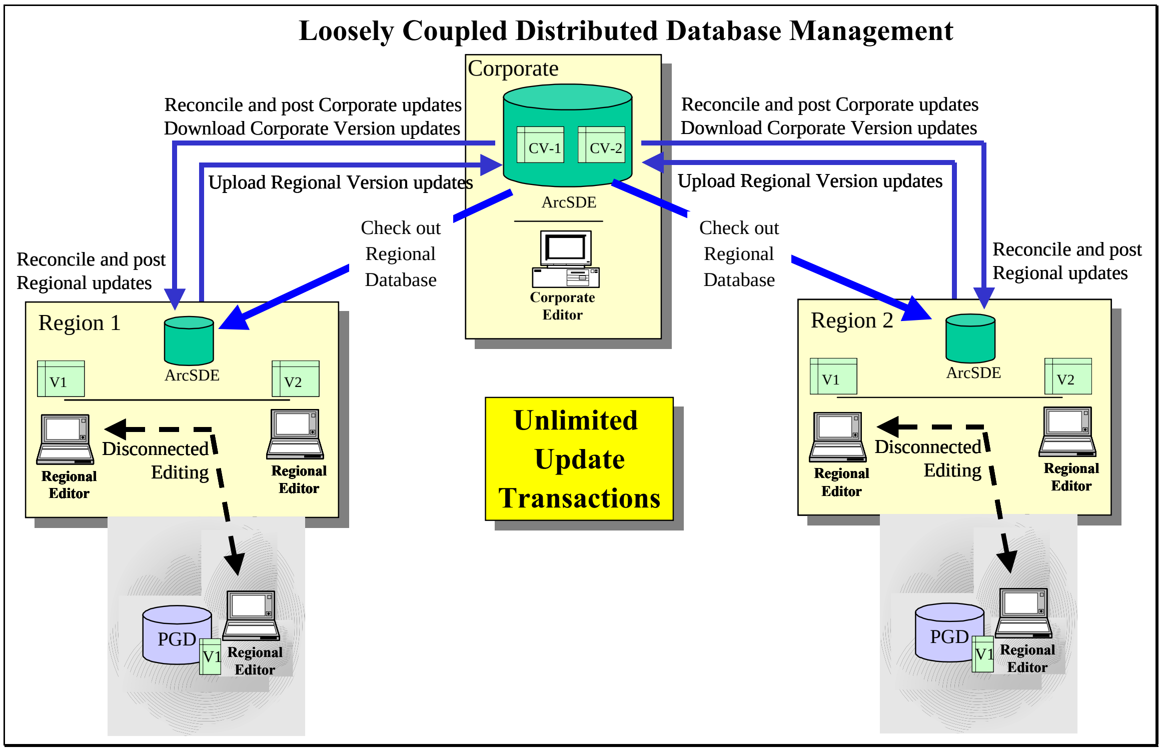
Figure 5-8 presents an overview of the ArcGIS 8.3 disconnected editing with check-out to a separate ArcSDE geodatabase. The ArcGIS 8.3 release is restricted to a single check-out/check-in transaction for each child ArcSDE database. The child ArcSDE database can support multiple disconnected or local version edit sessions during the check-out period. All child versions must be reconciled before check-in with the parent ArcSDE database (any outstanding child versions will be lost during the child ArcSDE database check-in process).

Figure 5-8
ArcGIS 8.3 Disconnected Editing - Database Checkout



The ArcGIS disconnected editing functionality will be expanded in future ArcGIS 9 releases to support loosely coupled ArcSDE distributed database environments. Figure 5-9 presents an overview of the future loosely coupled ArcSDE distributed database concept.

Figure 5-9
Future ArcSDE Distributed Database Architecture



Plans include supporting a single ArcSDE geodatabase distributed over multiple platform environments. The child check-out versions of the parent database will be able to support an unlimited number of update transactions without losing local version edits or requiring a new check-out. Updates will be passed between parent and child database environments through simple datagrams that can be transmitted over standard WAN communications. This new geodatabase architecture will support distributed database environments over multiple sites connected by limited bandwidth communications (only the reconciled changes will be transmitted between sites to support database synchronization).

5.5 Data Management Overview

Support for distributed database solutions has traditionally introduced high-risk operations, with potential for data corruption and use of stale data sources in supporting GIS operations. There are organizations that support successful distributed solutions. Their success is based on careful planning and detailed attention to their administrative processes that support the distributed data sites. The more successful solutions support central consolidated database solutions with effective remote user access and support. Future distributed database management solutions may significantly reduce the risk of supporting distributed environments. Whether centralized or distributed, the success of enterprise GIS solutions will depend heavily on the administrative team that keeps the system operational and provides an architecture solutions that supports user access needs.

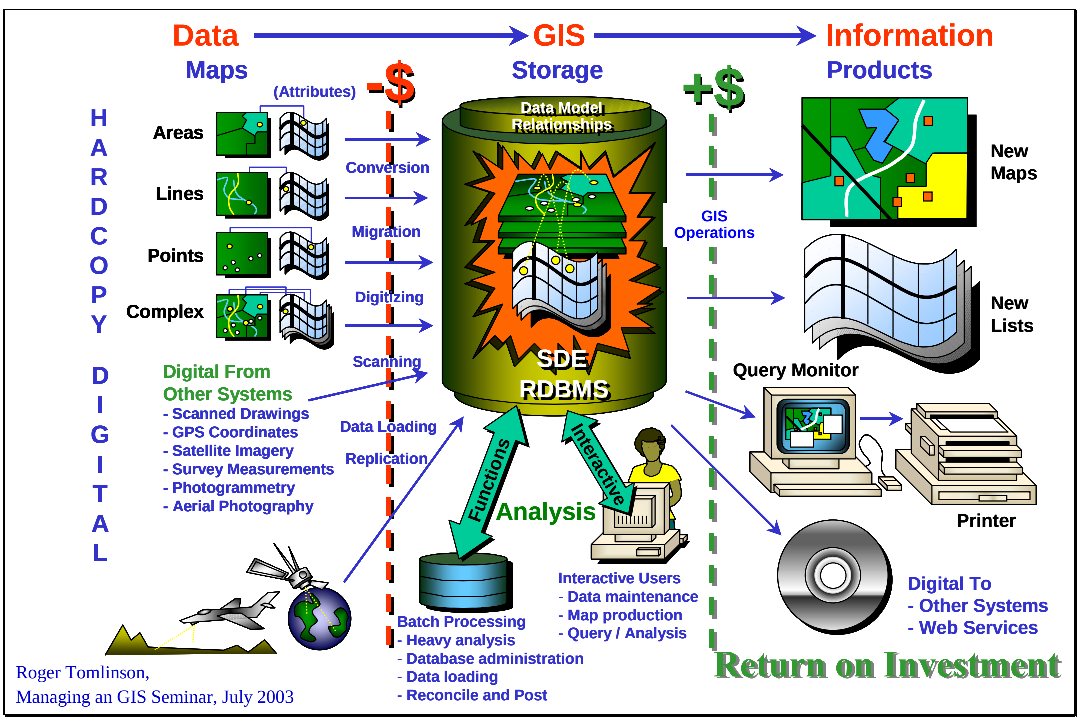
6 GIS User Needs

System architecture design provides a methodology for establishing hardware and network requirements that support the performance and communication needs of GIS application users. Hardware requirements should be established based on identified business needs. A fundamental understanding of user workflow requirements and the supporting GIS technology is required before one can identify the appropriate hardware and network requirements for supporting effective enterprise GIS operations.

6.1 Thinking about GIS

The value of a GIS is realized when users are provided access to business data resources. A significant amount of money is required to establish and maintain GIS data resources. Once data are available, this investment can be leveraged to support business operations. The business return on investment is realized when these data are used to produce information products that support improved business operations.

Figure 6-1
Geographic Information System

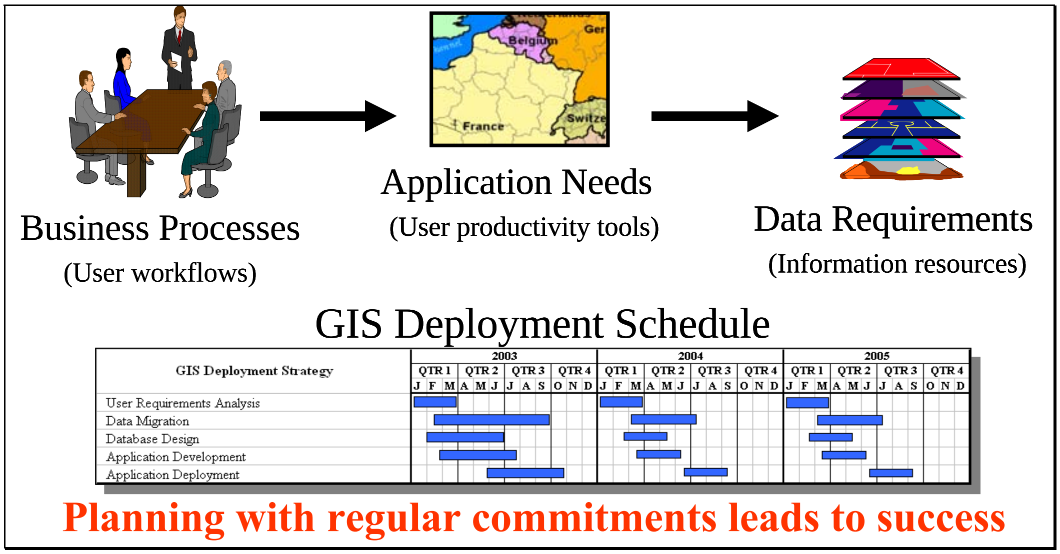


GIS provides technology to collect, store, manage, and analyze relationships between spatial data. Spatial data is represented in a database as points, lines, polygons, complex features, and image layers. These spatial data are stored in standard relational columns in a database. GIS applications support a broad variety of data integration and analysis to generate required business information products. GIS information products may be presented as maps, lists, or user workflows that support business operations. These information products can be displayed on a computer screen, printed on paper, or stored on digital media. Organizational benefits from the GIS are achieved by providing user access to these information resources.

Implementation of GIS on an enterprise level has many benefits for the organization, and the success of these benefits can be realized with proper investment in the required resources. Only you can plan for your success. Thinking of ways to leverage GIS data to support business operations is an effective way to capitalize on the GIS investment.

An application needs assessment must be completed by the business units that require the GIS information products. The needs assessment should be led by in-house GIS staff with support from an executive sponsor. Professional GIS consultants can be used to facilitate the planning process. Planning is normally critical to justify the required GIS investments and provides a framework to support enterprise GIS implementation.

Figure 6-2
Application Needs Assessment



Many technical efforts must be planned and coordinated to support a successful deployment. The application needs assessment involves a review of user workflow processes, and identifies data and GIS applications required for supporting these work processes. Understanding user workflow requirements provides an opportunity for optimizing business operations.

The user needs assessment should be documented and shared with users throughout the organization. The result of the application needs assessment should identify user workflow requirements, list existing and required data resources, and provide a prioritized list of GIS applications required to support operational needs. The results of the study should include a schedule for data acquisition and application deployment.

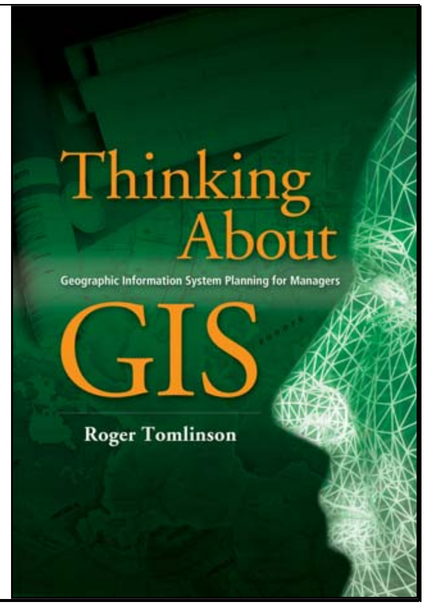
Dr. Roger Tomlinson's recently published book "Thinking About GIS" provides an excellent overview of the GIS planning process. Dr. Tomlinson has dedicated over 42 years of his life to the planning and deployment of GIS operations. Within the GIS community, Dr. Tomlinson is recognized as the father of GIS. Dr. Tomlinson's insight on enterprise GIS planning is also the foundation for the ESRI Planning for GIS, a self-study Web course available on the ESRI Virtual Campus. These resources can be very helpful to GIS managers and organizations that want to leverage their GIS resources and reap the benefits of a successful enterprise GIS.

Figure 6-3
Planning for GIS

Dr. Roger Tomlinson
Tomlinson Associates Ltd.
17 Kippewa Drive
Ottawa, Canada K1S 3G3
talgeo@magma.ca

Thinking About GIS
Based on the simple concept that you must think first and decide what you want from your GIS. Walks readers through a process that will result in a working GIS. Available through ESRI Press.
http://gis.esri.com/esripress

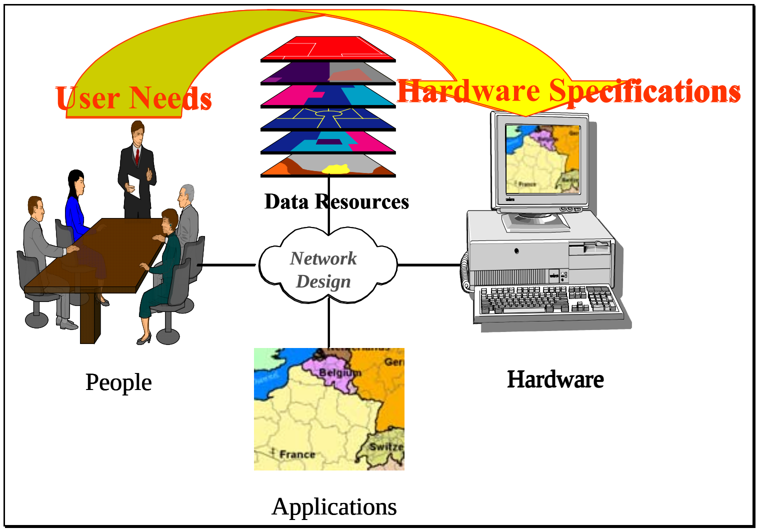
Planning for GIS
A self-study Web Course available on the ESRI Virtual Campus
http://campus.esri.com



6.2 System Design Prerequisites

Many factors contribute to a successful enterprise GIS. A GIS must have the right people, data resources, applications, and hardware to be successful. The type and nature of the GIS environment must match the needs and skills of the organization.

Figure 6-4
Total GIS Environment



Some basic objectives must be satisfied before an organization is ready to develop an enterprise system design strategy. These objectives include establishing a set of organizational goals for GIS development and identifying application needs and data requirements.

Approved organizational goals provide a foundation for getting resources necessary to support implementation. Implementation of an enterprise GIS solution will require top management support and must include a commitment from a number of departments throughout the organization. GIS goals should include objectives that define what changes the organization would like to see over the next three- to five-year period. These implementation objectives establish baseline requirements for the system design review.

6.3 GIS User Needs Assessment

There are a few basic user requirements that must be understood to support an effective system design solution. These requirements include identifying where the GIS users are located in relation to the associated data resources (site locations), what network communications are available to connect user sites with the GIS data sources, and what types of users are located at these locations. Figure 6-5 provides an overview of the system architecture needs assessment.

Figure 6-5
System Architecture Needs Assessment

- **GIS User Locations**
  - User Departments
  - Site Locations
- **Network Communications**
  - Local Area Network Standards
  - Wide Area Network Bandwidth
- **GIS User Types**
  - **ArcGIS** (ArcInfo, ArcEditor, ArcView)
  - **Web Services** (Web information products, project reporting)
  - **Concurrent Batch Processes** (Examples: Reconcile/Post, on-line compress, data loading, on-line backup, replication, and other heavy geoprocessing during peak production workflow)

6.3.1 GIS User Locations

All locations within the organization that require access to GIS applications and data resources must be identified. The system architecture design must be developed to support the peak user workflow. Understanding where the users are located, what applications they will need to support their work, and the location of the required data resources provides a basis for support the system design analysis.

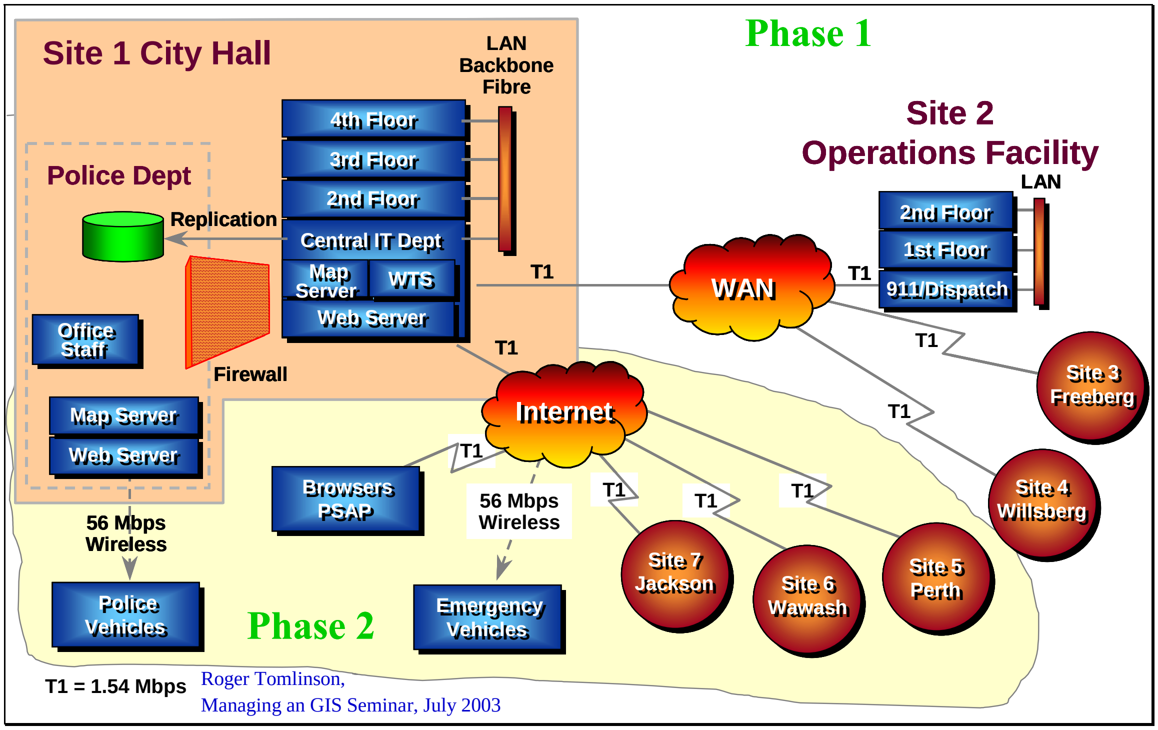
6.3.2 Network Communications

The network communications between the different locations must be identified to support the system design assessment. Network bandwidth will establish communication constraints that must be accommodated in the system design solution.

The City of Rome will represent a typical organization and be used as a case study to demonstrate the system design process. This City has over 450 employees that require GIS information to support their normal work processes. These employees are located in the Planning, Engineering, Police, and Operations departments throughout the City. Additional employees throughout the remaining City departments will benefit from deployment of standard GIS information products through published Web applications.

Figure 6-6 provides a sample format for identifying locations throughout a typical organization. This drawing provides an overview of the facility locations and the associated network environment to be addressed in the system design study.

Figure 6-6
Network Communications Overview



The drawing identifies each of the user locations and how they are connected through the wide area network and Internet.

6.3.3 GIS User Types

The types of GIS users can be divided into two basic categories. The ArcGIS desktop users will require desktop applications for GIS processing. The remaining users can be supported by ArcIMS map services.

- **ArcGIS Desktop**. Includes Desktop GIS specialists supporting general spatial query and analysis studies, simple map production, and general-purpose query and analysis operations, including all ArcEditor and ArcView clients. GIS applications for custom business solutions and other ArcView 3 GIS clients that support specific business needs should also be included in this category.
- **ArcIMS Map Services**. ESRI Internet Map Services provide transaction-based map products to intranet and Internet browser clients. ArcIMS supports transaction-based Web services for users requiring access to standard map products. ArcIMS can also be used as a data source for ArcGIS desktop clients.

6.3.4 User Workflow Analysis

The template provided in Figure 6-7 was used to document the Year-1 user application requirements for the City of Rome. The spreadsheet identifies user workflow requirements at each physical facility location, addressed at the department level.

Figure 6-7
City of Rome Planning
Workflow Analysis – Year 1

City of Rome					Peak Usage			
January 1, 2004				Total	ArcGIS Desktop			Web
Department	Workflow	Info. Product	User Type	Users	ArcInfo	ArcEditor	ArcView	Req/Hr
Site 1 - City Hall								
Planning	Zoning	1.0	Planner	20			8	
		1.1	Web Service					2,600
	Permits	1.2	Inspector	20			10	
		1.3	Appraiser	15	8			
		1.4	Supervisor	2			2	
		1.5	Web Service					600
Engineering	Sewer Backup	2.1	Engineer	4			3	
		2.2	Web Service					800
	Elec. Breaks	2.3	Electrician	13	6			
		2.4	Supervisor	2	1			
		2.5	Web Service					600
	Hwy Repair	2.6	Field Eng.	10			4	
		2.7	Contracts	4			4	
IT Department	Public	5.0	Web Service					5,000
Subtotal City Hall				90	15		31	9,600
Site 2 - Operations Facility								
Operations	Clean-up Prog.	3.1	Op. Staff	4			2	
Subtotal Operations				4			2	
Remote Field Offices (WAN)								
Site 3 Freeberg	Inspection	4.1	Field Engineer	40			35	
Site 4 Willsberg	Inspection	4.1	Field Engineer	30			20	
Field Offices	Inspection	4.2	Web Service					1,200
Subtotal Field Offices				70			55	1,200
CITY TOTALS				**164**	**15**		**88**	**10,800**

The following information was included in columns on the chart:

Department. Lowest organizational level addressed in the study.

Workflow. Type of work supported by the department.

Information Product. Provides a key for relating workflow to information products identified in the user needs assessment.

User Type. Job title or types of users requiring specific GIS applications to support their workflow.

Total Users. Total GIS users in the department who will use the application.

Peak Usage. Peak number of users on the system at one time. ArcGIS desktop users are identified by product level (ArcInfo, ArcEditor, ArcView). Web services are represented by estimated peak transaction rates (requests per hour). The peak usage loads will be applied in the design analysis to identify system capacity requirements.

Each department manager was held responsible to validate the final workflow analysis. A workflow analysis was completed for each implementation phase. Figure 6-8 provides the results of the City of Rome Year-2 workflow analysis.

Figure 6-8
City of Rome Planning
Workflow Analysis – Year 2

City of Rome					Peak Usage			
January 1, 2005				Total	ArcGIS Desktop			Web
Department	Workflow	Info. Product	User Type	Users	ArcInfo	ArcEditor	ArcView	Req/Hr
Site 1 - City Hall Network								
Planning	Zoning	1.0	Planner	25			15	
		1.1	Web Service					2,600
	Permits	1.2	Inspector	25			15	
		1.3	Appraiser	20	10			
		1.4	Supervisor	5	2			
		1.5	Web Service					900
Engineering	Sewer Backup	2.1	Engineer	5			3	
		2.2	Web Service					1,000
	Elec. Breaks	2.3	Electrician	13	6			
		2.4	Supervisor	2	1			
		2.5	Web Service					1,900
	Hwy Repair	2.6	Field Eng.	11			7	
		2.7	Contracts	4			4	
IT Department	Public	5.0	Web Service					10,000
Subtotal City Hall				**110**	**19**		**44**	**16,400**
Site 1 - Police Network								
Police (Firewall)	Patrol Sched.	5.1	Admin.	10			3	
		5.4	Web Services					200
	Crime Analysis	5.2	Detectives	10	5			
	Spec. Events	5.3	Traffic	10			3	
Subtotal Police				**30**	**5**		**6**	**200**
Site 2 - Operations Facility								
Operations	Clean-up Prog.	3.1	Op. Staff	4			2	
911	Response	3.2	Call Takers	50			40	
		3.3	Web Services					4,000
Remote Vehicles	Dispatch	3.4	Drivers	30			30	
Subtotal Operations				**84**			**72**	**4,000**
Remote Field Offices (WAN)								
Site 3 Freeberg	Inspection	4.1	Field Engineer	45			30	
Site 4 Willsberg	Inspection	4.1	Field Engineer	60			40	
WAN Field Office	Inspection	4.2	Web Services					1,200
Subtotal WAN Offices				**105**			**70**	**1,200**
Remote Field Offices (Internet VPN)								
Site 5 Perth	Inspection	4.3	Field Engineer	10			2	
Site 6 Wawash	Inspection	4.3	Field Engineer	50			40	
Site 7 Jackson	Inspection	4.3	Field Engineer	60			20	
Internet Field Offices	Inspection	4.2	Web Service					1,300
Subtotal Internet Offices				**120**			**202**	**3,700**
CITY TOTALS				**449**	**24**		**394**	**25,500**

Figure 6-9 provides an overview of the City of Rome user requirements. The total number of concurrent users provide a basis for establishing server platform specifications and network bandwidth requirements. Each department manager should carefully review their GIS needs and identify the number of concurrent application users required to support their work environment. Total GIS users are identified for each department. Peak concurrent user loads are identified by software license level (AI:ArcInfo, AE:ArcEditor, AV:ArcView). Estimated peak concurrent use provides a foundation for software licensing requirements and estimating peak system infrastructure processing loads. User inventory is represented over time by snapshot views of the user environment (January 2004, January 2005, etc.).

Figure 6-9
User Application Requirements Overview

CITY OF ROME	January 1, 2004					January 1, 2005				
	Total Users	Peak Loads AI	AE	AV	Web Req/Hr	Total Users	Peak Loads AI	AE	AV	Web Req/Hr
Site 1 - City Hall Network										
Planning	57	8		20	3,200	75	12		30	3,500
Engineering	33	7		11	1,400	35	7		14	2,900
IT Department (Public Web Services)					5,000					10,000
Subtotal City Hall	**90**	**15**		**31**	**9,600**	**110**	**19**		**44**	**16,400**
Site 1 - Police Network										
Police (Firewall)						30	5		6	200
Police totals						**30**	**5**		**6**	**200**
Site 2 - Operations Facility										
Operations	4			2		4			2	
911						50			40	4,000
Remote Vehicles						30			30	
Operations Totals	**4**			**2**		**84**			**72**	**4,000**
Remote Field Offices (WAN)										
Site 3 Freeberg	40			35	600	45			30	600
Site 4 Willsberg	30			20	600	60			40	600
Subtotal WAN Offices	**70**			**55**	**1,200**	**105**			**70**	**1,200**
Remote Field Offices (Internet VPN)										
Site 5 Perth						10			2	100
Site 6 Wawash						50			40	600
Site 7 Jackson						60			20	600
Subtotal Internet Offices						**120**			**62**	**1,300**
CITY TOTALS	**164**	**15**		**88**	**10,800**	**449**	**24**		**254**	**23,100**

Note: ArcGIS Desktop (AI = ArcInfo, AE = ArcEditor, AV = ArcView)

6.4 System Architecture Design Review

People skills and experience in maintaining distributed computer system solutions are important considerations when selecting a system design. Maintenance of the distributed computer environment will be a critical consideration in selecting appropriate vendor solutions. Experience and training in maintaining specific computer environments may identify a particular design solution as the best fit for your organization. Figure 6-10 provides an overview of issues to address during a system design review.

Figure 6-10
Build on Existing IT Investments

- **Platform and Network Environments**
  - Hardware Experience
  - Maintenance Relationships
  - Staff Training
- **Hardware Policies and Standards**
  - Management Preferences
  - Established Vendor Relationships
- **Operational Constraints and Priorities**
  - System Availability Requirements
  - System Security Requirements
  - Application Performance Needs
- **System Administration Experience**
  - System Administration Support
  - Network Administration Support
  - Support Staff Administration Strategies
- **Financial Considerations**
  - Available Financial Resources
  - Performance/Cost Considerations

- **Platform and Network Environments.** The design consultant should review the current vendor platforms and network environments. These are the environments that are currently maintained by the organization. Hardware experience, maintenance relationships, and staff training represent a considerable amount of investment for any organization. Proposed GIS design solutions should take advantage of corporate experience gained from working with the established platform and network environment.

- **Hardware Policies and Standards.** Organizations develop policies and standards that support their hardware investment decisions. Understanding management preferences and associated vendor relationships will provide insight into a design solution that can be supported best by the organization.

- **Operational Constraints and Priorities.** Understanding the type of operations supported by the GIS solution will identify requirements for fault tolerance, security, application performance, and the type of client/server architecture that would be appropriate to support these operations.

- **System Administration Experience.** The skills and experience of the systems support staff provide a foundation for supporting the final design solution. Understanding network administration and hardware support experience, in conjunction with support staff preference for future administration strategies, will help guide the consultant to compatible hardware vendor solutions.
- **Financial Considerations.** The final solution must be affordable. An organization will not implement a solution that is beyond their available financial resources. With system design, cost is a function of performance and reliability. If cost is an issue, the system design must facilitate a compromise between user application performance, system reliability, and cost. The design consultant must identify a hardware solution that provides optimum performance and reliability within identified budget constraints.

Current technology supports distribution of GIS solutions to clients throughout an enterprise environment, but there are limitations that apply to any distributed computer system design. It is important to clearly understand real GIS user needs and discuss alternative options for meeting those needs with your systems support staff in order to identify the most cost-effective solution.

6.5 System Configuration Alternatives

Several GIS configuration alternatives are available to support user processing requirements. The optimum configuration strategy can be identified once organizational and user requirements are understood.

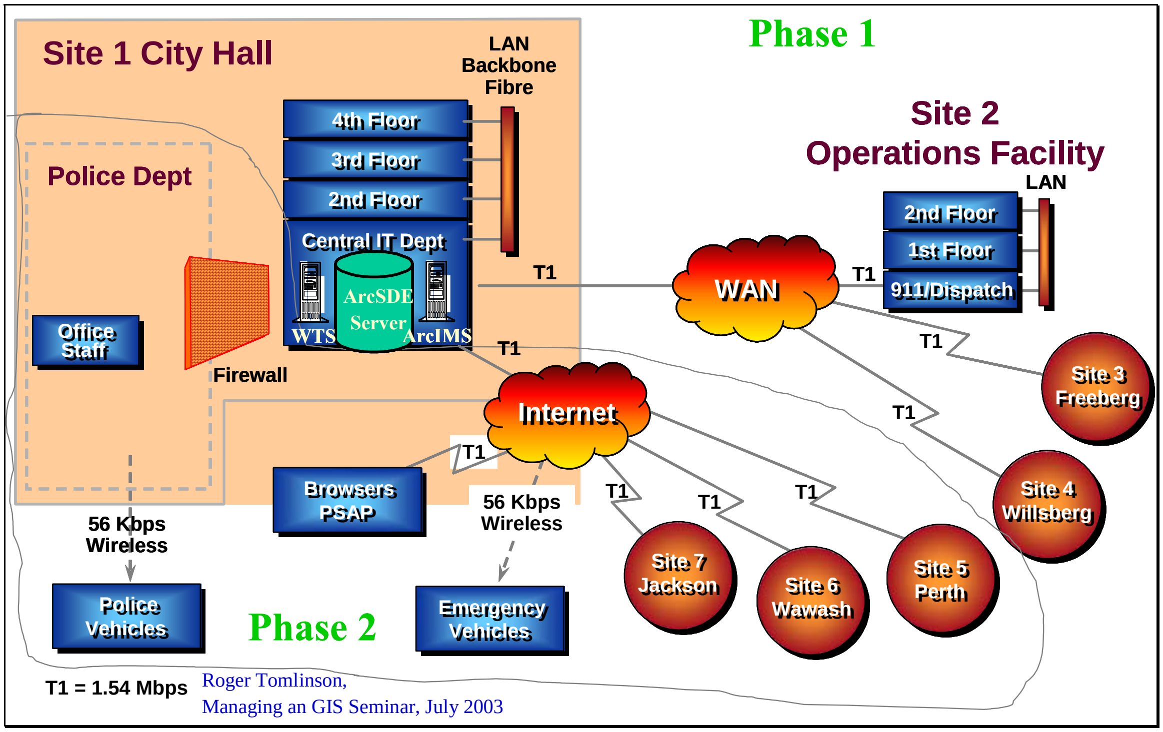
6.5.1 Central Computing Architecture

A central computing architecture can support ArcGIS desktop and ArcIMS map service clients throughout the enterprise network environment.

- ArcGIS desktop applications can be deployed in a distributed local area network (LAN) environment taking full advantage of standard network protocols. Applications are executed in supported local workstation operating system environments. Direct access to distributed GIS data is provided using standard network disk-sharing protocols.
- ArcGIS desktop applications can be installed on central application server platforms, hosting multiple remote terminal-based clients. Applications running on the application server are displayed and controlled by users located at remote desktop display terminals. Applications and GIS data servers can be located in the same controlled central computer environment.
- ArcIMS Web services support thin client GIS users and provide a data source for ArcGIS desktop clients. This environment allows a single application process to provide simultaneous support to a large number of concurrent GIS users. The ESRI Internet Map Server ArcIMS components are installed with a standard Web server that directs inbound map requests to waiting map service agents located on the map server. Each request is

serviced within seconds and returned to browser clients throughout the enterprise. Figure 6-11 provides an overview of ESRI centralized architecture solutions.

Figure 6-11
Central Server with Workstation Clients



Server and data consolidation is an effective way to reduce overall GIS implementation and support cost. There are several advantages of supporting GIS operations from a central processing environment:

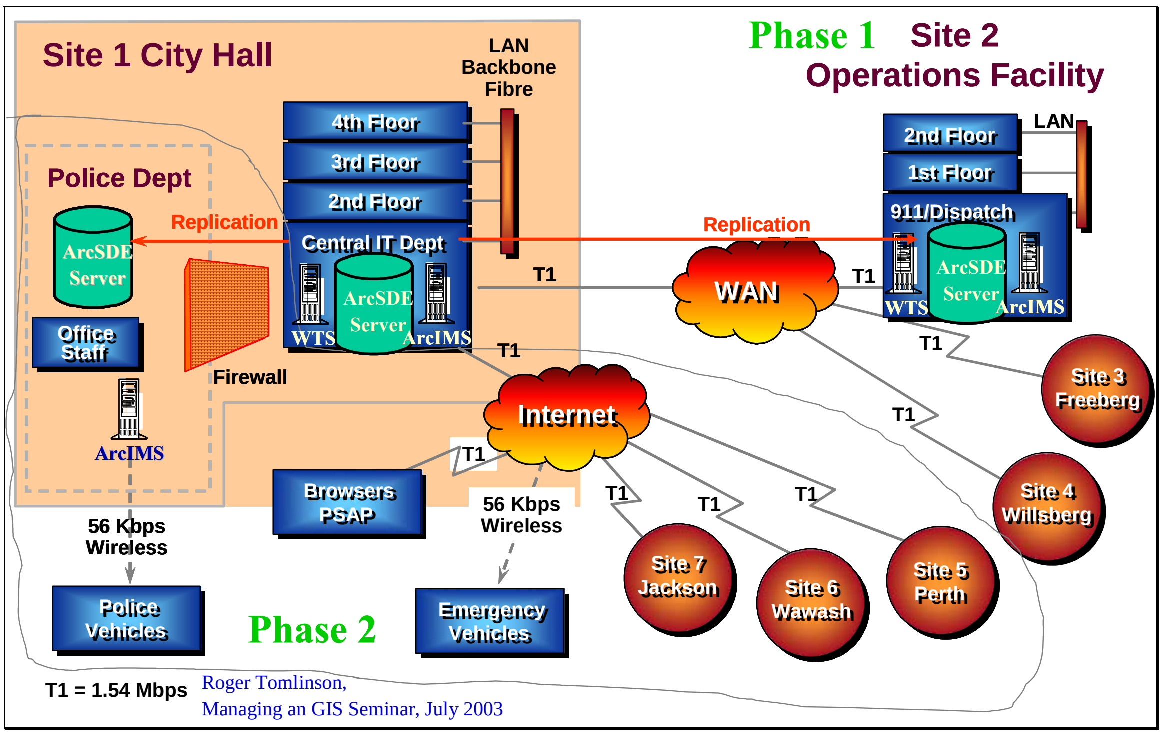
- **Reduce Hardware Cost**. Client workstation upgrades are much more expensive than supporting heavy applications on a central terminal server.
- **Reduce Administration Cost.** Applications and user workspaces are much easier to support from a centralized processing environment.
- **Low Implementation Risk**. Central solutions are much easier to deploy than distributed architectures. Once the system is installed and operational in the computer center, it can be deployed throughout the enterprise by simply upgrading the user group profiles.
- **Integrated Operations**. Data integration is much simpler to support with all data sources located in the computer center on the same network as the client applications.
- **Improved Data Access**. High bandwidth within the computer center reduces network contention and improves application performance.
- **Improved Security.** Applications and data access are restricted to the central computer processing environment.

- **Reduced Network Traffic**. Heavy traffic is isolated on the computer center network, enterprise traffic is limited to terminal client display information and plotting traffic.

6.5.2 Distributed Data and Workstation Processing (WAN)

This solution provides GIS data resources to each site location. It also includes applications running on the client desktop, with network access to distributed data sources at each location. This is a typical solution when users are located at a reasonable number of distributed sites and WAN communications are not reliable enough to support centralized operational requirements.

Figure 6-12
Distributed Data and Workstation Processing (WAN)



A central data server maintains a composite copy of the GIS data libraries. Required data is replicated from the central data server to regional data servers to support data currency requirements. Data updates from the regions are replicated back to the central data server for final processing.

Distributing data requires additional servers and disk storage. Distributed solutions require multiple copies of the data. As the size of data grows, the cost for supporting distributed solutions will increase. Distributed solutions continue to present both implementation risk and follow-on maintenance challenges, and clearly result in higher cost environments. A clear justification should be validated before recommending a distributed architecture environment.

6.6 Choosing a System Configuration

The best solution for a given organization will depend on the distribution of the user community and the type of operational data in use. User requirements determine the number of machines necessary to support the operational environment, the amount of memory required to support the applications, and the amount of disk needed to support the system solution.

Figure 6-13
Choosing a System Configuration

- **Best Solution Leverages Current IT Investments**
- **User Needs Set Foundation for Hardware Selection**
- **Platform Selection Based on User Needs**
  - Types of user applications
  - User locations and network communications
  - Location of GIS data resources
  - Peak user loads on system
  - Peak processing loads on selected hardware components
- **Contributing Factors to Final Design**
  - Existing hardware and support experience
  - Organizational system design policies/preferences
  - Operational constraints and priorities
  - Future growth plans/available budget

A basic ingredient to understanding and applying results of the user needs assessment is identification of the type of users on the system and the workstation performance needed to support these functions. Information required includes number of users on the system, the percent of time each will be using their GIS application, size of the user directories (workspace), size and type of other applications on the system, and user performance requirements. In addition, where data files will be located on the system, how users will access these data, and how much disk space will be needed to store the data are considerations. Also, it is important to understand the facility layout and available network communications and to evaluate the environment for potential performance bottlenecks. Other factors include accounting for existing equipment, organizational policies, preference toward available system design strategies, future growth plans, and available budget.

6.7 Hardware Component Selection

Once a configuration strategy is identified, the specific server platforms required to support the solution can be identified.

Figure 6-14
Hardware Component Selection
Centralized Solution

CITY OF ROME	January 1, 2004 Total Users	Peak Loads AI	AE	AV	Web Req/Hr	January 1, 2005 Total Users	Peak Loads AI	AE	AV	Web Req/Hr
Site 1 - City Hall Network										
Planning	57	8		20	3,200	75	12		30	3,500
Engineering	33	7		11	1,400	35	7		14	2,900
IT Department (Public Web Services)					5,000					10,000
Subtotal City Hall	**90**	**15**		**31**	**9,600**	**110**	**19**		**44**	**16,400**
Site 1 - Police Network										
Police (Firewall)						30	5		6	200
Police totals						**30**	**5**		**6**	**200**
Site 2 - Operations Facility										
Operations	4			2		4			2	
911						50			40	4,000
Remote Vehicles						30			30	
Operations Totals	**4**			**2**		**84**			**72**	**4,000**
Remote Field Offices (WAN)										
Site 3 Freeberg	40			35	600	45			30	600
Site 4 Willsberg	30			20	600	60			40	600
Subtotal WAN Offices	**70**			**55**	**1,200**	**105**			**70**	**1,200**
Remote Field Offices (Internet VPN)										
Site 5 Perth						10			2	100
Site 6 Wawash						50			40	600
Site 7 Jackson						60			20	600
Subtotal Internet Offices						**120**			**62**	**1,300**
CITY TOTALS	**164**	**15**		**88**	**10,800**	**449**	**24**		**254**	**23,100**
Note: ArcGIS Desktop (AI = ArcInfo, AE = ArcEditor, AV = ArcView)										

Server Platforms	January 1, 2004 Total Users	Peak Loads AI	AE	AV	Web Req/Hr	January 1, 2005 Total Users	Peak Loads AI	AE	AV	Web Req/Hr
City Hall Computer Room										
ArcSDE Geodatabase		15		88			24		254	
Windows Terminal Servers				57					204	
ArcIMS Web Server				**Requests per hour**	10,800				**Requests per hour**	23,100

- **Centralized Solution**. The first step is to identify required platform components to support user requirements and comply with infrastructure constraints. In this a centralized solution, we selected an ArcSDE geodatabase server, a Windows Terminal Server, and an ArcIMS server to be located at the City Hall IT Data Center. The central ArcSDE database will support all shared data resources, the Windows Terminal Server will provide remote user access to applications located at the central computer facility (this will comply with WAN bandwidth restrictions), and the ArcIMS server will support Web mapping services from the central database.

  The next step is to translate peak user loads identified at the site and department levels to the associated platforms that support their application and data processing. The result of this analysis identifies peak user loads for each of the selected hardware components. Section 7 will take these user loads and generate performance specifications for each of the selected hardware components.

Figure 6-15
Hardware Component Selection
Distributed Solution

CITY OF ROME	January 1, 2004					January 1, 2005				
	Total Users	Peak Loads AI	AE	AV	Web Req/Hr	Total Users	Peak Loads AI	AE	AV	Web Req/Hr
Site 1 - City Hall Network										
Planning	57	8		20	3,200	75	12		30	3,500
Engineering	33	7		11	1,400	35	7		14	2,900
IT Department (Public Web Services)					5,000					10,000
Subtotal City Hall	**90**	**15**		**31**	**9,600**	**110**	**19**		**44**	**16,400**
Site 1 - Police Network										
Police (Firewall)						[illegible]	5		6	200
Police totals						[illegible]	**5**		**6**	**200**
Site 2 - Operations Facility										
Operations	4			2		[illegible]			2	
911						[illegible]			40	4,000
Remote Vehicles						[illegible]			30	
Operations Totals	**4**			**2**		[illegible]			**72**	**4,000**
Remote Field Offices (WAN)										
Site 3 Freeberg	40			35	600	45			30	600
Site 4 Willsberg	30			20	600	[illegible]			40	600
Subtotal WAN Offices	**70**			**55**	**1,200**	**105**			**70**	**1,200**
Remote Field Offices (Internet VPN)										
Site 5 Perth						[illegible]			2	100
Site 6 Wawash						[illegible]			40	600
Site 7 Jackson						[illegible]			20	600
Subtotal Internet Offices						**120**			**62**	**1,300**
CITY TOTALS	[illegible]	**15**		**88**	**10,800**	[illegible]	**24**		**254**	**23,100**

Note: ArcGIS Desktop (AI = ArcInfo, AE = ArcEditor, AV = ArcView)

Server Platforms	January 1, 2004					January 1, 2005				
	Total Users	Peak Loads AI	AE	AV	Web Req/Hr	Total Users	Peak Loads AI	AE	AV	Web Req/Hr
City Hall Computer Room										
ArcSDE Geodatabase		15		86			19		176	
Windows Terminal Servers				55					132	
ArcIMS Web Server		Requests per hour			10,800		Requests per hour			18,900
Police Computer Room										
ArcSDE Server							5		6	
ArcIMS Web Server		Requests per hour					Requests per hour			200
Operations Facility										
ArcSDE Geodatabase				2					72	
Windows Terminal Servers									30	
ArcIMS Web Server		Requests per hour					Requests per hour			4,000

■ **Distributed Solution**. The first step is to identify required platform components to support user requirements and comply with infrastructure constraints. For the City of Rome distributed option, the Police required a separate secure data server and Operations required a server located at the Operations Facility's emergency control center.

In this distributed solution, we selected an ArcSDE geodatabase server, a Windows Terminal Server, and an ArcIMS server to be located at the City Hall Data Center. We identified a separate ArcSDE geodatabase server and Web server that would be located at the Police Network, and an ArcSDE server for the Operations Facility. The central ArcSDE database will maintain and support all enterprise GIS data resources. A copy of these data will be replicated to the Police and Operations data servers. Windows Terminal Servers will support remote user access for the remote locations to applications located at the City Hall Computer Facility, and the central ArcIMS server will support Web mapping services from the central City Hall database. The Police will have a separate ArcIMS server for their secure network.

The next step is to translate peak user loads identified at the site and department levels to the associated platforms that support their application and data processing. The result of this analysis provides peak user loads on the components we selected to support the enterprise GIS operations**.** Section 7 will take these user loads and generate performance specifications for each of the selected hardware components.

Sizing models introduced in Sections 6 and 7 will be used to identify candidate hardware platform configurations that support the peak user loads identified above.

6.8 Network Suitability Analysis

Enterprise GIS operations require adequate network capacity to support user performance needs. The network suitability analysis can be used to identify communication performance risk associated with deploying the GIS operations.

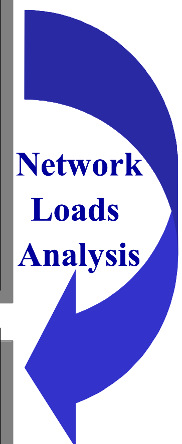
A complete network analysis is normally beyond the scope of a typical GIS system architecture design assessment. The network supports user applications throughout the organization. Although GIS users may be a small fraction of the total user population, the GIS applications may require a major portion of the available network bandwidth.

A network suitability assessment can be completed based on the identified GIS user needs. The first step is to identify critical network components that will be evaluated in the analysis. A clear understanding of the network traffic flow will be required to support the analysis. Network gateway components connecting each facility to the wide area networks or Internet service providers are the most common traffic bottlenecks, and these components would be appropriate candidates for evaluation during the network suitability analysis.

Figure 6-16 shows a network loads analysis for the centralized City of Rome configuration.

Figure 6-16
Network Loads Analysis
Centralized Solution

CITY OF ROME	January 1, 2004					January 1, 2005				
	Total Users	Peak Loads AI	AE	AV	Web Req/Hr	Total Users	Peak Loads AI	AE	AV	Web Req/Hr
Site 1 - City Hall Network	ArcSDE /ArcIMS for all offices and Public									
Planning	57	8		20	3,200	75	12		30	3,500
Engineering	33	7		11	1,400	35	7		14	2,900
IT Department (Public Web Services)					5,000					10,000
Subtotal City Hall	**90**	**15**		**31**	**9,600**	**110**	**19**		**44**	**16,400**
Site 1 - Police Network	ArcSDE for local clients / dialup for remote patrol cars									
Police (Firewall)						30	5		6	200
Police totals						**30**	**5**		**6**	**200**
Site 2 - Operations Facility	Terminal WAN access for local clients / Internet access for remote vehicles									
Operations	4			2		4			2	
911						50			40	4,000
Remote Vehicles						30			30	
Operations Totals	**4**			**2**		**84**			**72**	**4,000**
Remote Field Offices (WAN)	Terminal WAN access to City Hall									
Site 3 Freeberg	40			35	600	45			30	600
Site 4 Willsberg	30			20	600	60			40	600
Subtotal WAN Offices	**70**			**55**	**1,200**	**105**			**70**	**1,200**
Remote Field Offices (Internet VPN)	Terminal Internet VPN Internet access to City Hall									
Site 5 Perth						10			2	100
Site 6 Wawash						50			40	600
Site 7 Jackson						60			20	600
Subtotal Internet Offices						**120**			**62**	**1,300**
CITY TOTALS	**164**	**15**		**88**	**10,800**	**449**	**24**		**254**	**23,100**
Note: ArcGIS Desktop (AI = ArcInfo, AE = ArcEditor, AV = ArcView)										



Network Suitability	January 1, 2004					January 1, 2005				
	Bandwidth Mbps	Peak Loads AI	AE	AV	Web Req/Hr	Total Users	Peak Loads AI	AE	AV	Web Req/Hr
City Hall										
City WAN Connection	1.54			57	1,200	1.54			142	5,200
Internet Connection (T-1)	1.54				5,000	1.54			62	11,300
Operations Facility										
WAN Connection (T-1)	1.54			2		1.54			42	4,000
Remote Field Offices										
Site 3 Freeberg	1.54			35	600	1.54			30	600
Site 4 Willsberg	1.54			20	600	1.54			40	600
Site 5 Perth	1.54					1.54			2	100
Site 6 Wawash	1.54					1.54			40	600
Site 7 Jackson	1.54					1.54			20	600

Gateway connections to the WAN and Internet were identified for the analysis. User loads were identified for each of the gateway connections.

City WAN Connection. Includes peak loads from the Operations Facility and remote WAN field offices.

City Hall Internet Connection. Includes Web traffic from the IT Department, Remote Operations vehicle traffic, and traffic from the Internet connected field offices.

Operations Facility WAN Connection. Includes all traffic from the Operations Facility, except traffic from the remote vehicles (they access the City Hall Web server over the Internet connection).

Remote Field Office Connections. Includes all traffic from the remote field offices.

Once the peak traffic loads are identified for each of the component gateways, the user loads and transaction rates can be converted to traffic bandwidth. The conversion process is demonstrated in Figure 6-17.

Figure 6-17
Network Suitability Analysis – Step 1
Centralized Solution

Network Suitability	January 1, 2004					January 1, 2005				
	Bandwidth Mbps	Peak Loads AI	AE	AV	Web Req/Hr	Total Users	Peak Loads AI	AE	AV	Web Req/Hr
City Hall										
City WAN Connection	1.54			57	1,200	1.54			142	5,200
Internet Connection (T-1)	1.54				5,000	1.54			62	11,300
Operations Facility										
WAN Connection (T-1)	1.54			2		1.54			42	4,000
Remote Field Offices										
Site 3 Freeberg	1.54			35	600	1.54			30	600
Site 4 Willsberg	1.54			20	600	1.54			40	600
Site 5 Perth	1.54					1.54			2	100
Site 6 Wawash	1.54					1.54			40	600
Site 7 Jackson	1.54					1.54			20	600

Combine Convert

Network Suitability	Available Bandwidth Mbps	January 1, 2004 User Loads ArcGIS Desktop	ArcIMS Req/Sec	Network Loads Mbps ArcGIS Desktop	ArcIMS Req/Sec	Required Bandwidth
City Hall		**Design Factors**		**(0.028)**	**(0.5)**	**TOTAL**
City WAN Connection	1.54	57	0.33	1.60	0.17	1.76
Internet Connection (T-1)	1.54		1.39		0.69	0.69
Operations Facility		**Design Factors**		**(0.028)**	**(0.5)**	**TOTAL**
WAN Connection (T-1)	1.54	2		0.06		0.06
Remote Field Offices		**Design Factors**		**(0.028)**	**(0.5)**	**TOTAL**
Site 3 Freeberg	1.54	35	0.17	0.98	0.08	1.06
Site 4 Willsberg	1.54	20	0.17	0.56	0.08	0.64
Site 5 Perth	1.54					
Site 6 Wawash	1.54					
Site 7 Jackson	1.54					

Design Factors: Workstation 0.500 Mbps, Terminal 0.028Mbps, Browser 0.500Mbpq

In this analysis, ArcGIS desktop loads are combined into a single column, and Web transaction rates are converted from hours to seconds (divide by 3,600) to support the final network suitability analysis.

Network design factors are used to translate user loads to estimated network traffic. The translated network traffic (Mbps) was then combined to identify total network traffic requirements. LAN environments typically reach saturation at 25- to 35-percent bandwidth utilization, and should be upgraded to avoid saturation. WAN environments experience transport delays at roughly the same traffic levels, and upgrades should be considered as traffic approaches 50-percent utilization.

Figure 6-18 shows the same analysis for Year 2.

Figure 6-18
Network Suitability Analysis – Step 2
Centralized Solution

Network Suitability	January 1, 2004					January 1, 2005				
	Bandwidth Mbps	Peak Loads AI	AE	AV	Web Req/Hr	Total Users	Peak Loads AI	AE	AV	Web Req/Hr
City Hall										
City WAN Connection	1.54			57	1,200	1.54			142	5,200
Internet Connection (T-1)	1.54				5,000	1.54			62	11,300
Operations Facility										
WAN Connection (T-1)	1.54			2		1.54			42	4,000
Remote Field Offices										
Site 3 Freeberg	1.54			35	600	1.54			30	600
Site 4 Willsberg	1.54			20	600	1.54			40	600
Site 5 Perth	1.54					1.54			2	100
Site 6 Wawash	1.54					1.54			40	600
Site 7 Jackson	1.54					1.54			20	600

Combine Convert

Network Suitability	January 1, 2005					
	Available Bandwidth Mbps	User Loads ArcGIS Desktop	User Loads ArcIMS Req/Sec	Network Loads Mbps ArcGIS Desktop	Network Loads Mbps ArcIMS Req/Sec	Required Bandwidth
City Hall		**Design Factors**		**(0.028)**	**(0.5)**	**TOTAL**
City WAN Connection	1.54	142	1.44	3.98	0.72	4.70
Internet Connection (T-1)	1.54	62	3.14	1.74	1.57	3.31
Operations Facility		**Design Factors**		**(0.028)**	**(0.5)**	**TOTAL**
WAN Connection (T-1)	1.54	42	1.11	1.18	0.56	1.73
Remote Field Offices		**Design Factors**		**(0.028)**	**(0.5)**	**TOTAL**
Site 3 Freeberg	1.54	30	0.17	0.84	0.08	0.92
Site 4 Willsberg	1.54	40	0.17	1.12	0.08	1.20
Site 5 Perth	1.54	2	0.03	0.06	0.01	0.07
Site 6 Wawash	1.54	40	0.17	1.12	0.08	1.20
Site 7 Jackson	1.54	20	0.17	0.56	0.08	0.64

Design Factors: Workstation 0.500 Mbps, Terminal 0.028Mbps, Browser 0.500Mbpq

The results of the bandwidth suitability analysis shows a projected severe bottleneck for the City WAN connection (available bandwidth of 1.54 Mbps, required bandwidth of 1.76 Mbps). The Freeberg, Willsberg, and City Hall Internet connections were also exceeding 35-percent utilization rates. The City WAN connection should be upgraded to a T-2 connection (6 Mbps) to support the Year-1 implementation. The Freeberg, Willsberg, and City Hall Internet connections should be monitored very closely and upgraded, if necessary, to avoid user performance problems.

Wide area network updates can normally be deferred until required, as long as the service provider is able to support the required bandwidth upgrade. Service providers should be contacted as early as possible to verify bandwidth expansion capabilities (infrastructure upgraded to increase bandwidth capacity can take time).

This same analysis can be conducted for the distributed architecture, and the results will differ accordingly. Figures 6-19 and 6-20 show the results of the distributed network suitability analysis.

Figure 6-19
Network Suitability Analysis – Step 1
Distributed Solution

Network Suitability	January 1, 2004					January 1, 2005				
	Bandwidth Mbps	Peak Loads AI	AE	AV	Web Req/Hr	Total Users	Peak Loads AI	AE	AV	Web Req/Hr
City Hall										
City WAN Connection	1.54			55	1,200	1.54			100	1,200
Internet Connection (T-1)	1.54				5,000	1.54			92	11,300
Operations Facility										
WAN Connection (T-1)	1.54					1.54			30	
Remote Field Offices										
Site 3 Freeberg	1.54			35	600	1.54			30	600
Site 4 Willsberg	1.54			20	600	1.54			40	600
Site 5 Perth	1.54					1.54			2	100
Site 6 Wawash	1.54					1.54			40	600
Site 7 Jackson	1.54					1.54			20	600

Combine Convert

Network Suitability	January 1, 2005					
	Available Bandwidth Mbps	User Loads ArcGIS Desktop	ArcIMS Req/Sec	Network Loads Mbps ArcGIS Desktop	ArcIMS Req/Sec	Required Bandwidth
City Hall		Design Factors		(0.028)	(0.5)	TOTAL
City WAN Connection	1.54	55	0.33	1.54	0.17	1.71
Internet Connection (T-1)	1.54		1.39		0.69	0.69
Operations Facility		Design Factors		(0.028)	(0.5)	TOTAL
WAN Connection (T-1)	1.54					
Remote Field Offices		Design Factors		(0.028)	(0.5)	TOTAL
Site 3 Freeberg	1.54	35	0.17	0.98	0.08	1.06
Site 4 Willsberg	1.54	20	0.17	0.56	0.08	0.64
Site 5 Perth	1.54					
Site 6 Wawash	1.54					
Site 7 Jackson	1.54					

Design Factors: Workstation 0.500 Mbps, Terminal 0.028Mbps, Browser 0.500Mbpq

Figure 6-20
Network Suitability Analysis – Step 2
Distributed Solution

Network Suitability	January 1, 2004					January 1, 2005				
	Bandwidth Mbps	Peak Loads AI	AE	AV	Web Req/Hr	Total Users	Peak Loads AI	AE	AV	Web Req/Hr
City Hall										
City WAN Connection	1.54			55	1,200	1.54			100	1,200
Internet Connection (T-1)	1.54				5,000	1.54			92	11,300
Operations Facility										
WAN Connection (T-1)	1.54					1.54			30	
Remote Field Offices										
Site 3 Freeberg	1.54			35	600	1.54			30	600
Site 4 Willsberg	1.54			20	600	1.54			40	600
Site 5 Perth	1.54					1.54			2	100
Site 6 Wawash	1.54					1.54			40	600
Site 7 Jackson	1.54					1.54			20	600

Combine Convert

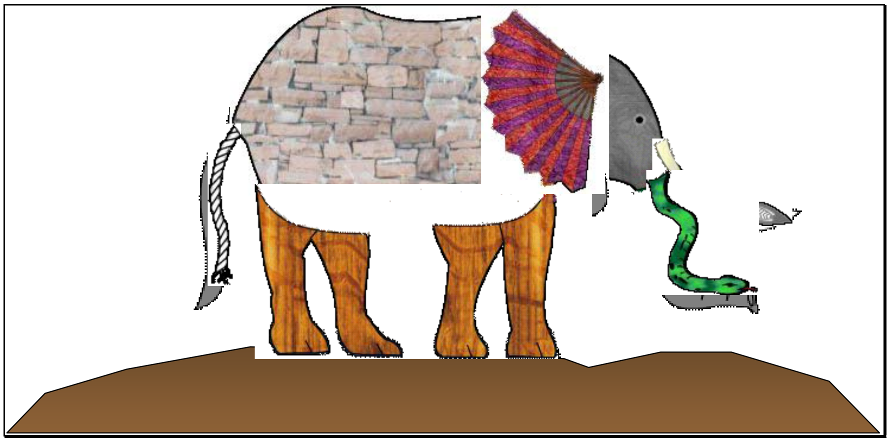
Network Suitability	January 1, 2005					
	Available Bandwidth Mbps	User Loads ArcGIS Desktop	ArcIMS Req/Sec	Network Loads Mbps ArcGIS Desktop	ArcIMS Req/Sec	Required Bandwidth
City Hall		Design Factors		(0.028)	(0.5)	TOTAL
City WAN Connection	1.54	100	0.33	2.80	0.17	2.97
Internet Connection (T-1)	1.54	92	3.14	2.58	1.57	4.15
Operations Facility		Design Factors		(0.028)	(0.5)	TOTAL
WAN Connection (T-1)	1.54	30		0.84		0.84
Remote Field Offices		Design Factors		(0.028)	(0.5)	TOTAL
Site 3 Freeberg	1.54	30	0.17	0.84	0.08	0.92
Site 4 Willsberg	1.54	40	0.17	1.12	0.08	1.20
Site 5 Perth	1.54	2	0.03	0.06	0.01	0.07
Site 6 Wawash	1.54	40	0.17	1.12	0.08	1.20
Site 7 Jackson	1.54	20	0.17	0.56	0.08	0.64

Design Factors: Workstation 0.500 Mbps, Terminal 0.028Mbps, Browser 0.500Mbpq

7 Sizing Fundamentals

Computer platforms must be configured properly to support system performance requirements. There are many factors that contribute to overall system performance. Enterprise GIS solutions include distributed processing environments, where user performance can be the product of contributions from several hardware platform environments. Many of these platform resources are shared with other users. Understanding distributed processing technology provides a fundamental framework for deploying a successful enterprise GIS environment.

Figure 7-1
Understanding the Technology



Six Blind Men and the Elephant

It was six men of Indostan
To learning much inclined,
Who went to see the Elephant
(Though all of them were blind),
That each by observation
Might satisfy his mind.

The First approached the Elephant,
And happening to fall
Against his broad and sturdy side,
At once began to bawl:
"God bless me! but the Elephant
Is very like a wall!"

The Second, feeling of the tusk
Cried, "Ho! what have we here,
So very round and smooth and sharp?
To me `tis mighty clear
This wonder of an Elephant
Is very like a spear!"

The Third approached the animal,
And happening to take
The squirming trunk within his hands,
Thus boldly up he spake:
"I see," quoth he, "the Elephant
Is very like a snake!"

The Fourth reached out an eager hand,
And felt about the knee:
"What most this wondrous beast is like
Is mighty plain," quoth he;
"'Tis clear enough the Elephant
Is very like a tree!"

The Fifth, who chanced to touch the ear,
Said: "E'en the blindest man
Can tell what this resembles most;
Deny the fact who can,
This marvel of an Elephant
Is very like a fan!"

The Sixth no sooner had begun
About the beast to grope,
Than, seizing on the swinging tail
That fell within his scope.
"I see," quoth he, "the Elephant
Is very like a rope!"

And so these men of Indostan
Disputed loud and long,
Each in his own opinion
Exceeding stiff and strong,
Though each was partly in the right,
And all were in the wrong!

Moral:

So oft in theologic wars,
The disputants, I ween,
Rail on in utter ignorance
Of what each other mean,
And prate about an Elephant
Not one of them has seen!

ESRI has implemented distributed GIS solutions since the late 1980s. For many years distributed processing environments were not well understood, and customers relied on the experience of a variety of technical experts to identify hardware requirements to support their implementation needs. Each technical expert had a different perspective on what hardware infrastructure might be required to support a successful implementation, and recommendations were not consistent. Many hardware decisions were made based on the size of the project budget, rather than a clear understanding of user requirements and the associated hardware technology.

System performance models were developed in the early 1990s to document what was understood about distributed processing systems. These system performance models have been used by ESRI consultants to support distributed computing hardware solutions since 1992. These same performance models have been used to identify potential performance problems with existing computing environments. This section will present the basis for these models. A fundamental understanding of these models will help users better understand their computing environment.

The models in this section will be presented with the assumption that all platforms have the same processing capacity. This is a simplified approach to presenting and understanding the performance models. The following section (Sizing Tools) will identify how these models are applied in the real world, where platform performance is not the same and is rapidly changing.

7.1 System Performance Profile

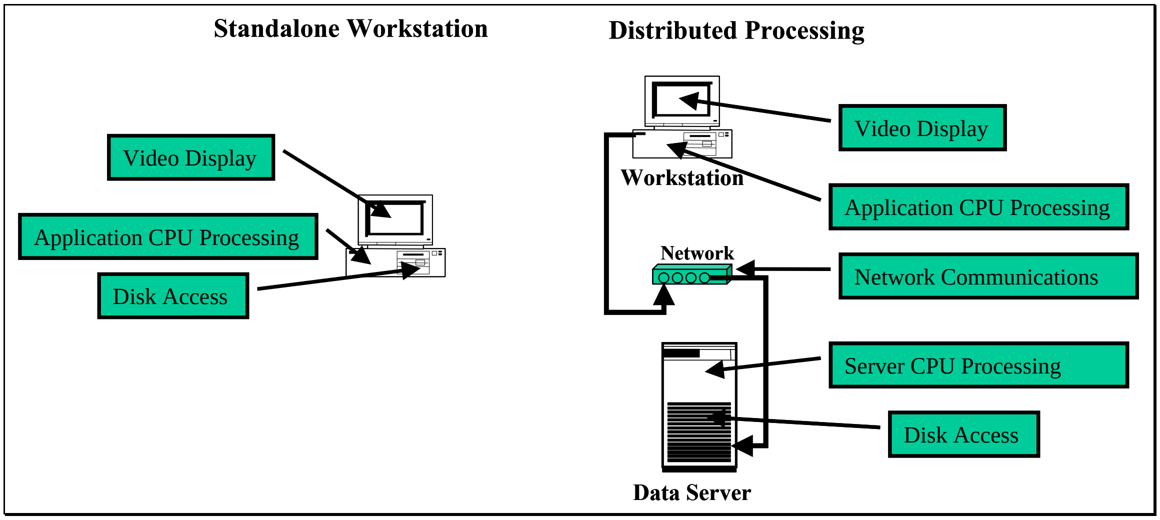
Computer platforms are supported by several component technologies. Each component technology contributes to the overall computer performance. Hardware vendors build computers with the appropriate component resources to optimize overall platform performance.

In much the same way, distributed computing solutions (enterprise computing environments) are supported by several hardware platforms that contribute to overall system performance. Each hardware component contributes to the overall system performance. Hardware platforms supporting a computing environment must be carefully selected to support optimum overall system performance.

The primary objective of the system design process is to provide the highest level of user performance for the available system hardware investment. Each hardware component must be selected with sufficient performance to support processing needs. Current technology can limit system design alternatives. Understanding distributed processing loads at each hardware component level provides a foundation for establishing an optimum system solution.

Figure 7-2 provides a simplified overview of the components in a standalone workstation and a distributed processing configuration. Each component participates sequentially in the overall program execution.

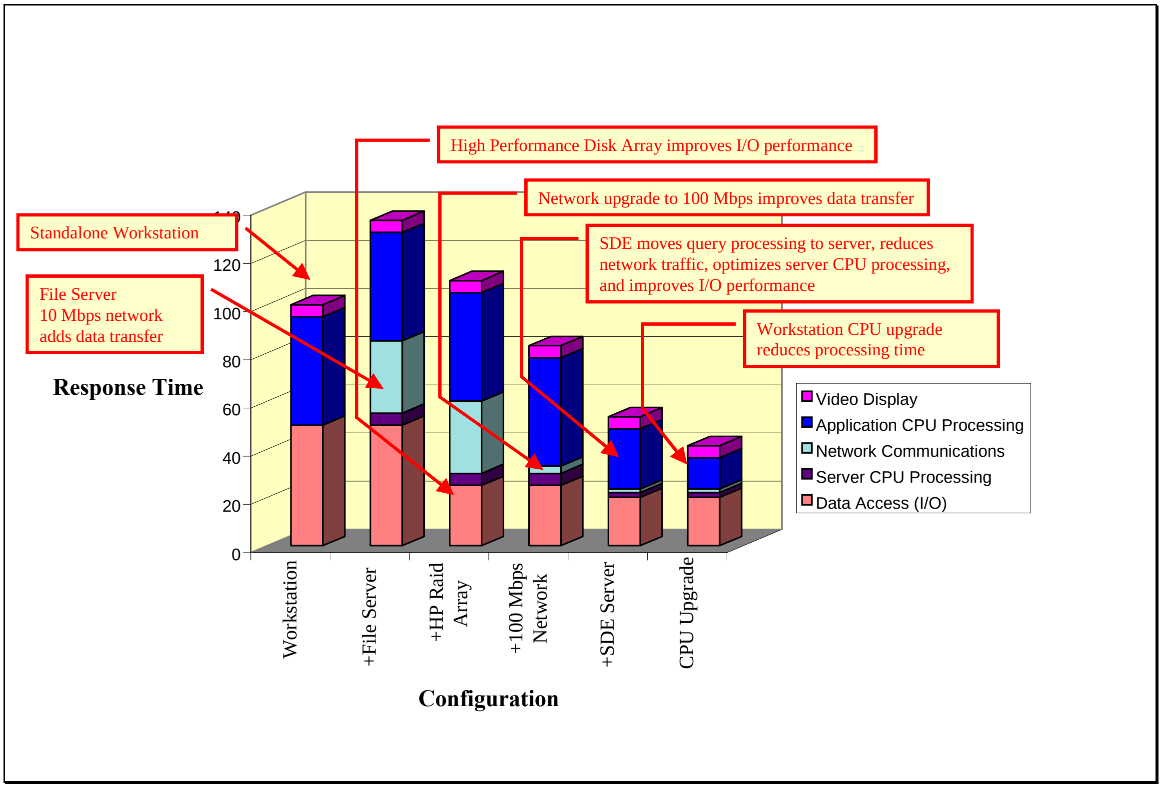
Figure 7-2
Platform Performance Components



The total response time of a particular application query will be a collection of the responses from each of these components. A computer vendor optimizes the component configuration within the workstation to support the fastest computer response to an application query. An IT/Systems department has the responsibility to optimize the organization's hardware and network component investments to provide the optimum system-level response at the user desktop. System performance can directly contribute to user productivity.

Figure 7-3 identifies performance gains as a result of a series of hardware investments. These investments contribute to the relative performance experienced at the user desktop.

Figure 7-3
System Performance Profile



The first column represents the performance of a standalone workstation performing a typical GIS operation (requesting display of a new map extent on the user screen). Experience shows that GIS applications tend to be both compute intensive and input/output (I/O) intensive. A standalone workstation spends roughly the same amount of time on data access and compute processing. A relatively small amount of remaining time is required to send the resulting map product to the video display.

The second column shows the system performance profile when accessing the data from a file server in place of local disk. This distributed solution includes additional server CPU processing and network data transfer. These additional system components extend the overall response time to include the additional system loads. Accessing data from a file server over a 10-Mbps network can reduce performance by roughly 30 percent.

The third column shows the result of upgrading the JBOD (just a bunch of disks) configuration on the file server to a high-performance RAID storage solution. High-performance RAID storage solutions can improve disk access performance by as much as 50 percent.

The fourth column shows the effect of increasing network bandwidth from 10-Mbps Ethernet to 100-Mbps Ethernet, a factor of 10 reduction in data transfer time. Users experience improved performance over having data on local workstation disk with this configuration.

The fifth column shows the result of moving the spatial data to an ArcSDE server. The ArcSDE server solution will improve performance in several areas. The ArcSDE server technology relocates query processing traditionally supported by the client application to the server platform. This reduces client CPU processing requirements by roughly 50 percent. Spatial data is compressed by 30 to 70 percent on the ArcSDE server, reducing network traffic by an additional 50 percent. The ArcSDE server also filters the requested data layer so only the requested map layer extent is sent over the network to the client, further reducing network traffic. The query processing performed by the ArcSDE server, using DBMS query indexing, data cache and search functions, will also reduce the processing load on the server to less than half that used to support the traditional client query processes. Moving spatial data to ArcSDE can significantly improve overall system performance in a distributed computing solution.

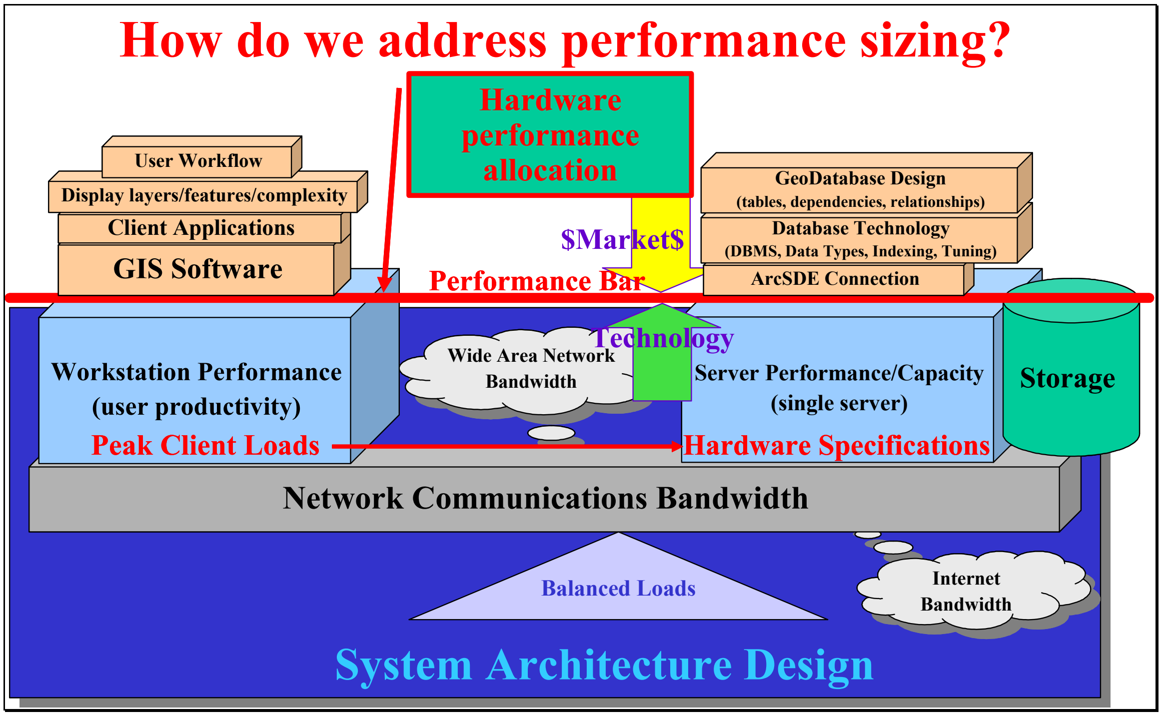
The final column shows the effect of upgrading the workstation CPU to one with twice the performance, reducing the workstation CPU processing time by 50 percent.

Hardware component investments contribute directly to user productivity, and the overall productivity of the organization. Computer technology is changing very rapidly, and the product of this change is higher performance and improved productivity at the user desktop. Organizations need to budget for this change, and make wise investments in their infrastructure portfolio to maintain high productivity in the workplace. A smart investment strategy pays very large dividends in supporting GIS operations.

7.2 How do we address performance sizing?

Figure 7-4 identifies some of the key factors that contribute to overall system performance. Proper hardware and architecture selection is one primary component of the overall system performance equation. There are many other performance factors that contribute to overall user productivity.

Figure 7-4
System Performance Factors



Improvements in any of the system performance factors will improve user productivity and impact total system performance capacity. Performance cannot be guaranteed by proper hardware selection alone. The sizing models described in this section were developed to support appropriate hardware selection, based on ESRI user business requirements. The performance allocation we have applied to the hardware components is based on over 10 years of experience supporting deployment of ESRI GIS technology. A balanced hardware investment, based on projected peak user loads on the systems, supports system performance requirements and saves money through properly targeted hardware purchases.

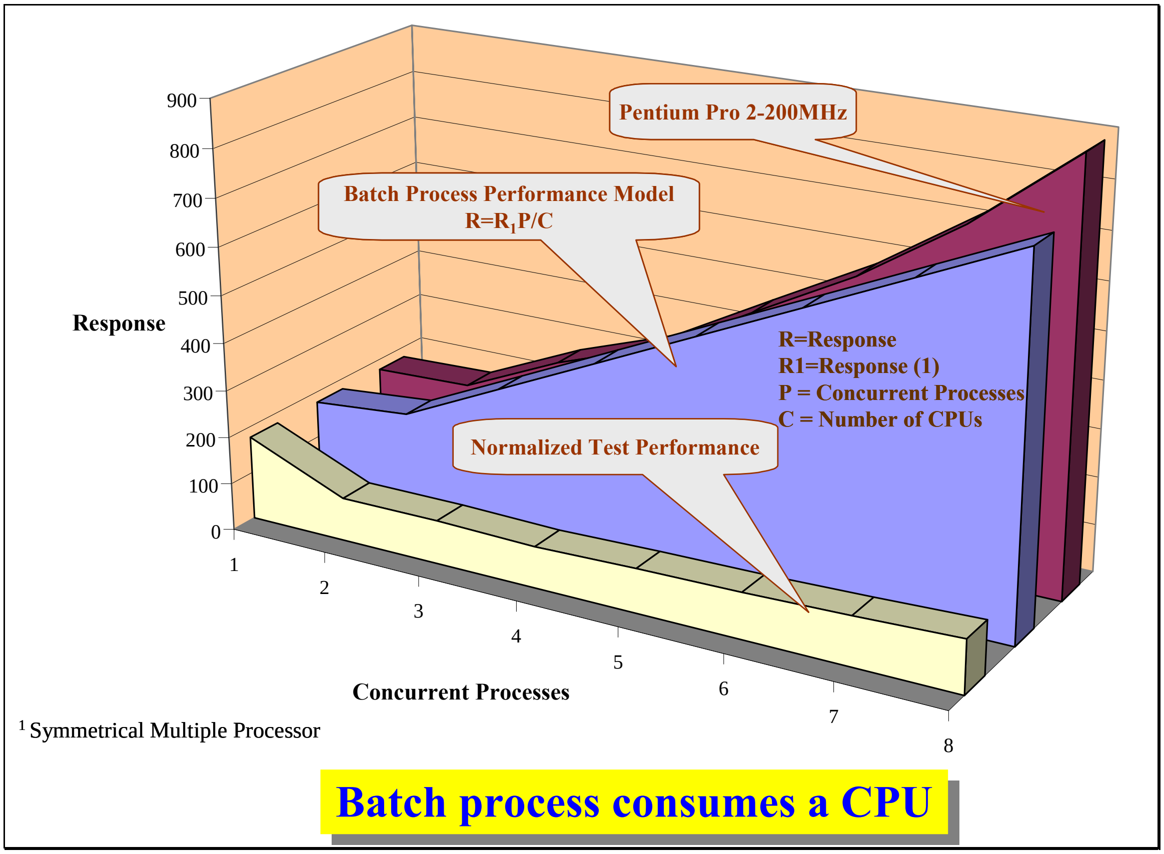
7.3 System Performance Testing

ArcInfo performance testing with the Microsoft Windows Terminal Server 4.0 Edition was conducted at the Data General development labs in Westborough, Massachusetts, in July 1998. This was an update of ArcInfo performance testing completed by ESRI in 1993. This performance testing provides a foundation for the sizing models used for configuring distributed GIS computing environments. The objectives of these models are to support proper selection and configuration of system hardware components for distributed GIS computing.

The ESRI system performance models are based on an understanding of how computer platforms respond to an increasing number of concurrent ArcInfo process loads. An ArcInfo performance benchmark is used to evaluate platform response to increasing user loads. Excessive memory was configured on each server platform (2-4 GB) to avoid paging and swapping of executables during the testing (recommended physical memory requirements are established by separate tests that measure memory allocated to support each application process).

Figure 7-5 provides a summary of the ArcInfo benchmark results from testing a dual-processor Pentium Pro 200 Windows Terminal Server.

Figure 7-5
Dual-Processor SMP Performance



An individual test was completed for each concurrent process configuration (1 through 8). The third-row graphic plots the average response time measured for each of the concurrent process test runs. The first-row graphic shows the rate at which the server platform was processing the ArcInfo instructions. The center row shows a plot of the sizing model for concurrent ArcInfo batch processing. The results of this test validate the ArcInfo design model, and demonstrate good Windows Terminal Server scaling performance with this platform configuration.

Figure 7-6 provides a summary of the ArcInfo benchmark results from testing a quad-processor Pentium Pro 200 Windows Terminal Server. An individual test was completed for each concurrent process configuration (1 through 16). The results of this test validate the ArcInfo design model, and demonstrate good Windows Terminal Server scaling performance with this platform configuration.

Figure 7-6
Quad-Processor SMP Performance

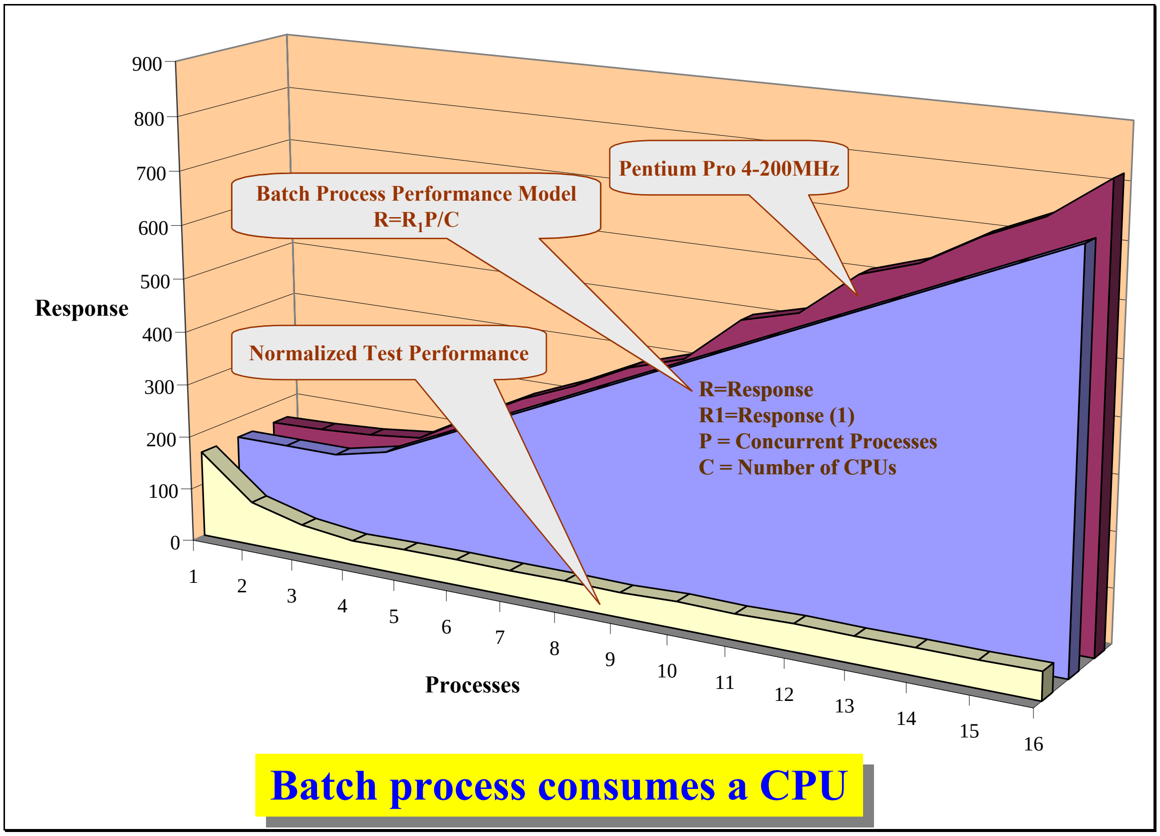
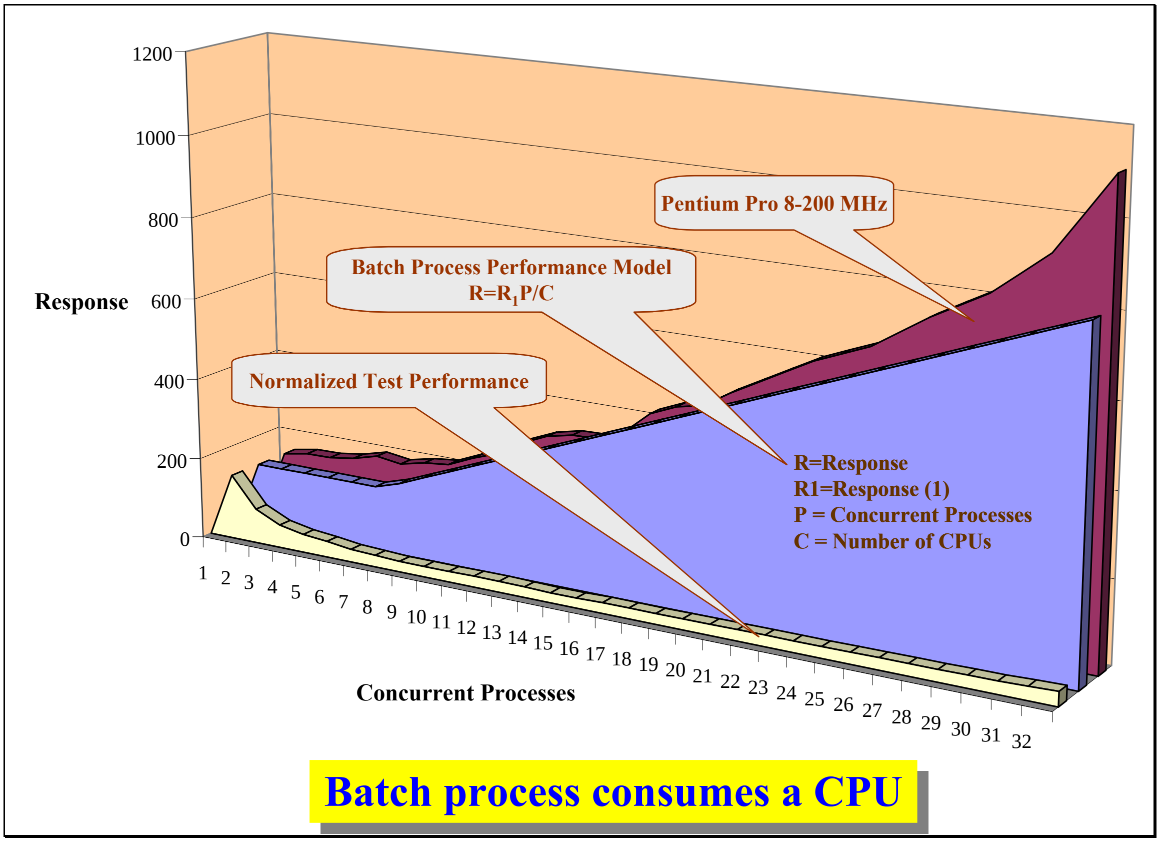


Figure 7-7 provides a summary of the ArcInfo benchmark results from an eight-processor Pentium Pro 200 Windows Terminal Server. An individual test was completed for each concurrent process configuration (1 through 32). The results of this test validate the ArcInfo design model, and demonstrate good Windows Terminal Server scaling performance with this platform configuration.

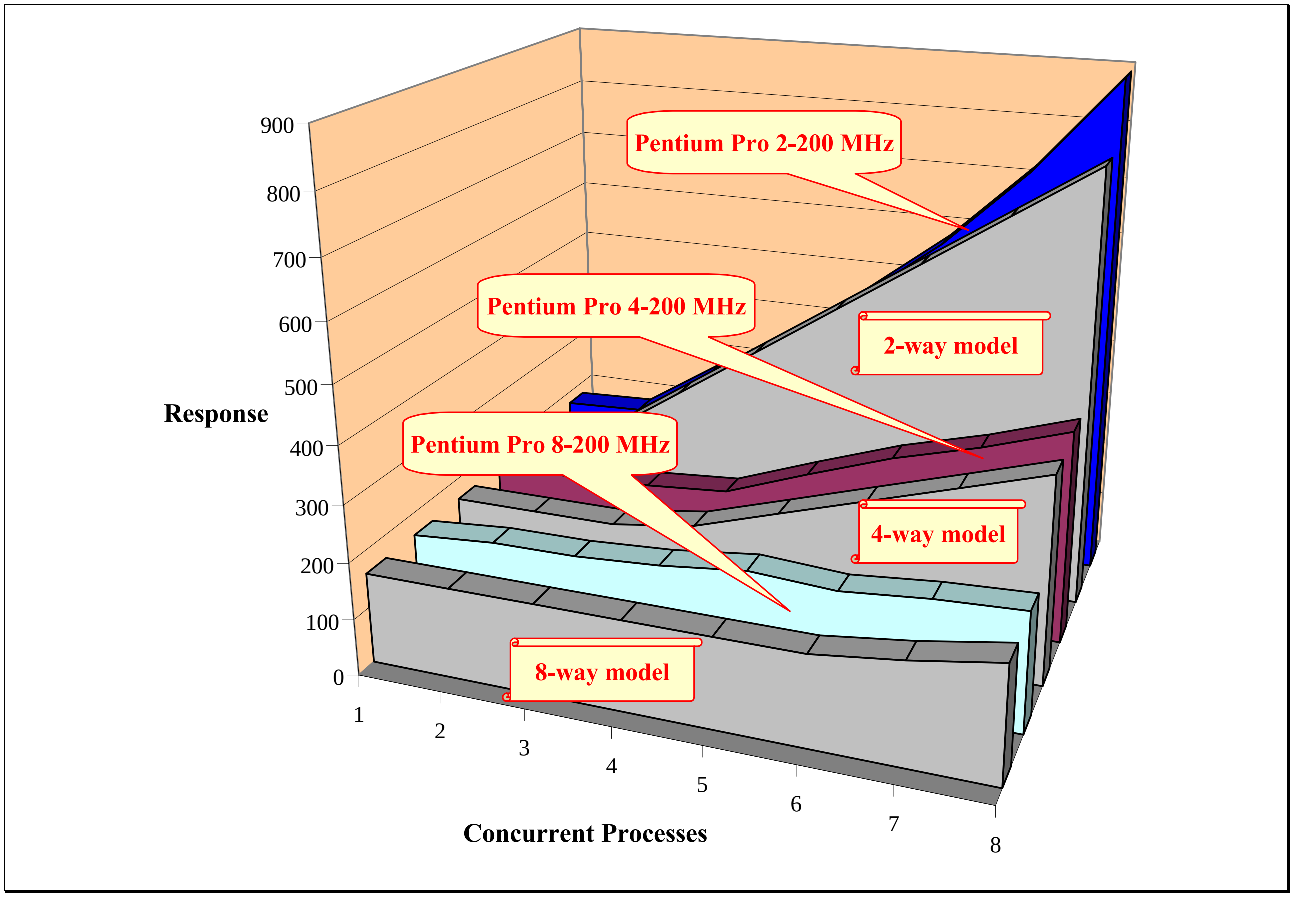
Figure 7-7
Eight-Way SMP Performance



Each benchmark test series was extended to evaluate platform support for four batch processes per CPU. The ArcInfo sizing model is seldom used to identify performance expectations beyond two concurrent batch processes per CPU. The sizing models perform very well at the lower range of these test series.

Figure 7-8 provides an overview of the Windows Terminal Server batch process testing. This same test series was conducted on a dual-processor UNIX platform (Sun Ultra 60). The performance scaling results (shape of the performance curve) for the UNIX application server testing was very similar to what we measured in the Windows server tests, suggesting performance scaling for Windows platforms through eight processors is similar to what we see with UNIX platforms.

Figure 7-8
Batch Processing Test Summary



7.4 Client/Server Models

Additional ArcInfo benchmark testing was conducted to evaluate processing performance with data located on a separate file server and on an ArcSDE server. The results of these tests provide a foundation for understanding distributed computing loads and developing our client/server computing performance sizing models.

7.4.1 Batch Processing Performance

Windows Terminal Servers. Figure 7-9 provides an overview of batch processing performance for symmetrical multiple processor (SMP) application server platforms (1- through 4-CPU configurations) accessing data located on a separate file server. Query processing is supported by the application server with data located on local disk or on a remote file server. Each batch process consumed the resources of a single CPU. The SMP operating system effectively distributes available processing loads across all CPUs. Performance remains the same until the number of concurrent batch processes exceeds the available number of CPUs. Performance slows at a relatively constant rate when the number of concurrent processes increases beyond the available CPUs.

Figure 7-9
Terminal Servers with File Server or Local Data

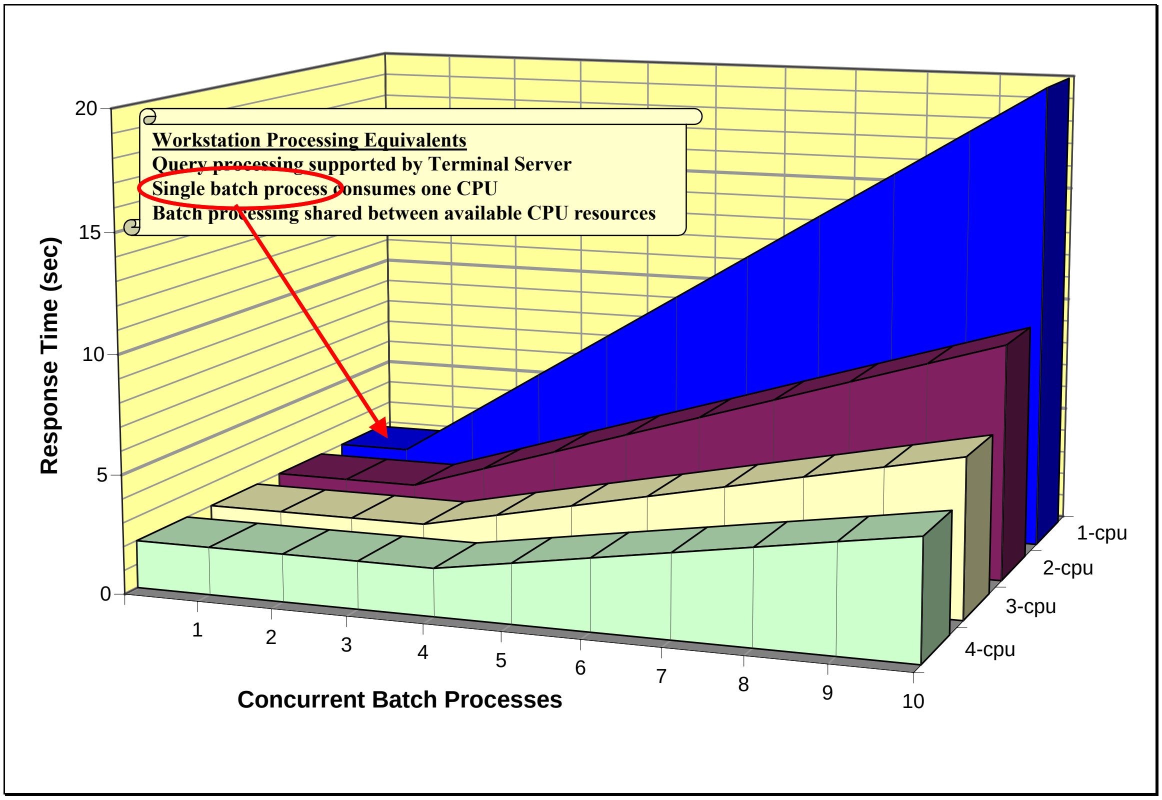
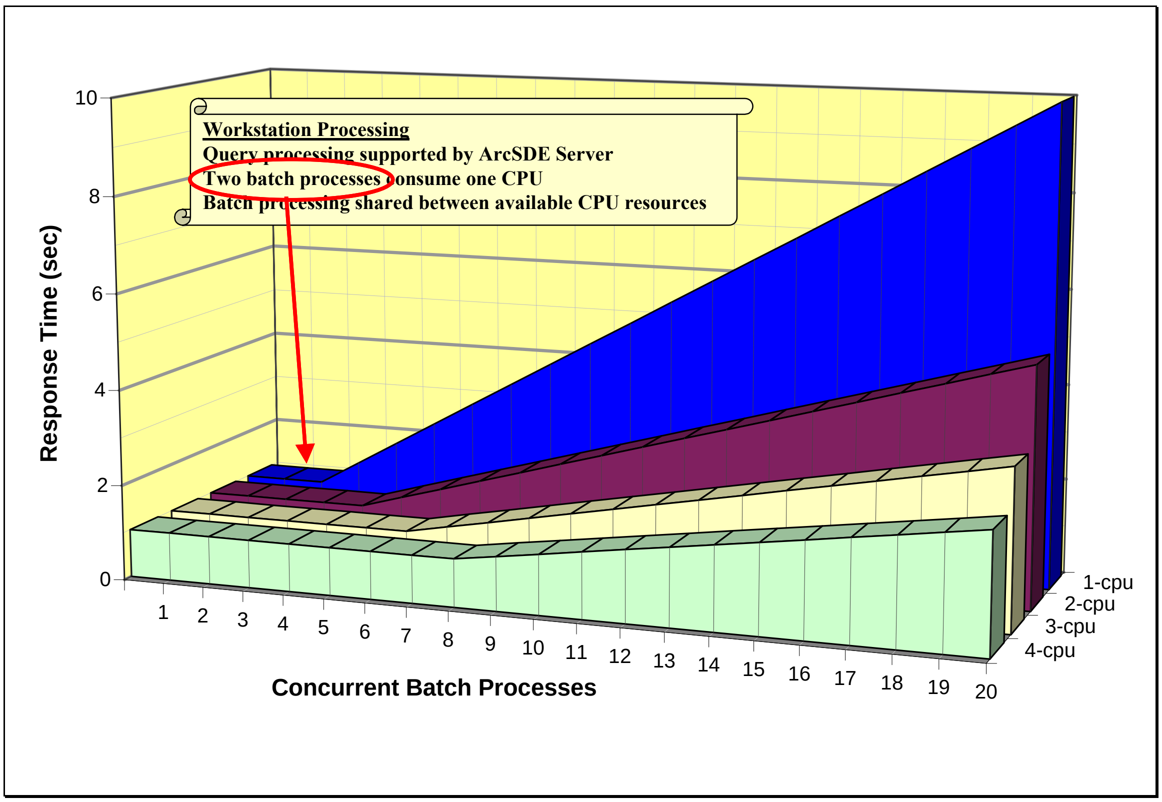


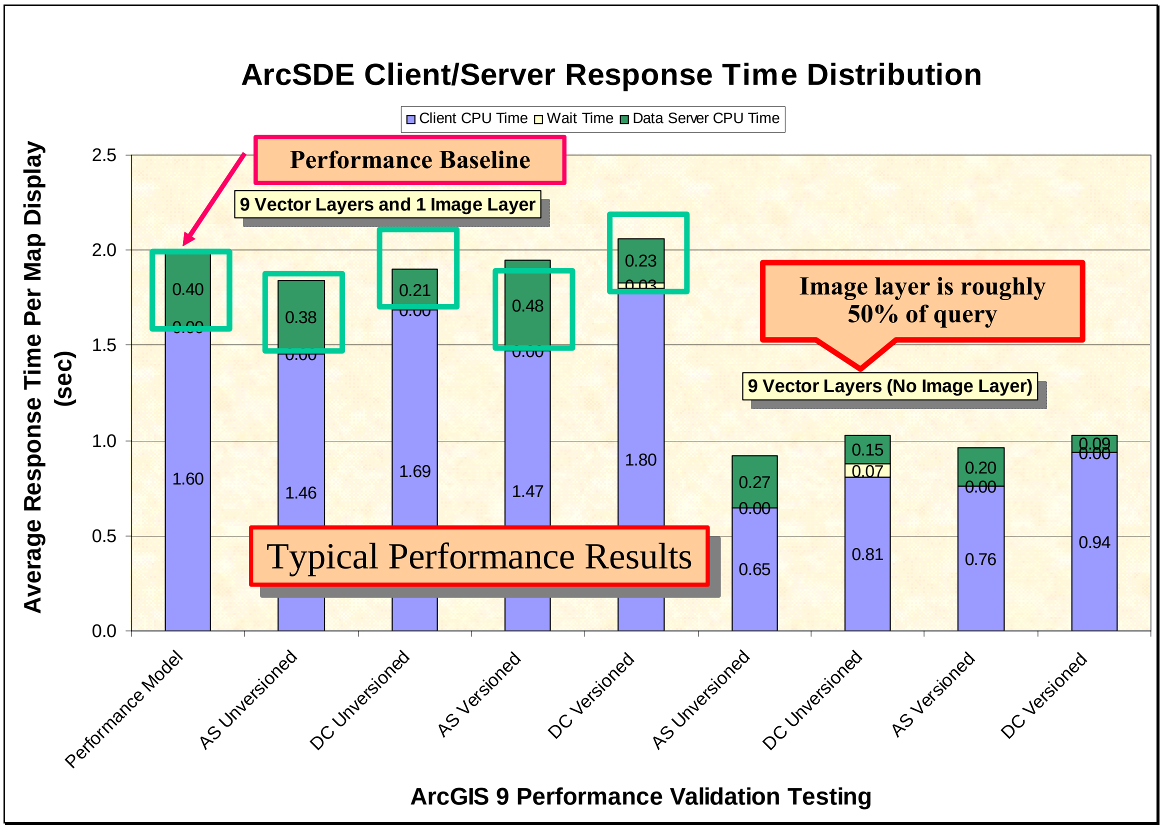
Figure 7-10 provides an overview of batch processing performance for SMP application server platforms (1- through 4-CPU configurations) accessing data located on an ArcSDE server. Query processing is supported by the ArcSDE server. Two batch processes are required to take full advantage of a single CPU. The SMP operating system effectively distributes available processing loads across all CPUs. Performance remains the same until the number of concurrent batch processing load exceeds the available CPU resources. Process response times will reduce at a relatively constant rate once the peak CPU processing capacity is reached – productivity will not increase when additional batch processes are introduced to the system beyond this point.

Figure 7-10
Terminal Servers with ArcSDE Data Source



ArcSDE Database Servers. Figure 7-11 provides a summary of ArcSDE client/server processing loads. The test results show roughly 20 percent of the distributed processing load (query processing) supported by the ArcSDE server, and roughly 80 percent of the processing load (map rendering) supported by the ArcGIS desktop client. This load distribution is evaluated during performance validation testing with each ArcGIS software release to help understand performance scalability risks.

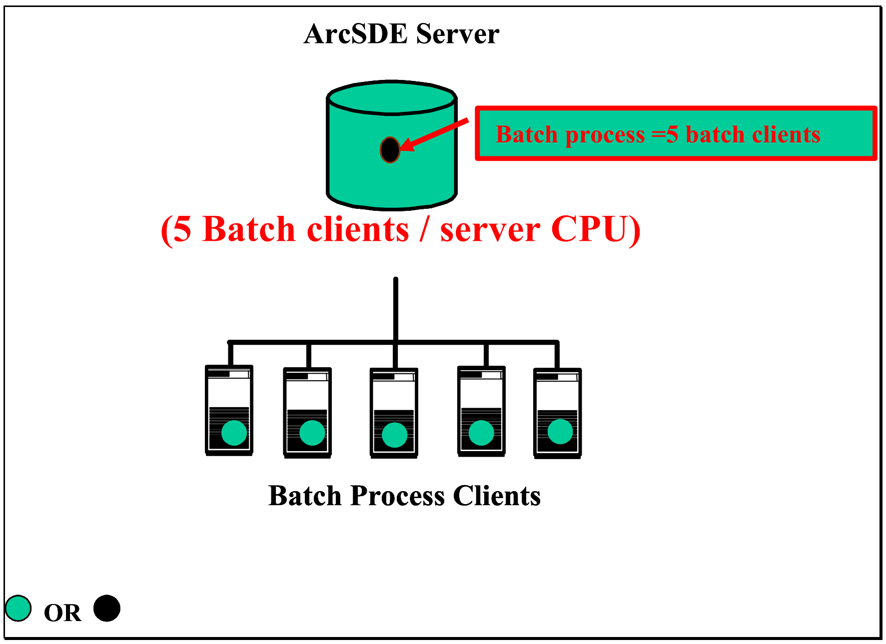
Figure 7-11
ArcSDE Data Server Loads



Query loads to an unversioned database performance better than queries to a versioned database. Application server connections (AS) represent configurations supported with ArcSDE on the database server environment, while ArcSDE direct connect (DC) represents connections using the ArcSDE Direct Connect API. The DC configuration supports ArcSDE gsvr processing on the client platform, which significantly reduces the required server load. The test results above were accessing an ArcSDE geodatabase with nine vector layers and one image layer. Results show roughly 50 percent of the total query load was supporting the image layer query.

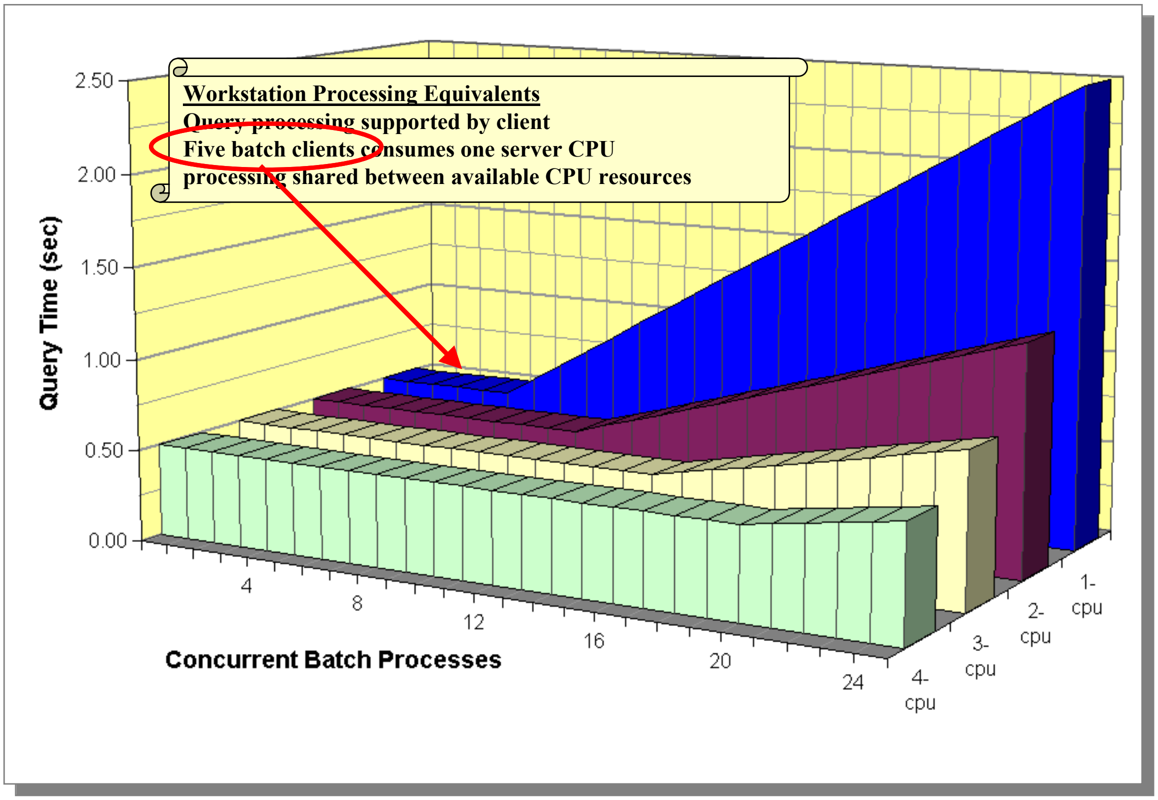
Figure 7-12 provides an overview of the ArcSDE data server sizing requirements for concurrent batch processing. The diagram shows a balanced distributed platform configuration, with server and workstation platforms having one CPU (all CPUs are the same). A single-CPU ArcSDE data server can support five batch client workstations. As a corollary, a batch process executed on the data server would be equivalent to five batch clients (either condition consumes a server CPU). Batch processes place considerable loads on the data server, and replace resources required to support client processing.

Figure 7-12
Data Server Performance Models



The ArcSDE data server performance model is provided in Figure 7-13. The model shows a single data server CPU supports up to five (5) concurrent batch clients for each server CPU. Additional clients supported by the server would result in reduced query performance. This performance profile clearly applies to compute-intensive ArcSDE server environments, where a variety of testing and real-life implementations has demonstrated the CPU-bound nature of the ArcSDE server environment.

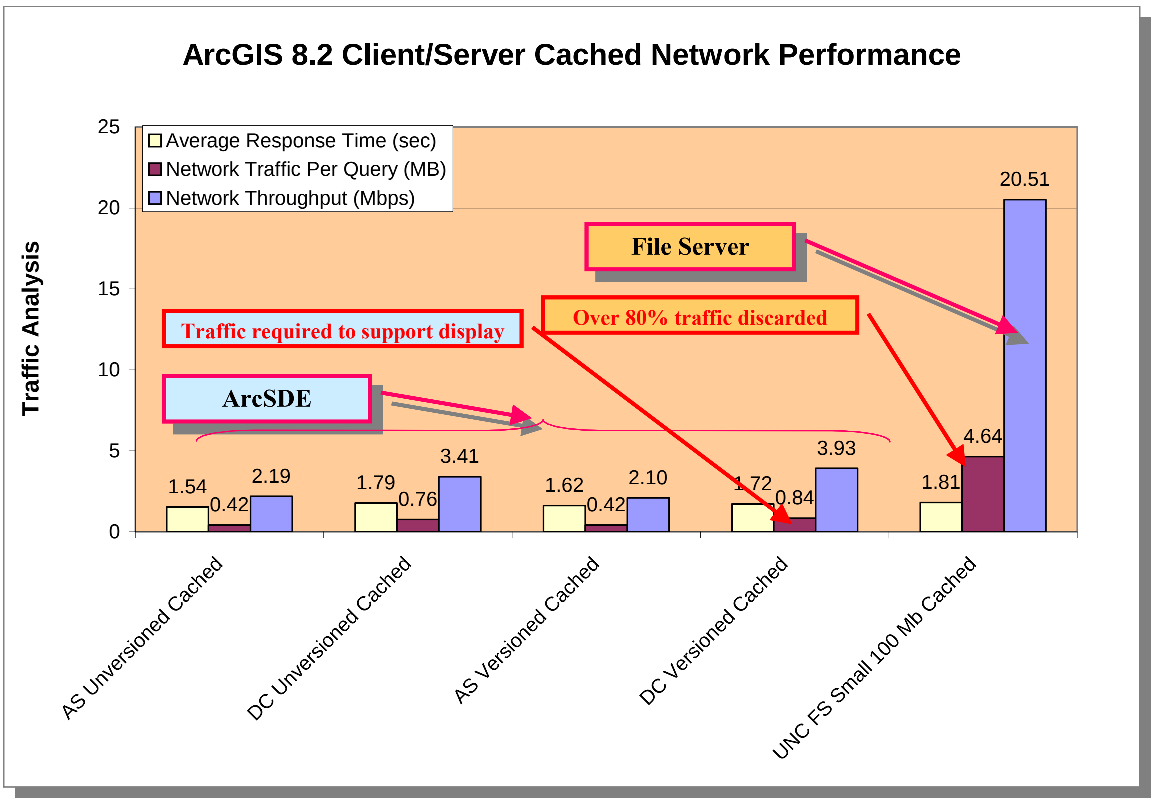
Figure 7-13
GIS Data Server Performance Model



GIS File Servers. The foundation for the file server model was based on several years of experience configuring distributed ArcInfo enterprise environments. File servers tend to show less CPU processing intensity, although quickly start to exhibit performance problems if standard sizing guidelines are not followed.

Figure 7-14 provides a summary of ArcSDE and file server test results, showing average response time, network traffic per query, and average network throughput measured during ESRI ArcGIS performance benchmark testing. This chart highlights the performance advantages of an ArcSDE data source. Over 80 percent of the data transferred from the file server to the client workstation are discarded, and are not required to support the map display.

Figure 7-14
ArcGIS Client/Server Network Traffic Analysis



The baseline performance test dataset used for the previous ArcSDE/file server performance comparison uses a subset of a larger San Diego dataset. The area of interest used for the performance validation tests is represented in Figure 7-15.

Figure 7-15
Performance Validation Test Dataset

Figure 7-16 compares client/server performance sensitivity to larger database environments. When running the same benchmark test with the complete San Diego database, the file data source tests show a significant increase in network throughput. This increase is expected, since the larger shapefiles must be transferred to the client workstation to support the query processing. The ArcSDE test results were the same as the previous chart, and are not effected by the size of the database.

Figure 7-16
ArcGIS File Server Network Throughput

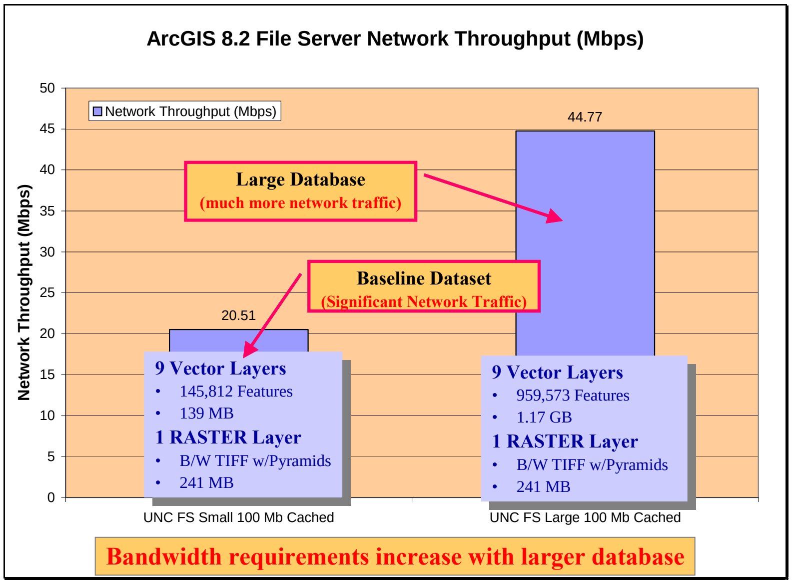
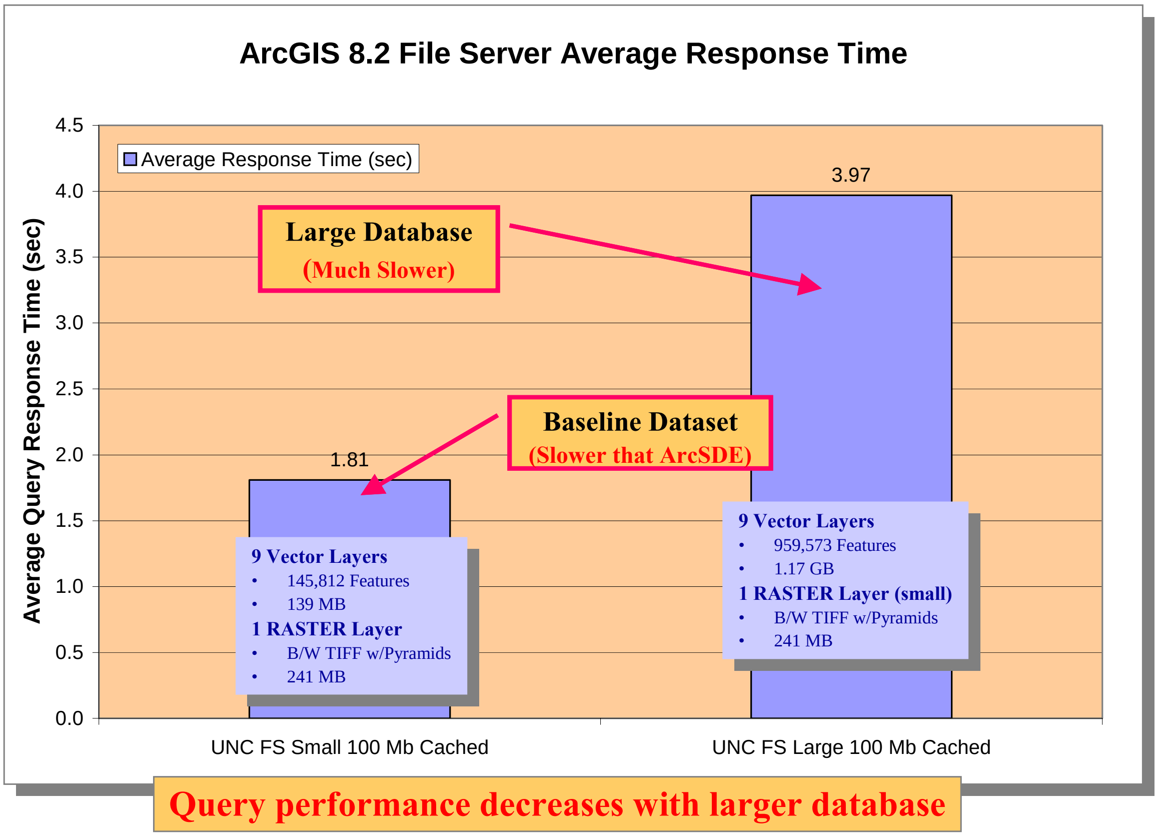


Figure 7-17 provides a summary of the average response time for the same benchmark test when using a file data source. Response time with the file data source is much slower due to the larger shapefiles. In comparison, very little difference in performance was measured with the ArcSDE data source testing.

Figure 7-17
ArcGIS File Server Network Performance



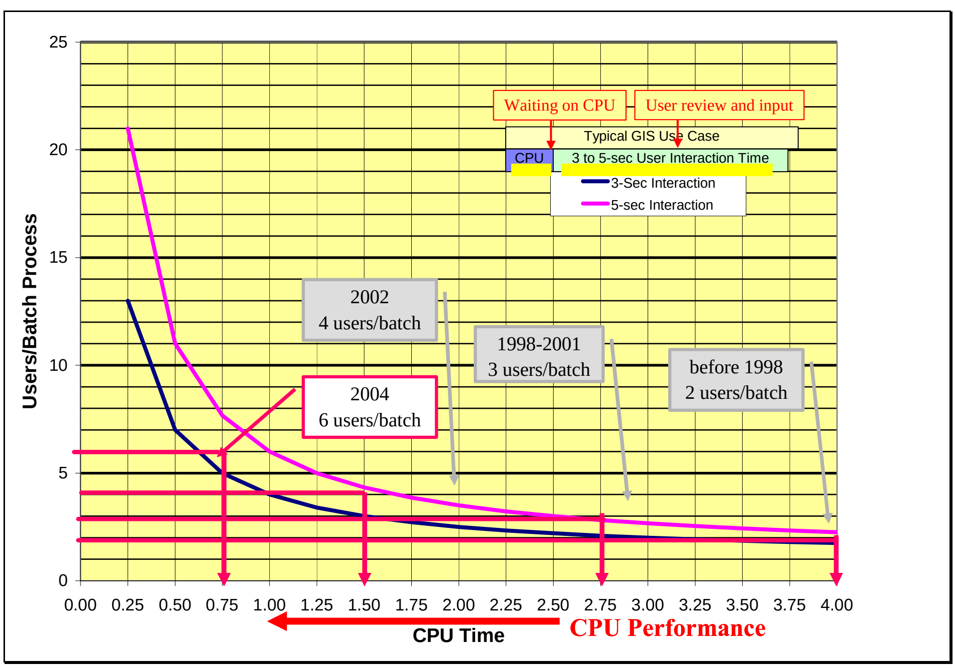
7.4.2 ArcGIS Desktop Terminal Server Performance

ArcGIS desktop users include a variety of professional analysts, data maintenance personnel, and business query and analysis specialists who use GIS to manage their data processing requirements. GIS project efforts can take minutes, hours, and sometimes several days to complete, including review of very large volumes of data resources during the project sessions.

User requirements can be used as a foundation for identifying the number of terminal sessions supported by the server during a peak processing period. The definition of a concurrent user (desktop use case) is based on comparison of real-life user loads on the system during live benchmark testing and reviewing real live operational GIS customer experiences.

Figure 7-18 provides an overview of a typical GIS use case, demonstrating how user performance (user experience) has changed as workstation performance has improved over the past 10 years. The standard use case applied to the ArcGIS performance models assumes a typical client display can be rendered within roughly 2 seconds, and the average user interaction time (time to review the display and enter data) is roughly 6 seconds. This results in an average user cycle time (between screen displays) of roughly 8 seconds. These assumptions establish the basis for translating our benchmark test results (batch process models) to sizing models for real interactive user environments. For the ArcGIS performance models, users wait on CPU processing about 12 percent of the time. With these assumptions, a single ArcGIS desktop batch process provides the equivalent processing load of six concurrent ArcGIS desktop clients.

Figure 7-18
ArcGIS Use Case Parameters

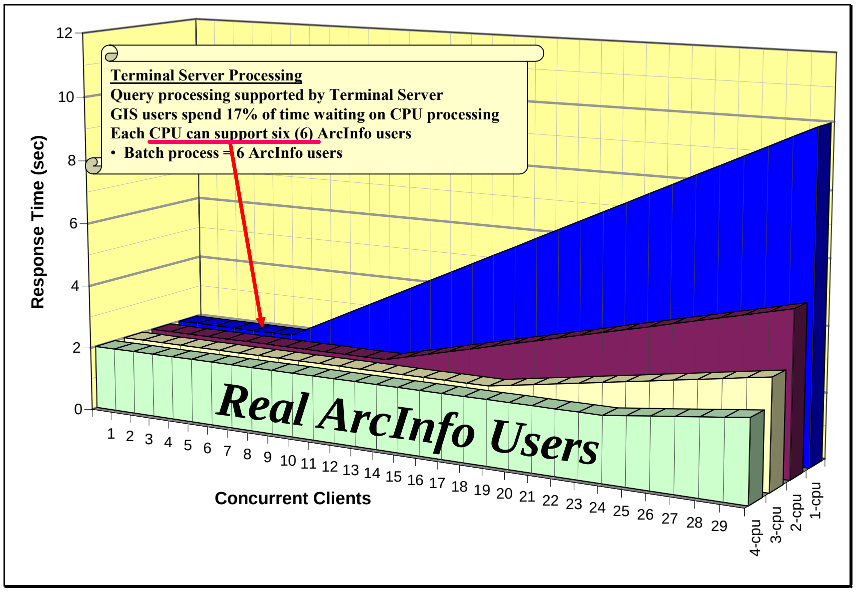


The amount of time it takes a typical user to view a new display and enter appropriate data for the next display (user interaction time) is the fundamental difference between batch processing (no user interaction) and a real user work environment. GIS processing is compute intensive, resulting in users routinely waiting on computer processing during normal operations. The sizing models used prior to 1999 (Arc95 through Arc98) assumed ArcInfo users had to wait about 50 percent of their time for computer processing (terminal servers could support two users per CPU). Computing performance has increased over ten times what was available five years ago. GIS operations have become more productive during this same period. The Arc99, Arc00, and Arc01 performance models assume GIS concurrent users wait on CPU processing 33 percent of the time, while the remaining time is spent on data review and input. The Arc02 and Arc03 models assumed users wait on CPU processing 25 percent of the time. The Arc04 models are assume users wait on CPU processing 12 percent of the time (platform performance doubled during the past year).

Platform performance has improved every year, and this technology improvement trend is expected to continue for the foreseeable future. As platform processing performance improves, the time GIS users wait on CPU processing will decrease and operational productivity may improve. At some point, which may already be the case, user interaction time will reach a minimum required response time based on user performance limitations. As the CPU processing time continues to decrease faster than the user interaction time, the relationship between batch processes and real interactive users will continue to improve.

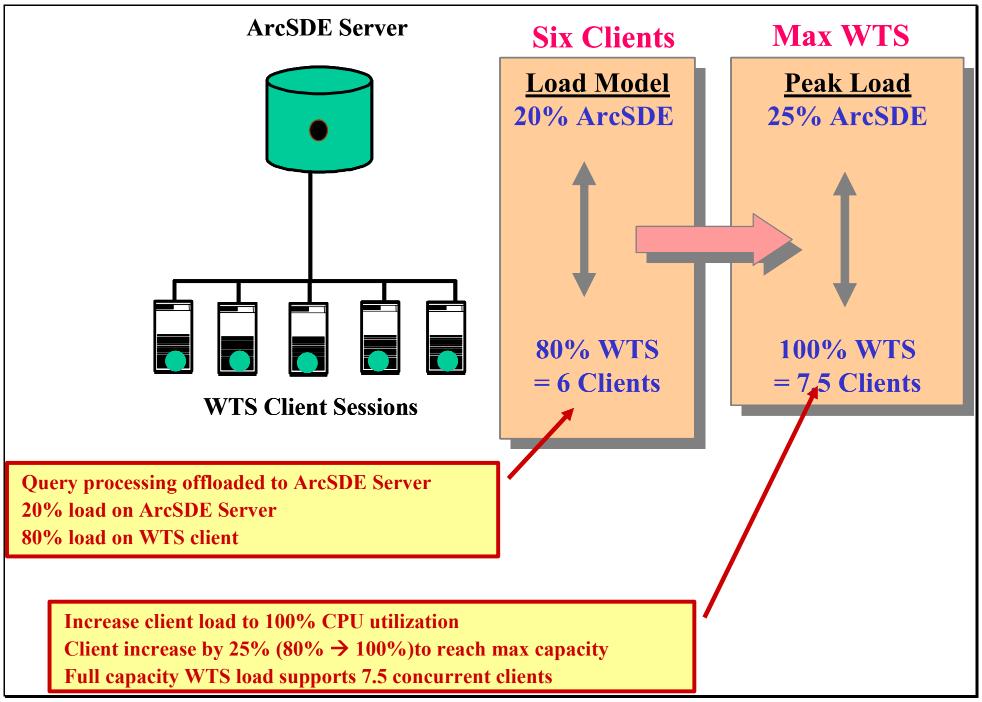
Figure 7-19 provides an overview of the current terminal server performance model for a local disk or file server data source. Each CPU can support six (6) ArcInfo users, thus, performance will stay roughly the same until the total number of users exceed six (6) times the number of CPUs. Performance slows at a relatively constant rate when the number of concurrent users increases beyond six (6) times the number of available CPUs.

Figure 7-19
Terminal Server with File Server or Local Data



The Windows Terminal Server load is decreased when ArcSDE is used as a data source and query processing is supported by the ArcSDE data server. Figure 7-20 shows the impact of this load distribution on the Windows Terminal Server platform processing capacity.

Figure 7-20
Windows Terminal Server Load Analysis



When using an ArcSDE data source, 20 percent of the processing is supported by a separate ArcSDE server platform. Increasing the WTS processing load to 100-percent capacity would accommodate 25 percent more user load (80% → 100% CPU utilization). The WTS 100-percent peak capacity load is reached when the WTS platform is supporting 7.5 ArcGIS users (increase of 25% over the file server load).

Figure 7-21 provides an overview of the current terminal server performance model with data on a remote ArcSDE server. The ArcSDE server supports query processing, reducing each user load on the terminal server by 20 percent. Each CPU can support 7.5 ArcGIS Desktop users, and performance will stay roughly the same until the total number of users exceeds 7.5 times the number of CPUs. Performance slows at a relatively constant rate when the number of concurrent users increases beyond 7.5 times the number of available CPUs.

Figure 7-21
Terminal Server with ArcSDE Server

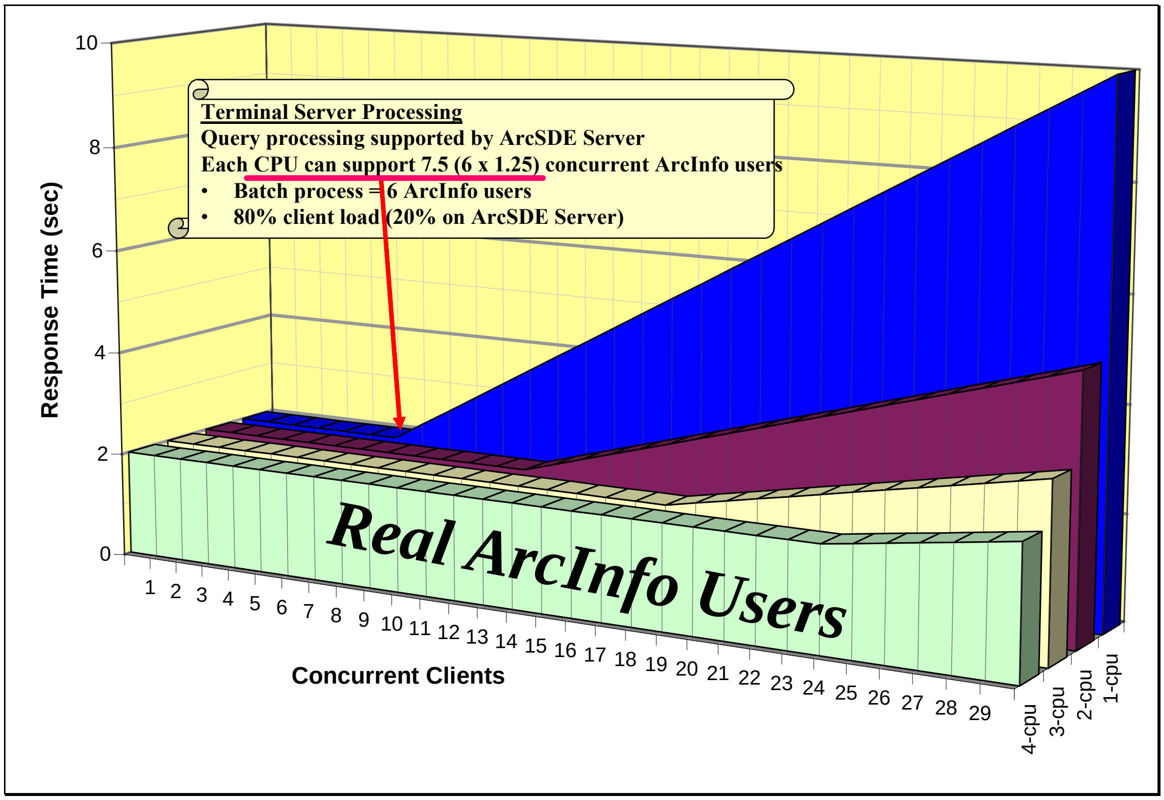
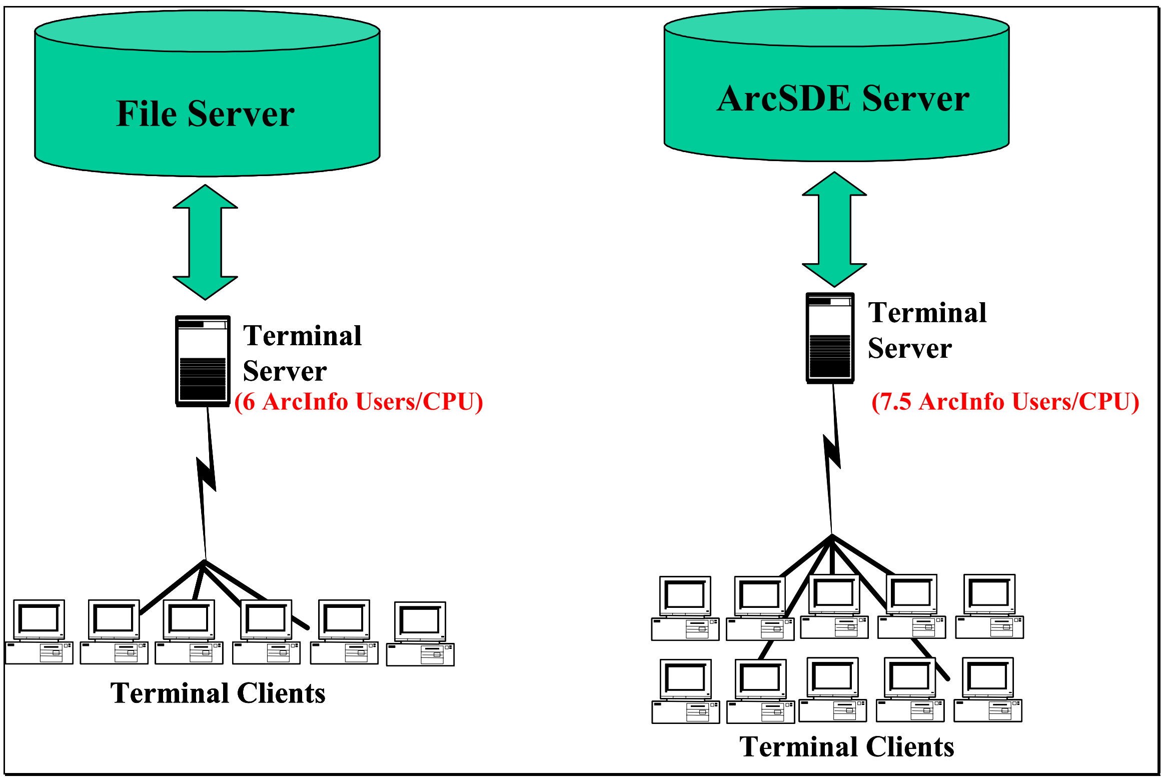


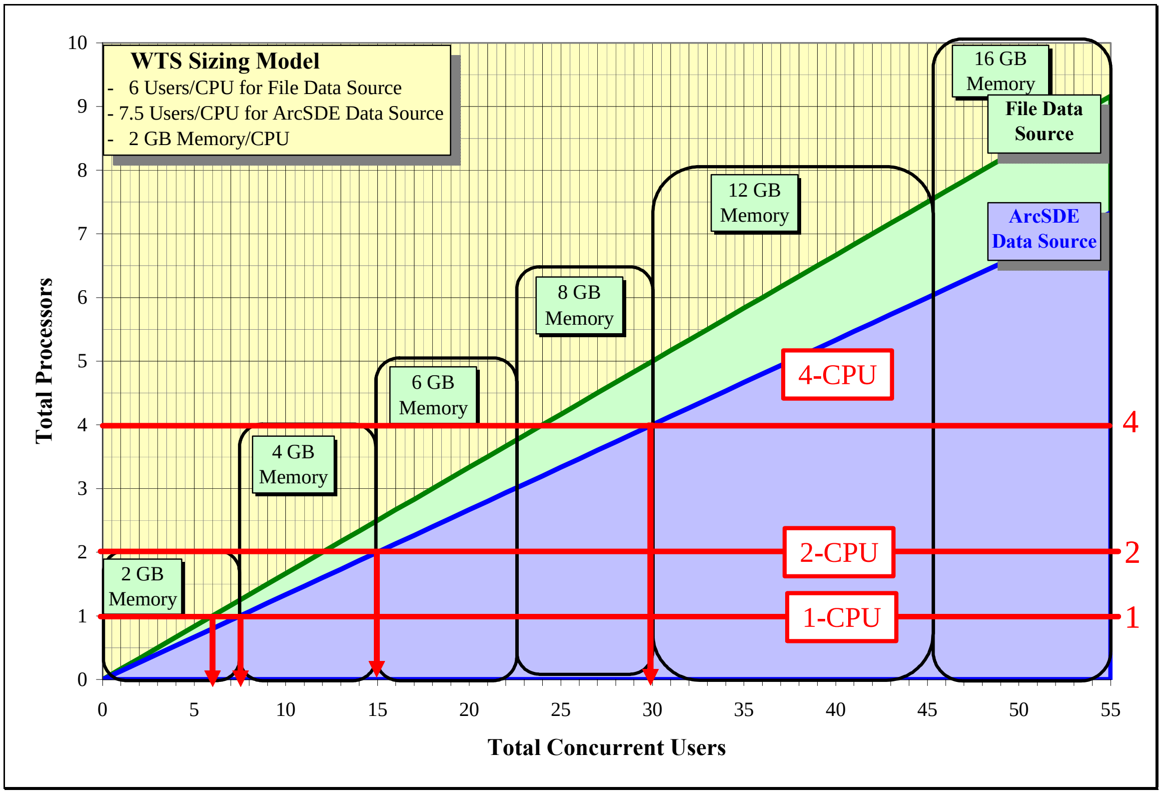
Figure 7-22 provides an overview of the terminal server sizing models based on configuring a system with the same single-CPU servers. Six (6) ArcGIS Desktop users can be supported per CPU when accessing data on local disk or a separate file server; and 7.5 ArcGIS Desktop users can be supported per CPU when accessing data on an ArcSDE server.

Figure 7-22
Terminal Server Performance Model



The CPU sizing chart in Figure 7-23 provides a visual representation of the terminal server CPU sizing model.

Figure 7-23
Terminal Server CPU Sizing Chart



The chart identifies the number of terminal server platform CPUs on the vertical axis, and the total number of peak concurrent users on the horizontal axis. Platform configurations (dual-CPU platform, quad-CPU platform) are represented by horizontal lines on the sizing chart (based on number of CPUs in the platform configuration). The performance sizing models are represented by diagonal lines on the chart (6 users per CPU for a file data source, 7.5 users per CPU for an ArcSDE data source). Memory requirements are also shown on the chart, based on the number of concurrent users and appropriate platform memory configurations.

7.4.3 Data Server Performance

Data server client performance is an extension of the models introduced with batch processing. There are two primary types of GIS data servers. File servers support simple query processing from the client workstation. ArcSDE servers incorporate high-performance geodatabase solutions that support query processing on the data server platform.

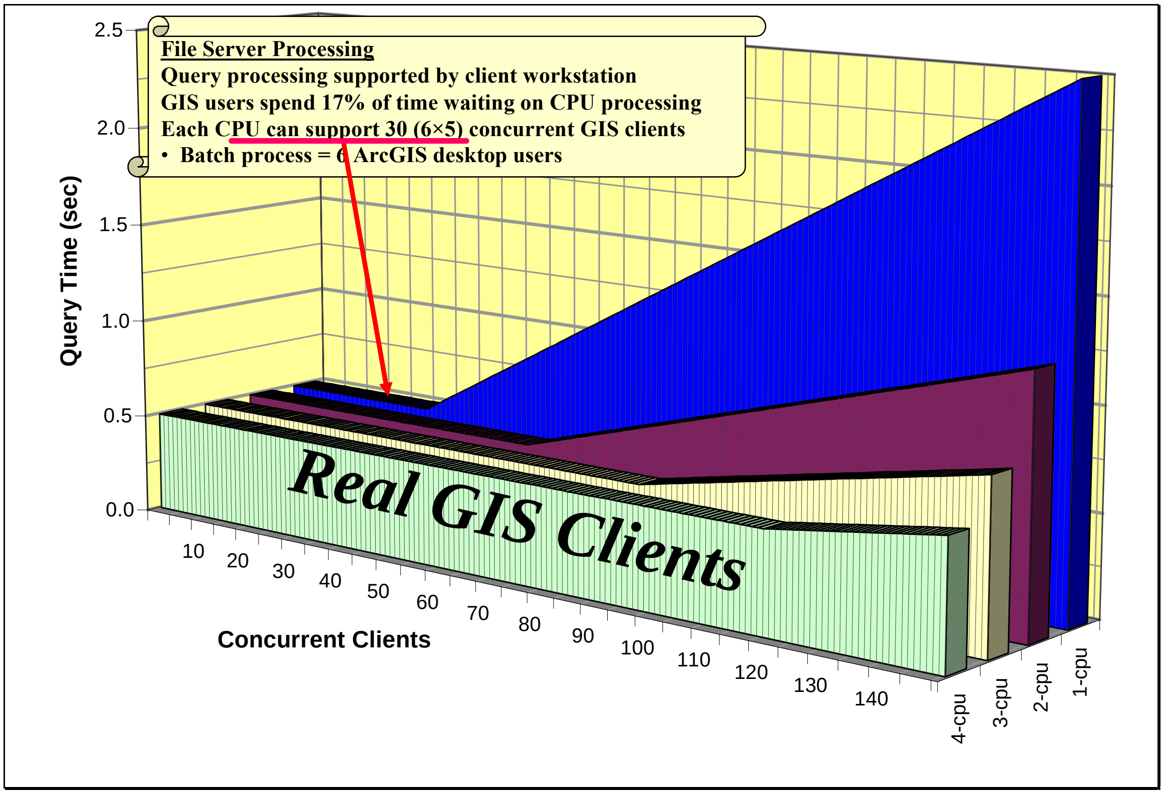
The GIS file server model has supported effective system sizing requirements for GIS workgroup environments since the early 1990s. Customers that have followed these design guidelines have been able to support their server capacity requirements. File server performance is directly related to the size of the files supporting the client query. Smaller files (spatial files with an extent relatively close to the size of the query display) will perform very well from a file server, and very little performance gain will be achieved with migrating these data to an ArcSDE server environment. On the other hand, larger data files (spatial files much larger than the average user query display) will see a significant performance benefit when migrating these data to an ArcSDE server environment.

The ArcSDE data server provides the most scalable and highest performance GIS data source. Server query processing takes advantage of high-performance DBMS query functions and optimized data caching, reducing the overall server processing load and improving data access performance. ArcSDE is a logical choice for larger enterprise data sources and operational system environments.

The performance model supports six (6) users per batch process, and each GIS data server CPU can support five batch processes. The GIS data server performance model will support 30 (5 x 6) concurrent ArcGIS desktop "real user" clients per CPU. Server query performance will remain roughly the same until data server clients exceed 30 times the number of available CPUs. Performance slows at a relatively constant rate when the total number of clients increases beyond 30 times the number of available CPUs.

Figure 7-24 provides an overview of the current ArcSDE data server performance sizing model.

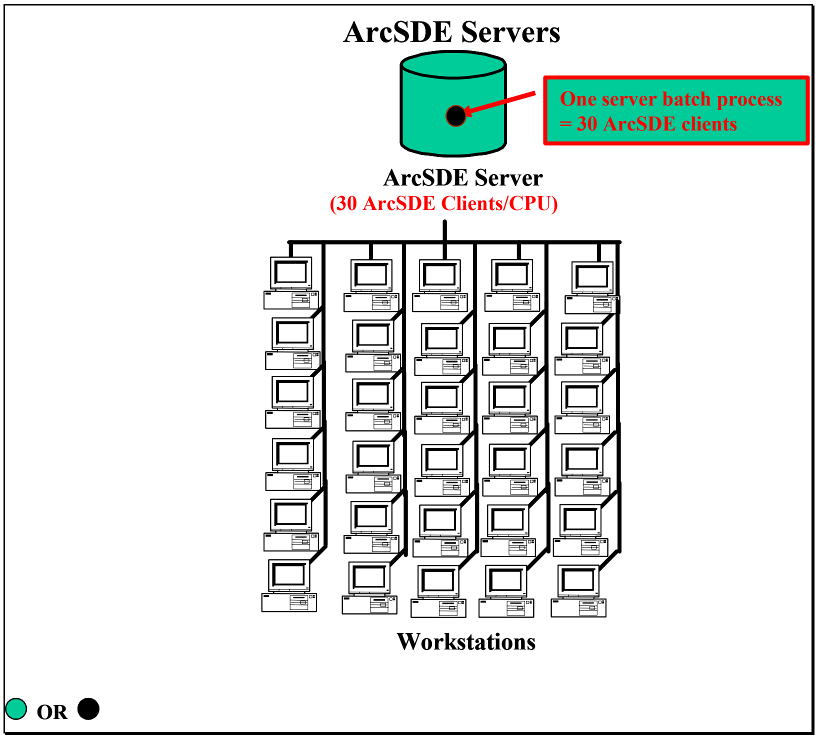
Figure 7-24
ArcSDE Server Performance



ArcSDE geodatabase performance is somewhat dependant on the complexity of the data model. The object-relational geodatabase provides a rich environment for establishing data standards and spatial feature dependencies. Relationships between geodatabase tables can generate additional server loads during edit and query operations. Simple data models will perform better than the more complex geodatabase environments. Also, versioned database environments require more server load than non-versioned feature data sets. Several additional tables are included in a versioned query, which results in increased processing load on the server. ArcSDE performance tuning can be very effective, and performance considerations should be an integral part of database planning and administration.

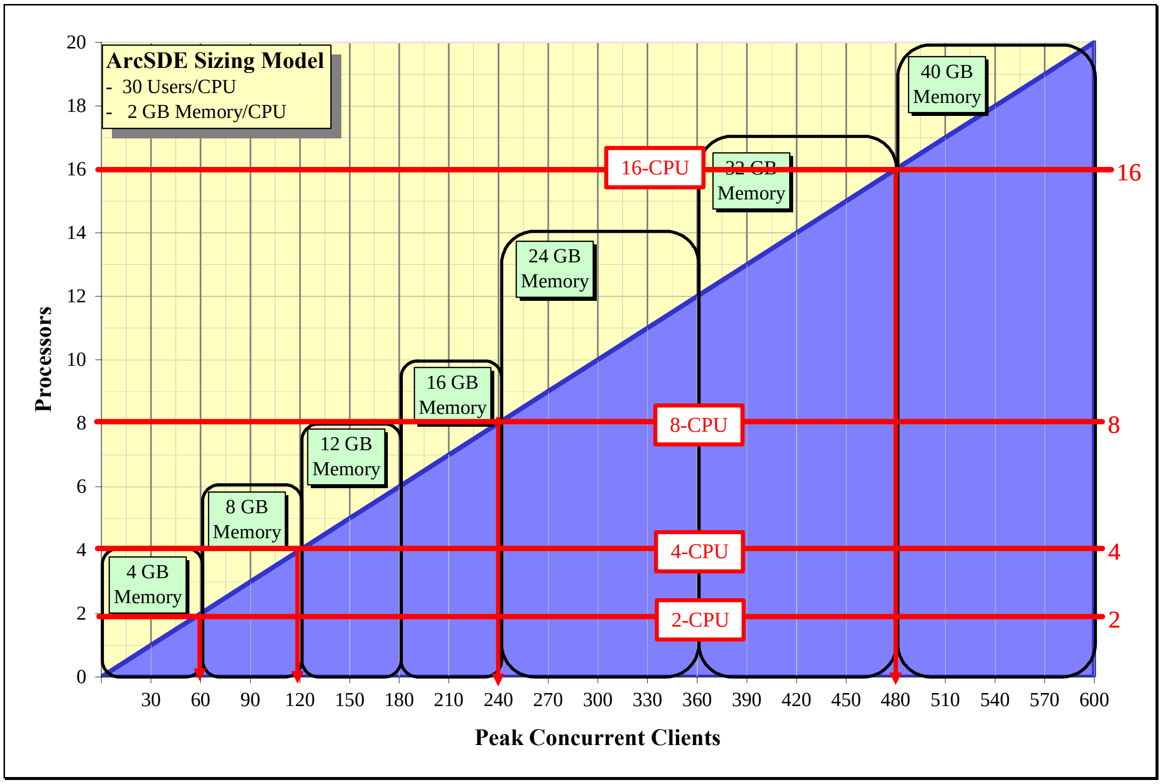
Figures 7-25 provides an overview of the data server sizing models based on configuring a system with the same single-CPU servers. A single-CPU GIS data server can support 30 GIS clients (a batch process located on the data server will take the place of 30 clients).

Figure 7-25
ArcSDE Server Performance Summary



The chart in Figure 7-26 provides a visual representation of the ArcSDE server CPU sizing model.

Figure 7-26
ArcSDE CPU Sizing Chart



The chart identifies the number of server platform CPUs on the vertical axis, and the total number of peak concurrent clients on the horizontal axis. Platform configurations are represented by horizontal lines on the sizing chart (based on number of CPUs in the platform configuration). The performance sizing model is represented by a diagonal line on the chart. Memory requirements are also shown on the chart, based on the number of concurrent clients and appropriate platform memory configurations.

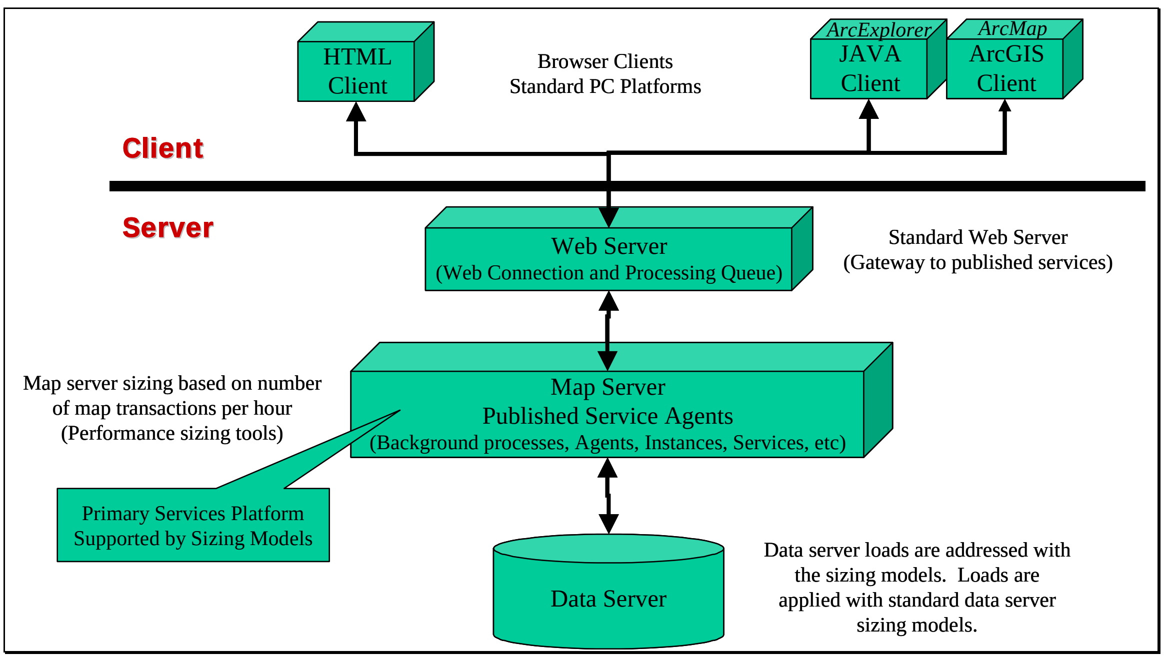
7.5 ArcIMS Web Map Services Models

ArcIMS Web services provide a transaction-based computing environment. Service agents (ArcIMS spatial servers) are installed on map server platforms to support browser client requests for map services (i.e., create a map product). These map services are published (connected to the Web server) to support browser client Web service requests. Each map service can be considered a published map template that is processed by ArcIMS spatial server batch processes to support service requests from a browser client. Each client transaction generates a new map product.

The Web services architecture is a departure from traditional application environments, where user sessions are supported by dedicated executables (programs) running on workstations or application servers. Web services support random client requests (transactions), supporting a large number of users with a single service engine (background process).

Figure 7-27 provides an overview of the typical platform components supporting an ArcIMS Web site. Clients can be simple HTML-based browsers or more sophisticated client applications with access to the Web server. ArcIMS provides a Java client (ArcExplorer) that can be supported by a client browser to support an enriched client application environment. ArcIMS servers can also support basic HTML client browsers. ArcGIS clients (ArcInfo, ArcEditor, and ArcView 8.1) can access ArcIMS services as an intelligent browser client.

Figure 7-27
ArcIMS Platform Architecture



Several server components work together to support map services. The primary Web services components include the Web server, map server, and data server.

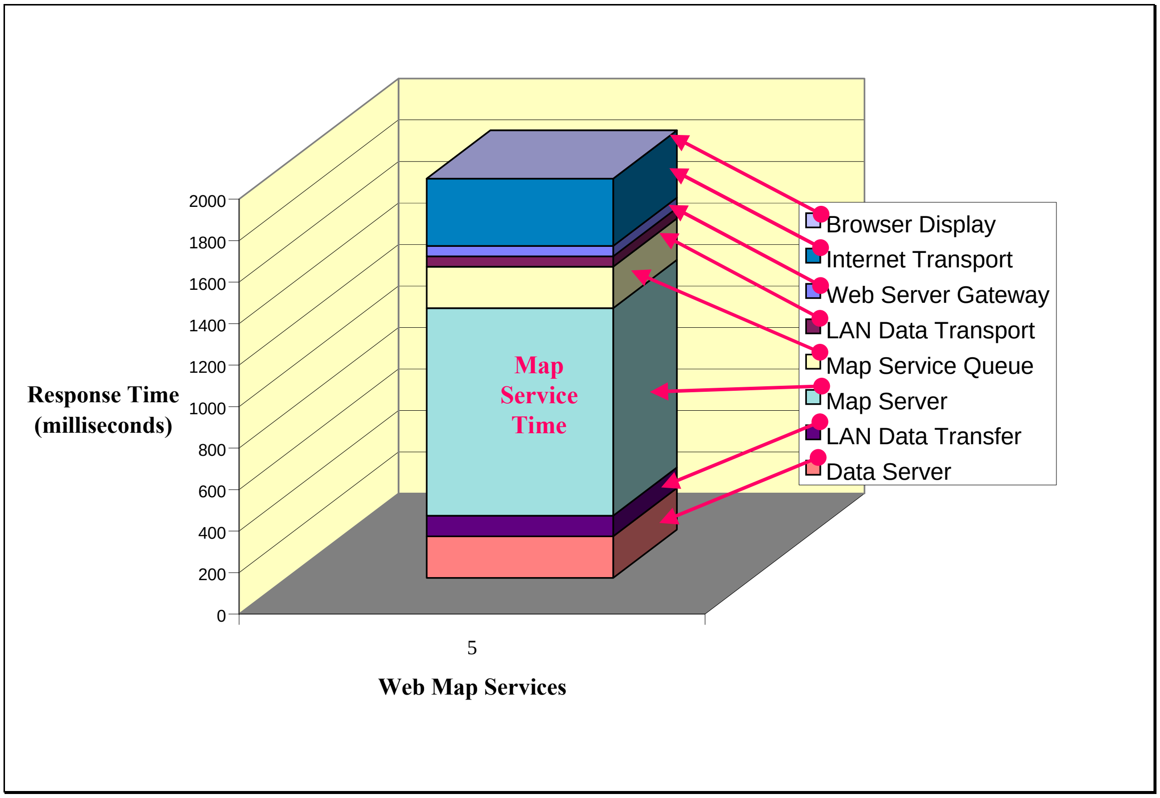
The Web server connects the browser clients with the ArcIMS map services. The specific ArcIMS Java servlet connectors and map service processing queues are typically installed on this platform.

The map server supports most of the ArcIMS processing load for the Web site. The map server includes the executables that service the map request (create the map product). For larger sites, this is typically a dedicated server or cluster of servers supporting the spatial server executables.

Data can be installed on the map server, or accessed from a separate GIS data server. A separate server is normally used for larger sites with multiple map server platforms.

Figure 7-28 provides a sample performance profile representing the life of a typical map service request. This graphic provides an overview of the platform and network loads associated with processing a Web transaction and delivering the HTML page and graphic image to the client browser.

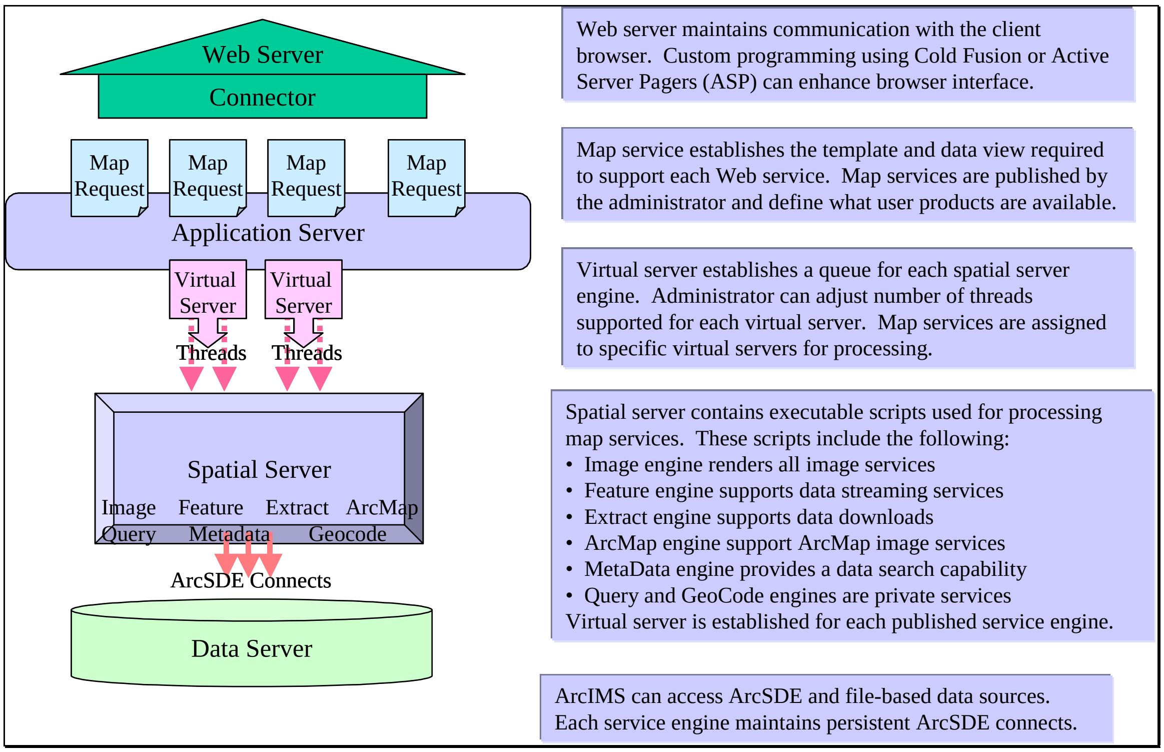
Figure 7-28
Map Services Performance Profile



7.5.1 ArcIMS Server Components

The ArcIMS software components provide a variety of configuration alternatives that support the Web services environment. Figure 7-29 identifies the ArcIMS software components and where they are supported in the system platform architecture.

Figure 7-29
ArcIMS Server Components



The ArcIMS server is supported by the following functional components:

- **Web Server.** The Web server manages the interface and translation between the external network client communications and the ArcXML communications supporting the ArcIMS services. Web server components include Java connectors that translate HTTP XML traffic to ArcXML service requests.
- **Application Server.** The ArcIMS application server component establishes a physical location for the virtual servers. A virtual server is established for each ArcIMS service engine supported by the site environment (Image Virtual Service, Feature Virtual Service, etc.). The virtual server is registered with the all the ArcIMS service engine threads supporting the designated service, and provides a waiting queue for inbound service requests and assigns these requests to available service threads for processing. Each inbound map service is assigned to the appropriate virtual server for processing, and waits in the queue until an agent thread is available to service the request.

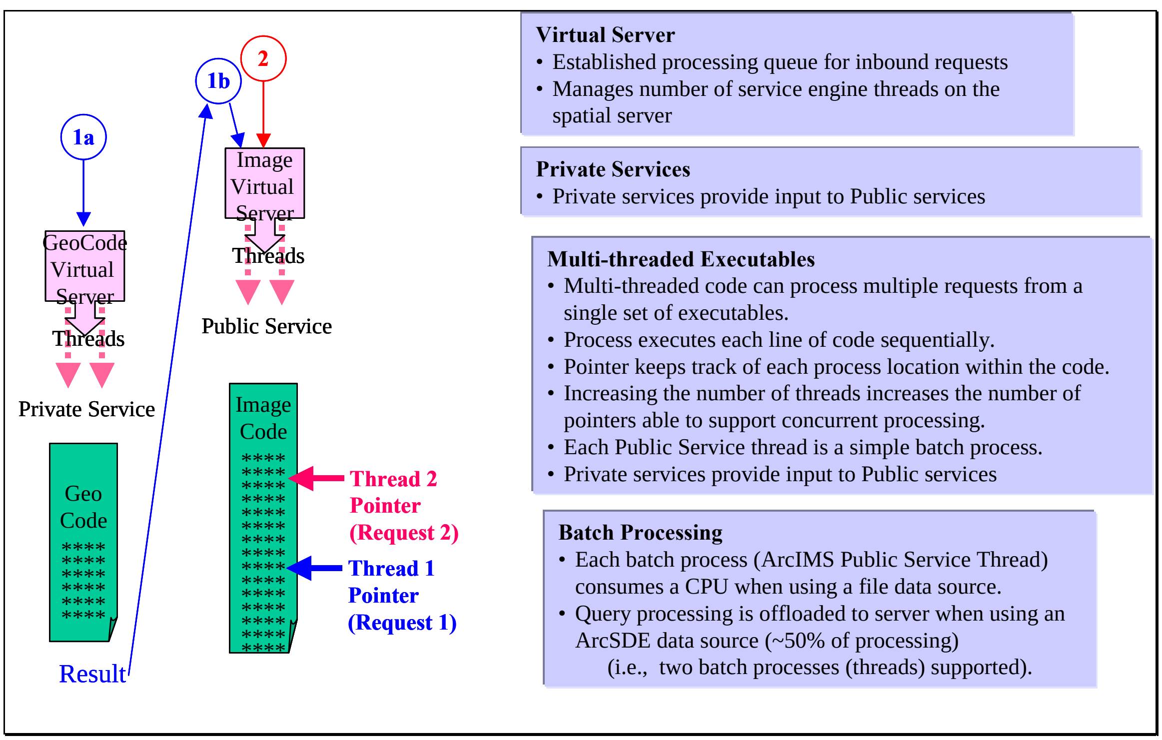
- **Spatial Server.** The ArcIMS spatial server, or map server, provides the "container" for the ArcIMS service engines that process the inbound map service requests.
- **Data Server.** The ArcIMS service engines can access local shapefile, image, and ArcSDE data sources. The service engines support query processing for local shapefile and image data sources. The ArcSDE DBMS supports query processing for ArcSDE data sources. An ArcSDE for Coverages interface is provided to support access to ArcInfo coverage files.

ArcIMS is a transaction-based service, configured to support requested services as they arrive at the site. Each request is processed using preconfigured background scripts with persistent connections to the associated data source. During the service time, these scripts consume CPU resources the same as any other batch process. These scripts are idle when not processing requests. During peak processing loads, requests are held in a processing queue and assigned for processing as each script completes delivery of the previous request.

7.5.2 ArcIMS Multi-threaded Service Engines

The ArcIMS service engines located on the spatial server are compiled as multi-threaded executables. This means each executable can be configured to process multiple requests with a single set of code. This type of configuration simplifies site tuning and reduces the amount of executables supported by platform memory. Figure 7-30 provides a depiction of how multi-threaded executables can process concurrent multiple requests.

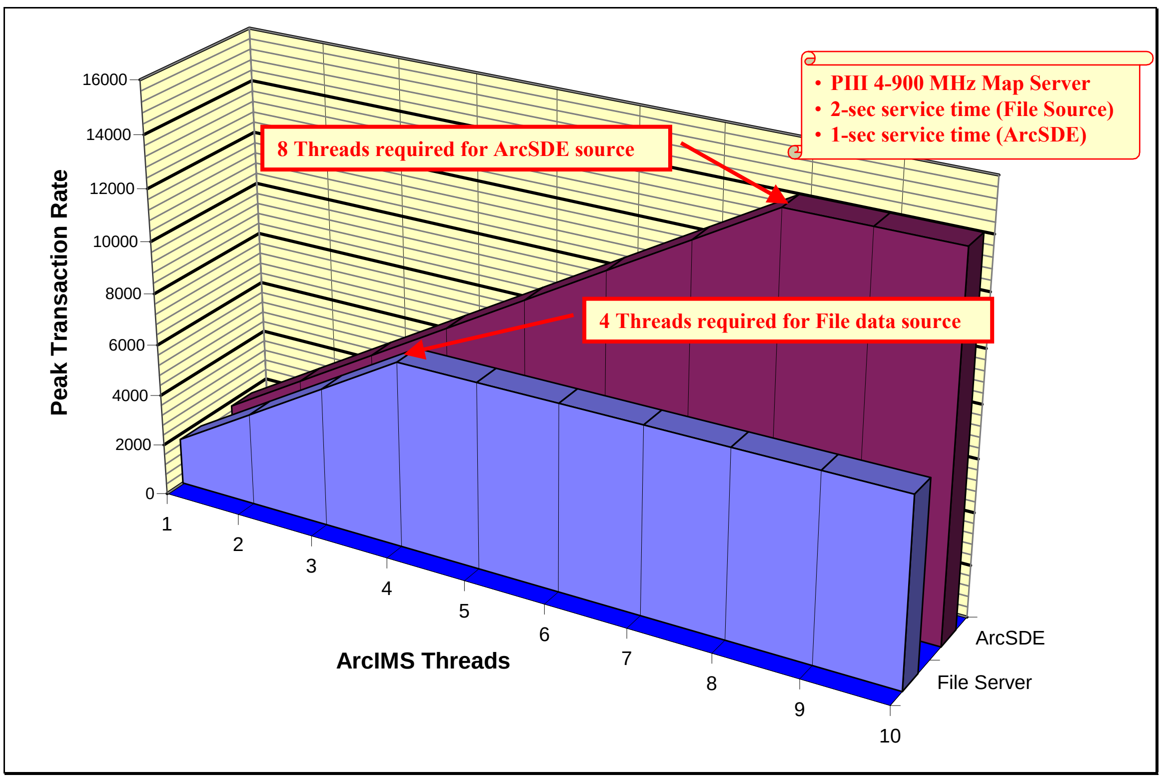
Figure 7-30
Multi-threaded ArcIMS Service Engines



Each request is tracked through the code using a pointer. Each line of code is executed as the pointer selects that line of instruction. Each request will execute only one instruction at a time, same as any other batch process and, as such, cannot take advantage of more than one CPU at a time. If two threads are assigned to a single server, that service can take advantage of up to two CPUs at the same time since it will be processing instructions for both pointers at the same time.

Figure 7-31 addresses the importance of configuring the proper number of ArcIMS threads on the map server to support peak transaction loads. The chart shows a Pentium III 4-CPU 900-MHz platform as the map server, and shows the peak transaction rate as a function of the number of ArcIMS threads. A minimum configuration of four ArcIMS threads is required to reach full map server capacity with a file data source, and eight ArcIMS threads with an ArcSDE data source.

Figure 7-31
Optimized Service Agent Configuration
Number of Threads Matter

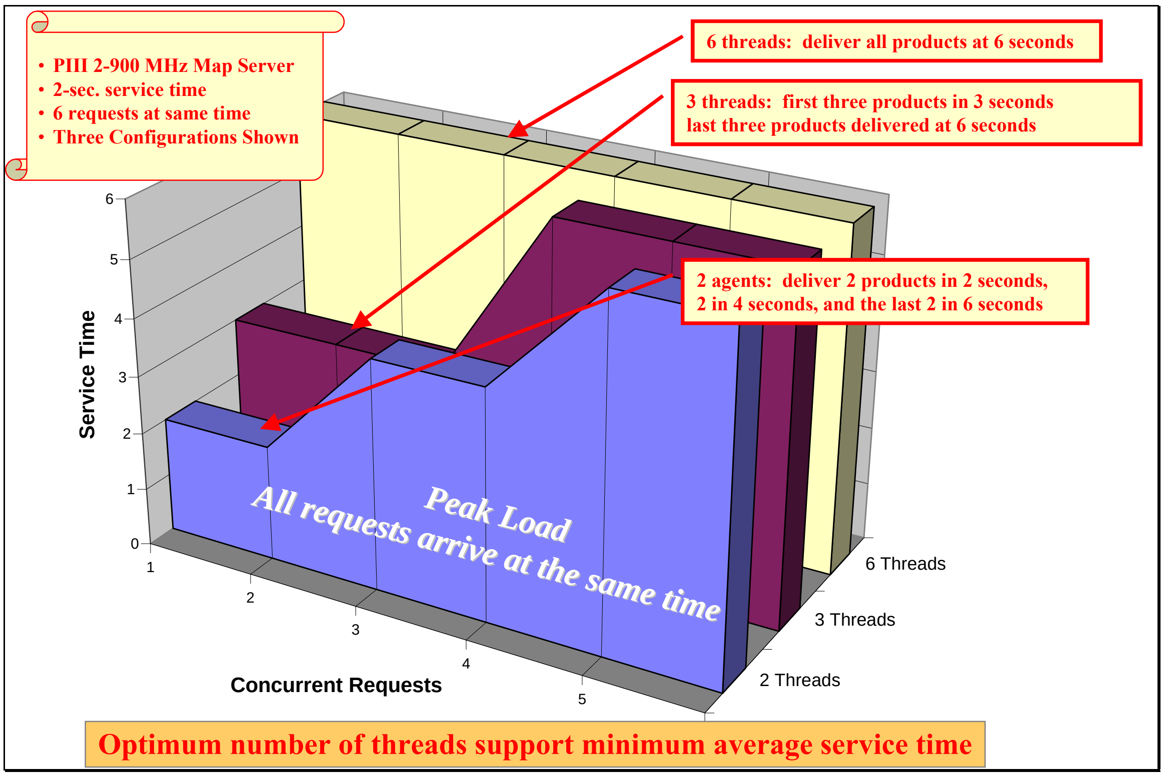


During ArcIMS operations, the virtual server queue does not release a request for processing once it receives the output from the ArcIMS spatial server thread. There can be a slight delay from the time the map server completes service processing and starts processing the next request. This delay is a result of network transfer time between the map server and the Web server. During ArcIMS tuning, it may be necessary to add an additional thread to achieve maximum map server output capacity. An additional thread will support an additional process on the map server to compensate for this delay.

Figure 7-32 addresses the importance of configuring the proper number of ArcIMS threads. This chart shows a Pentium III 900-MHz map server with two CPUs. Three different ArcIMS thread configurations are displayed on the chart (two threads, three threads, and six threads). Corresponding client response times for each of the six map requests are provided for each ArcIMS thread configuration, assuming all six requests arrive at the Web site at the same time.

- **Six-thread Configuration**. All six map requests are assigned by the virtual server to the six available spatial service threads. All requests are processed by the two available map server CPUs (service time for all six requests is 6 seconds).

Figure 7-32
Web Server Configuration



- **Three-thread Configuration**. Six requests arrive at the Web site. Three are assigned to the three available threads for processing, and three are held in the service queue waiting for available threads. The first three requests are processed in 3 seconds. The next three requests are processed in the next 3 seconds. Total service and wait time (query response time) for the first three requests is 3 seconds, and 6 seconds for the second three requests.

- **Two-thread Configuration**. Six requests arrive at the Web site. Two are assigned to the two available threads for processing and four are held in the service queue waiting for available threads. The first two requests are processed in 2 seconds, followed by the second two requests which are processed in the next 2 seconds, followed by the third two requests which are processed in the final 2 seconds. Total service and wait time for the first two requests is 2 seconds, the second two requests 4 seconds, and the third two requests 6 seconds.

This simple analysis of the service sequence of arriving requests demonstrates the penalty for configuring too many ArcIMS threads. This analysis also shows the advantage of configuring the proper number of threads, supporting minimum average map service delays. The following guidelines are provided for configuring service agents for optimum Web performance.

- **Map Servers with File Data Source**. For each map service, configure one ArcIMS public service thread for each map server CPU.

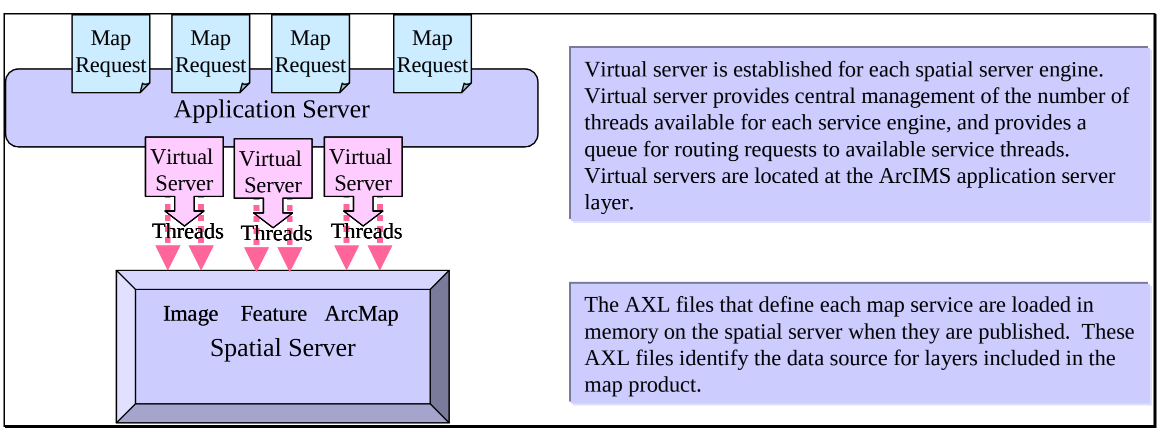
- **Map Servers with ArcSDE Data Source.** For each map service, configure two ArcIMS public service threads for each map server CPU.

Include one additional thread to take advantage of map server CPU resources not being used during the slight delay between completing a request and starting on the next request (network transfer delay between map server and application server).

7.5.3 Virtual Services and the Processing Queue

When configuring the ArcIMS server, a virtual service is identified for each active service engine. Map services are then published relative to an associated virtual server. Requests for a specific map service are routed to the associated virtual server for processing. The virtual server is registered to associated spatial server service threads that will be used for processing the service request. Requests are held in the virtual server queue until an associated thread is available, at which time the service request is assigned to the thread for processing. Once the processing is complete, the next waiting service request can be assigned to that same thread. A single thread can process only one request at a time. Figure 7-33 shows three virtual servers, each assigned two threads. One virtual server supports an image service engine, another virtual server supports a feature service engine, and the third virtual server supports the ArcMap service engine. The virtual servers are located with the ArcIMS application server component.

Figure 7-33
ArcIMS Virtual Servers



7.5.4 Published Map Services

Map services are authored and published using the ArcIMS Manager administration tools. Wizards are included to support publishing of ArcIMS map services. A large variety of simple map services can be configured out-of-the box using simple authoring tools. The map services are simple instruction sets (identifying layers and layout for the map service in an AXL file). These AXL files are assigned to a virtual server and appropriate network connections are preconfigured to support deployment of these service instructions. Once the map services are deployed, they can be requested by users through the Web site.

7.5.5 ArcIMS Performance Sizing Model

The ArcInfo batch process sizing model is used to support ArcIMS map server sizing. The maximum capacity of the ArcIMS spatial server is achieved with 100-percent map server CPU utilization. Each map service engine thread performs as a batch process, and consumes a CPU when servicing a request using a file data source (thread performs both query and rendering functions). Two service threads are required to consume a CPU when using an ArcSDE data source, same as with previous batch process models.

Figure 7-34 provides alternative options for estimating the peak transaction capacity of an ArcIMS map server. The peak requests per hour supported by the ArcIMS spatial server can be determined by dividing the number of seconds per hour by the average map service time in seconds.

ArcIMS spatial servers with ArcSDE data sources offload the query processing to the ArcSDE data server, reducing the service time on the map server by roughly 50 percent. ArcIMS map servers with a separate ArcSDE data source can generally support twice as many transactions per hour as the same map server with a file data source.

During ArcIMS peak loads, the average request wait time (time in the virtual server queue) is roughly four times longer than the average map service time (these estimates assume random arrival times; estimate is based on standard queuing theory). Total average wait-plus-service time is five times the average service CPU processing time during calculated peak system loads (100-percent CPU utilization on map server).

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Figure 7-34
ArcIMS Map Server Sizing Model

- **Calculate Maximum Configuration Capacity**
  - Measure Average Map Service Time (existing ArcIMS site)
    - Measure CPU utilization during average map service transaction
  - (#CPU × 3,600) ÷ Average Map Service Time
    - Standard map service time for 2004 performance baseline
      - 0.6 seconds for file data source
      - 0.3 seconds for ArcSDE data source
- **Standard Peak Transaction Rate for ArcIMS Spatial Server**
  - 2004 Baseline (per map server CPU)
    - 6,000 requests per hour for local data or remote file data source
    - 12,000 requests per hour for separate ArcSDE data source

Example ArcIMS Configuration

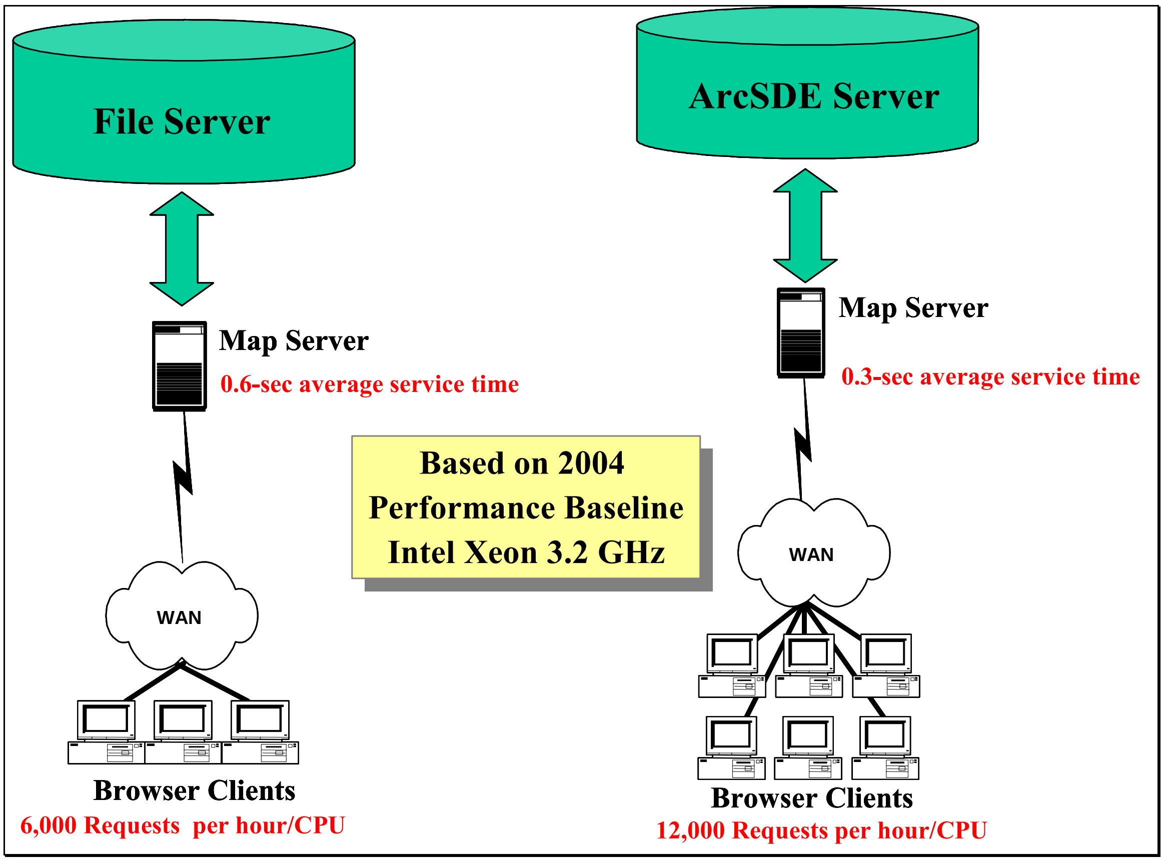
Peak performance for two dual-CPU map server configuration

- 2 x 2 CPU x 6,000 TPH/CPU. = 24,000 requests per hour for file data source
- 2 x 2 CPU x 12,000 TPH/CPU = 48,000 requests per hour for separate ArcSDE data source

In many cases, it is not practical to measure published ArcIMS map service times, since the specific map services have not been developed or published for testing. In these situations, hardware selection must be based on established performance standards. ArcIMS map server sizing models, based on a performance review of standard published map services, are provided to support users in selecting an appropriate hardware solution.

Figure 7-35 provides an overview of ArcIMS map server performance sizing models. The 2003 ArcIMS map server platforms (Intel Xeon 3200-MHz platforms) can support 6,000 requests per hour (per CPU) for a file data source and 12,000 requests per hour (per CPU) with an ArcSDE data source.

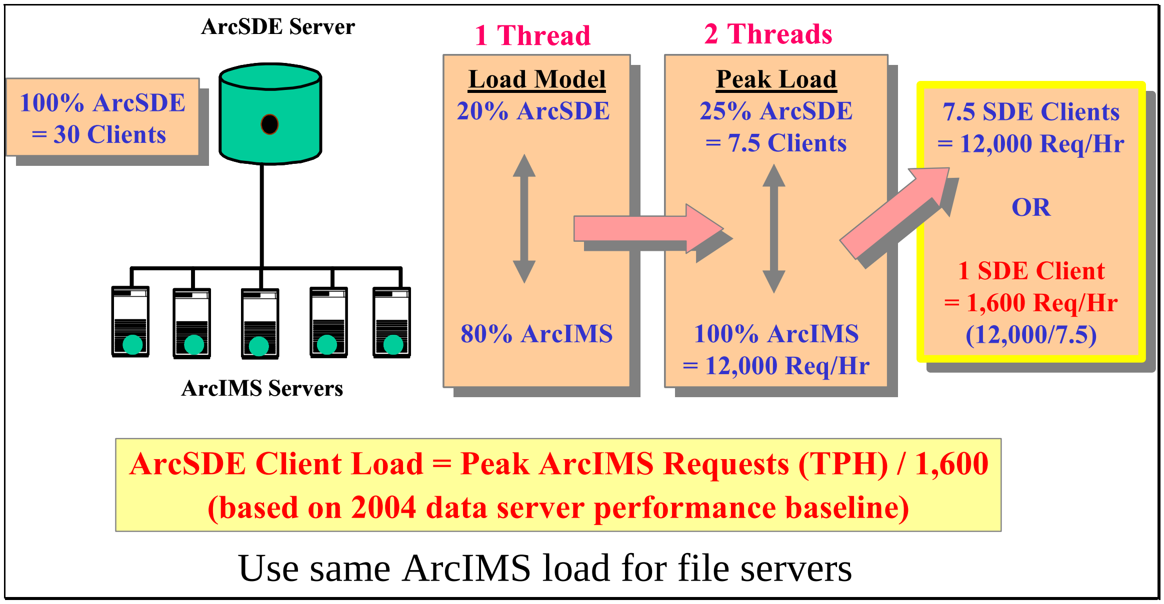
Figure 7-35
ArcIMS Performance Sizing Model



7.5.6 ArcIMS Data Server Loading Model

During peak ArcIMS loads, the map server CPUs are performing at 100-percent utilization. This is the same peak client platform performance experienced when supporting batch processes. For this reason, the ArcInfo batch process server load model can be used to identify ArcIMS peak data server loads. Peak data server loads are roughly 20 percent of the map server loads (one data server CPU can support five map server CPUs). Figure 7-36 provides an overview of the ArcIMS server loading model.

Figure 7-36
ArcIMS Server Loading Model



During peak transaction loads, an ArcIMS thread is equivalent to an ArcGIS desktop batch process. Based on our Arc04 performance models, a batch process is equivalent to 7.5 concurrent ArcGIS clients.

ArcSDE Data Source. An ArcIMS map server with an ArcSDE data source will require at least two ArcIMS threads to reach peak platform capacity (query processing is supported by the separate ArcSDE server platform). The initial load for a single thread is distributed between the two platforms, with roughly 80 percent on the client and 20 percent on the ArcSDE server. If threads are increased to peak load levels on the ArcIMS map server, the ArcSDE server load would increase to roughly 25-percent single-CPU capacity. This 25-percent CPU capacity load on the ArcSDE server is equivalent to five ArcSDE desktop clients, and based on the ArcIMS performance model, this configuration would produce peak loads of 12,000 requests per hour.

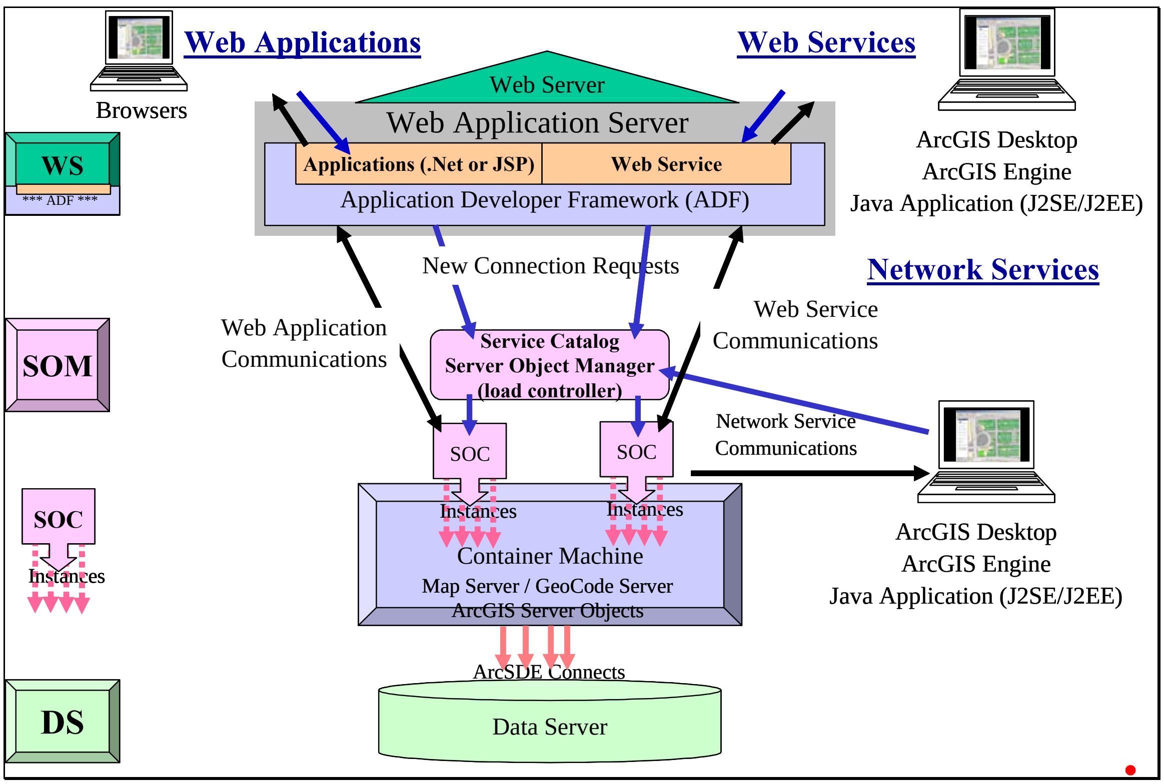
The equivalent data client load generated from separate map servers can be estimated by dividing the projected ArcIMS peak transaction rate by 1,600 transactions per hour (12,000 TPH / 7.5 clients). If the ArcIMS spatial server were installed on the data server, the peak load per ArcIMS thread would consume a server CPU, which would be equivalent to 30 concurrent ArcGIS clients.

The chart in Figure 7-36 provides a visual representation of the ArcIMS data server loading model.

7.6 ArcGIS Server Performance Sizing Model

Figure 7-37 provide a review of the ArcGIS server component architecture. The primary ArcGIS server platform processing environments include the container machine (CM) and the Web server (Web application server) platform. For Web browser applications, the Web application may require as much as 50 percent the CPU resources required to support the container machine server object container (SOC) processing.

Figure 7-37
ArcGIS Server Component Architecture



The ArcInfo batch process sizing model can also be used to support ArcGIS server container machine and Web server sizing. The maximum capacity of the ArcGIS server container machine is achieved with 100-percent map server CPU utilization. Each server object container thread performs as a batch process, and consumes a CPU when servicing a request using a file data source (thread performs both query and rendering functions). Two SOC instances are required to consume a CPU when using an ArcSDE data source, same as with previous batch process models.

Figure 7-38 provides alternative options for estimating the peak transaction capacity of an ArcGIS Server (AGS) Container Machine and the Web Application Server platform. The peak requests per hour supported by the AGS SOC can be determined by dividing the number of seconds per hour by the average map service time in seconds.

AGS SOC with ArcSDE data sources offload the query processing to the ArcSDE data server, reducing the service time on the map server by roughly 50 percent. AGS SOC with a separate ArcSDE data source can generally support twice as many transactions per hour as the same map server with a file data source.

During ArcGIS server peak loads, the average request wait time (time in the virtual server queue) is roughly four times longer than the average map service time (these estimates assume random arrival times; estimate is based on standard queuing theory). Total average wait-plus-service time is five times the average service CPU processing time during calculated peak system loads (100-percent CPU utilization on map server).

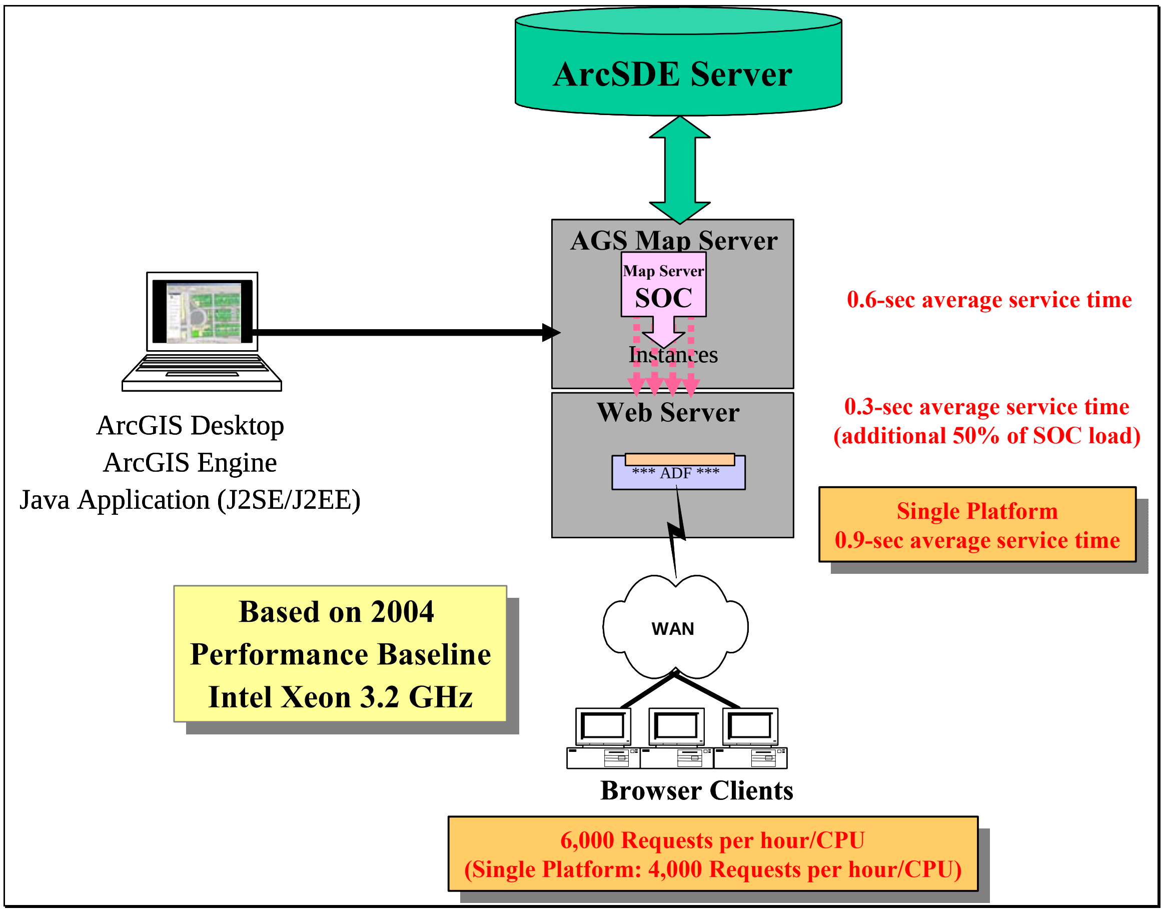
Figure 7-38
ArcGIS Server Sizing Models

- **Review Web Services and Application Workflow**
  - Measure CPU utilization during average transaction
    - Establish average service time on SOC platform
    - Establish average service time on Web Application platform
  - (#CPU × 3,600) ÷ Average Map Service Time for each platform
- **Standard Service Times for AGS Map Service (2003 baseline)**
    - Standard AGS map service time
      - 0.6 seconds for ArcSDE data source
      - 1.2 seconds for file data source
    - Standard AGS web application service time
      - 10% of map server load for thick client AGS Web services
      - 50% of map server for ArcSDE data source
      - 25% of map server for file data source
- **Standard Peak Transaction Rate for AGS Map Service**
  - 2004 Baseline (per platform CPU)
    - 6,000 requests per hour for separate ArcSDE data source
      - 4,000 requests per hour for Web Applications on single platform
    - 3,000 requests per hour for local data or remote file data source
      - 2,000 requests per hour for Web Applications on single platform

In many cases, it is not practical to measure published ArcIMS map service times, since the specific map services have not been developed or published for testing. In these situations, hardware selection must be based on established performance standards. ArcGIS server sizing models, based on a performance review of standard published map services, are provided to support users in selecting an appropriate hardware solution.

Figure 7-39 provides an overview of ArcGIS server performance sizing models. The 2004 ArcGIS server platforms (Intel Xeon 3200-MHz platforms) can support 3,000 requests per hour (per CPU) for a file data source and 6,000 requests per hour (per CPU) with an ArcSDE data source (roughly 50% the performance of an ArcIMS map server for a simple map service).

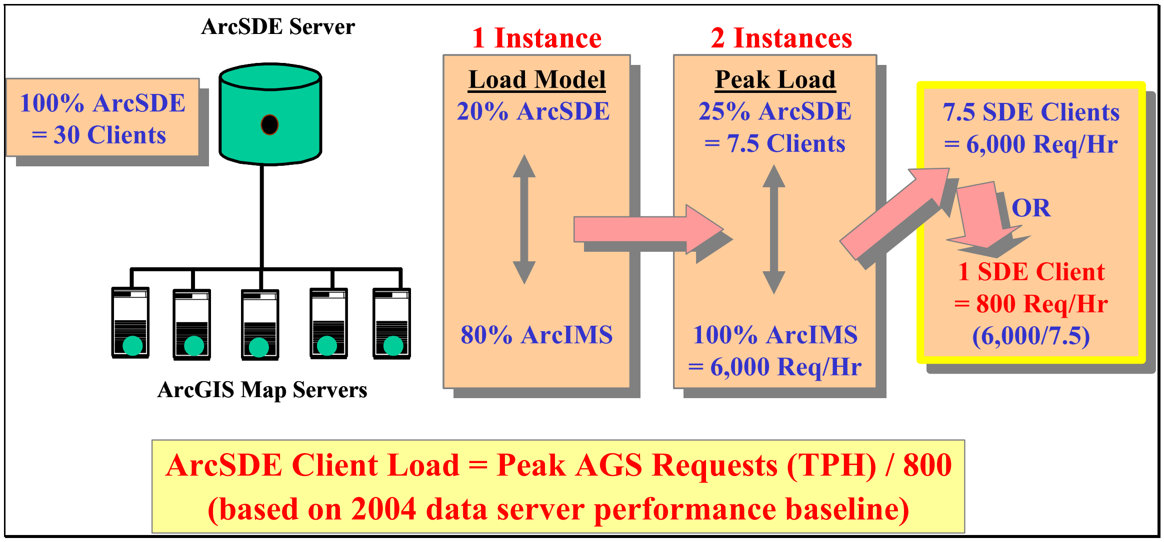
Figure 7-39
ArcGIS Server Map Server Performance Sizing Model



7.6.1 ArcGIS Server Data Server Loading Model

During peak ArcIMS loads, the map server CPUs are performing at 100-percent utilization. This is the same peak client platform performance experienced when supporting batch processes. For this reason, the ArcInfo batch process server load model can be used to identify ArcIMS peak data server loads. Peak data server loads are roughly 20 percent of the map server loads (one data server CPU can support five map server CPUs). Figure 7-40 provides an overview of the ArcIMS server loading model.

Figure 7-40
ArcGIS Server Loading Model



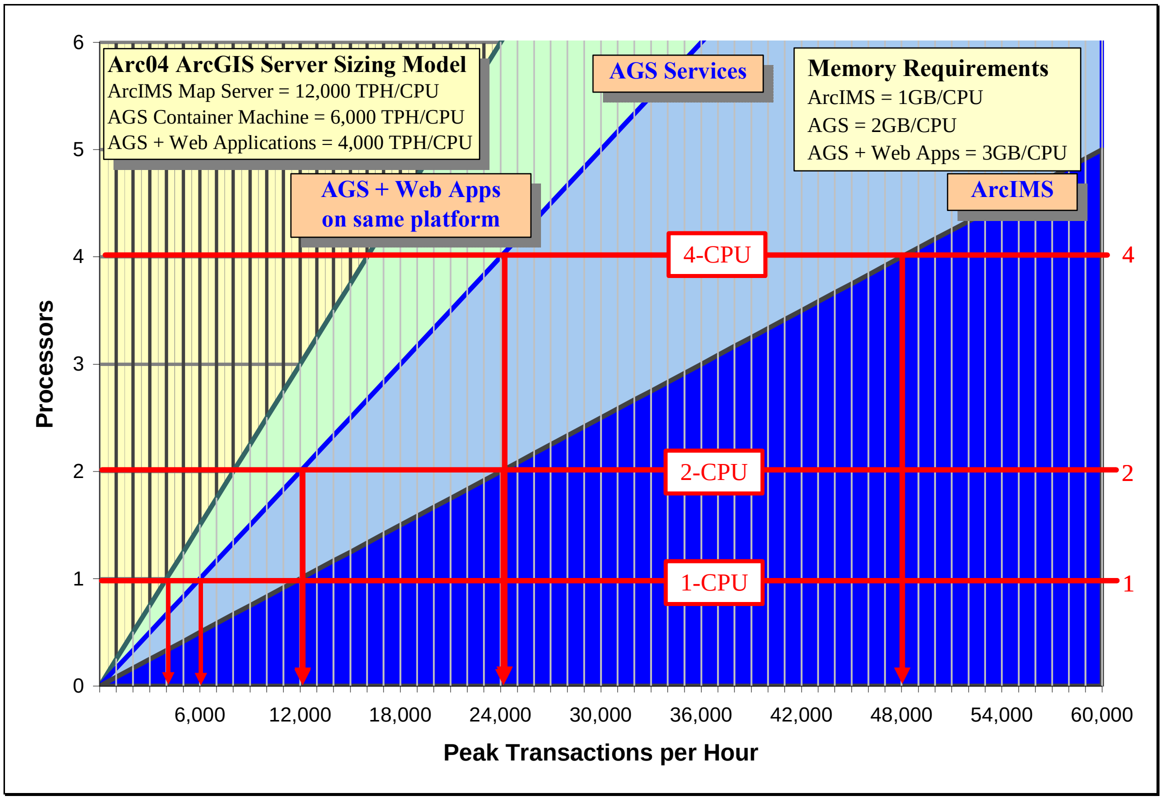
During peak transaction loads, an ArcIMS thread is equivalent to an ArcGIS desktop batch process. Based on our Arc04 performance models, a batch process is equivalent to 7.5 concurrent ArcGIS clients.

ArcSDE Data Source. An ArcIMS map server with an ArcSDE data source will require at least two ArcIMS threads to reach peak platform capacity (query processing is supported by the separate ArcSDE server platform). The initial load for a single thread is distributed between the two platforms, with roughly 80 percent on the client and 20 percent on the ArcSDE server. If threads are increased to peak load levels on the ArcIMS map server, the ArcSDE server load would increase to roughly 25-percent single-CPU capacity. This 25-percent CPU capacity load on the ArcSDE server is equivalent to five ArcSDE desktop clients, and based on the ArcIMS performance model, this configuration would produce peak loads of 6,000 requests per hour.

The equivalent data client load generated from separate map servers can be estimated by dividing the projected ArcIMS peak transaction rate by 800 transactions per hour (6,000 TPH / 7.5 clients). If the ArcIMS spatial server were installed on the data server, the peak load per ArcIMS thread would consume a server CPU, which would be equivalent to 30 concurrent ArcGIS clients.

Web Server Sizing Chart. The chart in Figure 7-41 provides a visual representation of the ArcGIS Server and ArcIMS CPU sizing model.

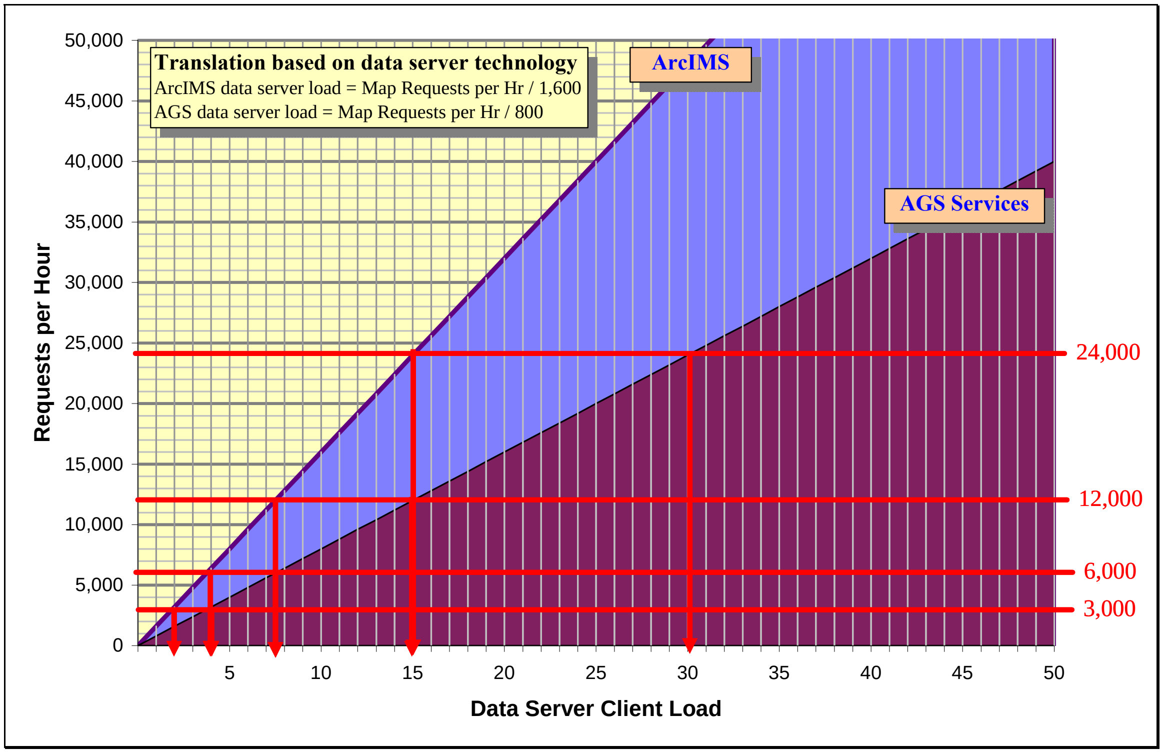
Figure 7-41
ArcGIS Server and ArcIMS Performance Sizing Chart



The chart identifies the number of server platform CPUs on the vertical axis, and the peak transaction rate on the horizontal axis. Platform configurations are represented by horizontal lines on the sizing chart (based on number of CPUs in the platform configuration). The performance sizing models are represented by diagonal lines on the chart (4,000 TPH per CPU for AGS and Web applications on the same platform, 6,000 TPH per CPU for AGS, and 12,000 TPH per CPU for ArcIMS). Preliminary memory requirements are also shown on the chart. Transaction rate expectations are reduced by 50 percent with file data source.

Web Data Server Load Chart. The chart in Figure 7-42 provides a visual representation of the ArcGIS Server and ArcIMS CPU sizing model.

Figure 7-42
ArcIMS Data Server Loading Chart



The chart identifies the peak map requests per hour on the vertical axis, and the peak server client load on the horizontal axis. Peak transaction rates are represented by horizontal lines on the sizing chart (based on the application needs assessment). The ArcIMS and ArcGIS server loading models are represented by diagonal lines on the chart (1,600 TPH per client for ArcIMS and 800 TPH per client for ArcGIS server).

7.7 Conclusion

The sizing models presented in this section provide a foundation for understanding system performance issues. The models were presented throughout this section assuming CPU resources were all the same. In the real world, platform performance is not the same. Hardware vendors release new platforms every three to six months as faster CPUs enter the market and new technology is introduced to improve processing performance. The next section will address how these models can be applied to support system design in a world where each platform configuration has its own performance capacity.

8 Sizing Tools

The real world we live in today is experiencing the benefits of rapidly changing technology. Technology advancements are directly impacting our individual productivity—the way we all deal with information and contribute to our environment. Our ability to manage this change and take advantage of its benefits can contribute to our success in business and in our personal life.

Section 7 (Sizing Fundamentals) provided an overview of the system configuration performance models assuming all hardware platforms were the same. This section will identify how we can use these same models to make proper hardware selections when all hardware platforms are different.

The system design process identifies the optimum system configuration strategy, selects the appropriate hardware components, and provides platform specifications that will support user performance requirements. Section 6 presented a methodology for identifying an enterprise system configuration strategy that would support specific user requirements. This methodology provides peak user loads for a list of selected platform components required to support the system solution. This section will provide practical tools that can be used to convert peak user platform loads to specific platform specifications.

8.1 Performance Baseline Selection

To develop a system design, it is necessary to identify user performance needs. User performance requirements are represented by the workstation platforms selected by users to support computing needs. Application and data servers must be configured to support user desktop performance requirements.

User performance expectations have changed significantly over the past several years. This change in performance needs is encouraged primarily by faster platform performance and lower hardware costs. This change directly contributes to increased user productivity.

Figure 8-1 identifies the change in single-user ArcInfo platform requirements since the ArcInfo 7.0.2 release in September 1994.

Figure 8-1
ArcInfo Platform Performance History

- **ArcInfo 7.0.2 (Sept. 1994)**
  - Sun SPARCstation 10 Model 40, 32 MB Memory
- **ArcInfo 7.0.4 (Feb. 1996)**
  - Sun SPARCstation 20 Model 71, 64 MB Memory
- **ArcInfo 7.1.1 (Feb. 1997)**
  - Pentium Pro 200 MHz, 64 MB Memory
- **ArcInfo 7.2.1 (April 1998)**
  - Pentium II 300 MHz, 128 MB Memory
- **ArcInfo 8 (July 1999)**
  - Pentium III 500 MHz, 128 MB Memory
- **ArcInfo 8.0.2 (July 2000)**
  - Pentium III 733 MHz, 256 MB Memory
- **ArcInfo 8.1 (July 2001)**
  - Pentium III 900 MHz, 256 MB Memory
- **ArcInfo 8.2 (July 2002)**
  - Pentium 4 1.5 GHz, 512 MB Memory
- **ArcInfo 8.3 (July 2003)**
  - Intel Pentium 2.4 GHz, 512 MB Memory
- **ArcInfo 9.0 (May 2004)**
  - Intel Xeon 3.2 GHz, 512 MB Memory

The Sun SPARCstation 10 Model 40 was a powerful single-user workstation in 1994. This platform was competitive with similar price/performance options provided by other UNIX vendors during this same period.

In February 1996, ESRI released ArcInfo 7.0.4. Sun released their SPARCstation 20 models, and the SPARCstation 20 Model 71 was a common selection as a single-user workstation. The SPARC 20 Model 71 was roughly 2.5 times faster than the SPARC 10 Model 40.

In February 1997, ESRI released ArcInfo 7.1.1. The first Windows ArcInfo product was supported on the Intel Pentium Pro 200. The Pentium 200 platforms provided standard workstation performance for ArcInfo users during 1997. The Pentium 200 performed more than four times faster than the SPARC 10 Model 40.

In April 1998, ESRI released ArcInfo 7.2.1. Intel was selling the Pentium II-300 platform, which provided the standard workstation performance baseline for ArcInfo users during 1998. The Pentium II-300 platforms performed more than six times faster than the SPARC 10 Model 40.

ArcInfo application performance improved throughout this same period as the code was optimized with new ArcInfo 7 incremental releases. A script developed with ArcInfo 7.0.2 in

September 1994 would run faster using the ArcInfo 7.2.1 release, both running on the same platform. The change in the ArcInfo performance baseline was not a software-driven requirement, but rather a change in user performance expectations brought on by the faster and less expensive platform technology.

In July 1999, ESRI demonstrated the first release of ArcInfo 8. The Intel Pentium III-500 platform was the popular ArcInfo workstation candidate. The Pentium III-500 was over 11 times faster than the SPARC 10 Model 40.

In May 2000, ESRI released ArcInfo 8.0.2. The Pentium III-733 was selected as the performance baseline supporting the summer 2000 deployments. The Pentium III 733-MHz platform is over 22 times faster than the SPARC 10 Model 40.

Modest performance improvements continued into 2001. The slowdowns in performance increases were contributed to development of the next-generation processor technology. The Pentium III 900-MHz platform is selected as the performance baseline supporting the ArcInfo 8.1 release.

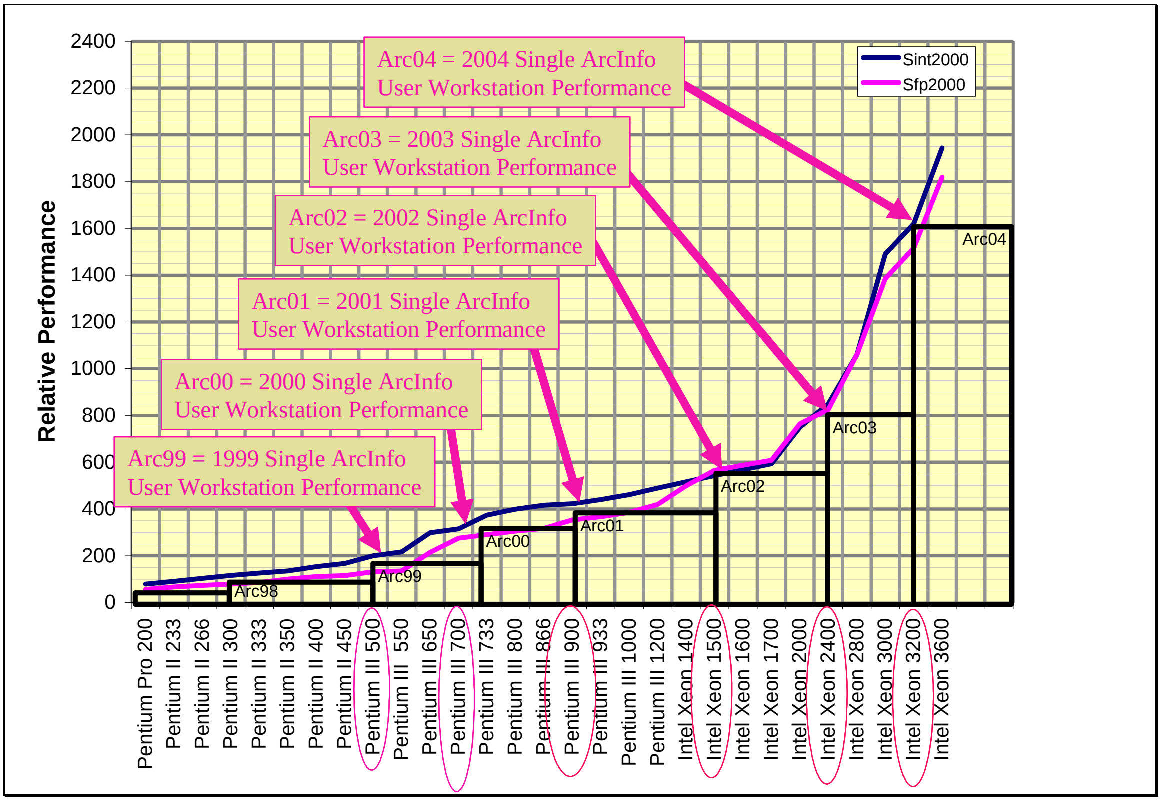
In June 2002, the Intel Xeon MP 1500-MHz server provided a significant performance gain. Intel server technology was still lagging behind workstations, which are reaching the Intel Xeon 2400-MHz performance thresholds by mid-year. IBM and Sun UNIX server platforms are keeping pace with the Intel workstation performance levels. Intel was having some performance problems with the 1500-MHz chips, and deployment was delayed until the fall. The Intel Xeon 1500-MHz platform was selected as the performance baseline for the ArcInfo 8.2 release.

In June 2003, the Intel Xeon MP 2000-MHz platform was the current technology Windows server. Performance issues for the Intel Xeon MP were resolved, and the 2000-MHz processors supported the current server platforms. This server provided an impressive gain over the previous year, matching performance of the Intel Xeon 2400-MHz workstation. Intel was releasing the Intel Xeon 3060-MHz workstation platforms before mid-year. Intel was planning to release a 2800-MHz server version in the fall. The Intel Xeon 2400 was selected as the 2003 performance baseline.

In June 2004, the Intel Xeon MP 3000-MHz platform was the current technology Windows server. Performance issues for the Intel Xeon MP were resolved, and the 3000-MHz processors supported the current server platforms. This server provided an impressive gain over the previous year, matching performance of the Intel Xeon 3200-MHz workstation. Intel was releasing the Intel Xeon 3600-MHz workstation platforms before mid-year. The Intel Xeon 3200-MHz platform was selected as the 2004 performance baseline.

Figure 8-2 provides a graphic overview of Intel workstation performance over the past eight years. Vendor-published commercial benchmark results establish the relative performance represented on this chart.

Figure 8-2
Windows Platform Performance History



The boxes along the bottom of the chart represent selected ArcGIS Desktop user performance baselines. Each box is labeled to represent the corresponding year (Arc99 represents the 1999 performance baseline, Arc00 the 2000 performance baseline, and so forth, through Arc04 which represents the year 2004 performance baseline). These performance baselines agree with the user platforms identified on Figure 8-1, and represent user performance requirements during that time period. You can see from the chart that ArcInfo platform performance is more than 10 times faster today than five years ago.

8.2 Hardware Life Cycles

Platform performance improvements have a direct impact on infrastructure investment strategies. Most organizations today find it essential to reinvest in hardware on a three- to five-year cycle to stay productive. A basic understanding of hardware life cycles is important in supporting an effective IT infrastructure.

Figure 8-3 provides definitions used in establishing a measure of hardware productivity. These definitions are useful in quantifying expected infrastructure investment strategies to support system performance requirements.

Figure 8-3
Hardware Life Cycles

Definitions	
Current	**Length of time between major hardware technology releases**
Useful	**Current release software is still supported on this equipment**
Obsolete	**New releases of software are not supported with this equipment**
Non-functional	**After this point the infrastructure is no longer functional. Cost of maintenance is greater than residual value of equipment**

Estimated hardware life expectancies are identified in Figure 8-4. These estimates provide guidelines for budget planning. Hardware should be purchased when needed based on user performance requirements, and planned for 50 percent utilization within the first year of deployment. Replacement for most hardware should be planned every three to four years to maintain production productivity.

Figure 8-4
Hardware Life Cycles

(Months)

Technology	Current	Useful	Obsolete	Non-functional
Network Infrastructure				
• Local area networks	24-36	37-84	85-120	120+
• Wide area networks*	12-24	25-60	61-84	84+
Computer Hardware				
• Data Servers	12-18	19-48	49-72	72+
• Application Servers	6-12	13-48	49-72	72+
• Desktop Workstations	6-12	13-36	37-60	60+
• Laptop Workstations	6-12	13-34	25-48	48+
• Terminal clients	24-36	37-60	61-72	72+

* Internet bandwidth increasing at 300% per year

8.3 How Do We Handle Change?

Hardware platforms used to configure an enterprise GIS environment may include many configurations and different models. Each configuration must support user performance needs for the system to perform properly. Platform performance is not represented by the number of CPUs or the CPU speed (MHz) alone. There are many components within a specific platform configuration that contribute to overall performance including the design and model of the CPU, the speed of the system bus, and the installed operating system.

Benchmark performance of a specific platform model and configuration is a better measure of total performance capacity than the number of CPUs. A common set of benchmarks can be used to measure the relative performance of two different hardware platform configurations. If you know the relative performance of two platform configurations, you can identify the corresponding relative performance capacity of those two platforms.

Figure 8-5 provides a definition of the theory of relative performance that can be used along with the sizing models in Section 7 to quantify platform specification requirements based on user needs.

Figure 8-5
Theory of Relative Performance

Theory of Relative Performance

The relative performance of two servers is directly proportional to their compute capacity

$$\frac{\text{Performance of Server A}}{\text{Performance of Server B}} = \frac{\text{Clients of Server A}}{\text{Clients of Server B}}$$

The theory of relative performance identifies the compute capacity of a new server based on its relative performance to a known server configuration. As an example, if we know an existing server can support 100 clients and that the new server has twice the performance as the existing server, we then can expect the new server will support 200 clients.

8.4 How Do We Measure Change?

It is a challenge to find a reliable and objective set of benchmarks that can be used to establish relative performance between vendor platforms. It is desirable to find a set of benchmarks that are simple, consistent, and reliable over time (we would like to know the performance of newer workstations relative to older models that exist in the current inventory). We would also like every vendor platform to be tested against these benchmarks, and these benchmarks published by the vendor and made available on the Web for customer reference. We would also like these benchmarks to be neutral in nature, and not to have their validity challenged by the vendors.

The Standard Performance Evaluation Corporation (SPEC) was formed during the 1980s to identify and create objective sets of application-oriented tests that can serve as common reference points and be used to evaluate performance across different workstation platforms. Figure 8-6 provides the current SPEC charter. ESRI system design consultants have used the SPEC benchmark suite since 1992 as an independent source to identify relative performance of supported hardware platforms. The SPEC relative performance measures have been very helpful in representing relative platform performance, and have been used with ESRI sizing models to identify appropriate platform solutions to support GIS user performance needs.

Figure 8-6
How Do We Measure Change?

Standard Performance Evaluation Corporation (SPEC Mission)

To develop technically credible and objective benchmarks so that both computer designers and purchasers can make decisions on the basis of realistic workloads

SPEC announced the release of the SPEC2000 benchmark suites in early 2000. Figure 8-7 provides an overview of the SPEC2000 benchmark suite. SPEC2000 includes two sets (or suites) of benchmarks: CINT2000 for compute-intensive integer performance and CFP2000 for compute-intensive floating-point performance. The two suites provide component-level benchmarks that measure the performance of the computer's processor, memory architecture, and compiler. SPEC benchmarks are selected from existing application and benchmark source code running across multiple platforms. Each benchmark is tested on different platforms to obtain fair performance results across competitive hardware and software systems.

Figure 8-7
SPEC2000 Benchmark Suites

- **SPEC2000 Comprises Two Suites of Benchmarks**
  - **CINT2000: Compute-Intensive Integer**
    - Twelve (12) CPU-intensive integer benchmarks (C and C++ Language)
    - Conservative (SPECint_base2000, SPECint_rate_base2000)
    - Aggressive (SPECint2000,SPECint_rate2000)
  - **CFP2000: Compute-Intensive Floating Point**
    - Fourteen (14) CPU-intensive floating-point benchmarks (FORTRAN 77 & 90 and C Languages)
    - Conservative (SPECfp_base2000, SPECfp_rate_base2000)
    - Aggressive (SPECfp2000,SPECfp_rate2000)
- **Sun Ultra 10 300-MHz Reference Platform**

The CINT2000 suite, written in C and C++ languages, contains twelve CPU-intensive integer benchmarks. CINT2000 is used to measure and calculate the geometric mean of twelve normalized ratios (one for each integer benchmark) when compiled with aggressive (SPECint2000) and conservative (SPECint_base2000) optimization for each benchmark, and the geometric mean of twelve normalized throughput ratios when compiled with aggressive (SPECint_rate2000) and conservative (SPECint_rate_base2000) optimization for each benchmark.

The CFP2000 suite, written in FORTRAN 77 & 90 and C languages, contains fourteen CPU-intensive floating-point benchmarks. CFP2000 is used to measure and calculate the geometric mean of fourteen normalized ratios (one for each floating-point benchmark) when compiled with aggressive (SPECfp2000) and conservative (SPECfp_base2000) optimization for each benchmark, and the geometric mean of fourteen normalized throughput ratios when compiled with aggressive (SPECfp_rate2000) and conservative (SPECfp_rate_base2000) optimization for each benchmark.

8.5 Hardware Platform Selection

Several factors should be considered when selecting a platform vendor. The two most visible and obvious criteria are platform performance and purchase price. These criteria are critical to system design and acceptance but do not address other hidden factors that contribute to total system cost. Today's leading hardware platform vendors are very competitive in both technical performance and pricing. Purchase of a GIS platform environment may extend over several months or possibly years, and platform performance leadership will change several times between leading hardware manufacturers during this period.

System supportability may be a deciding factor. In many cases, companies invest heavily in training and staff infrastructure in support of a particular hardware vendor solution. Hiring, training, and maintaining staff to support the appropriate computer environment is an important factor contributing to system success.

Company relations with vendor sales and support personnel may be a deciding factor in choosing the appropriate vendor. Vendor support is not the same throughout the country, and these personal relationships can make a difference in how well the system will be supported.

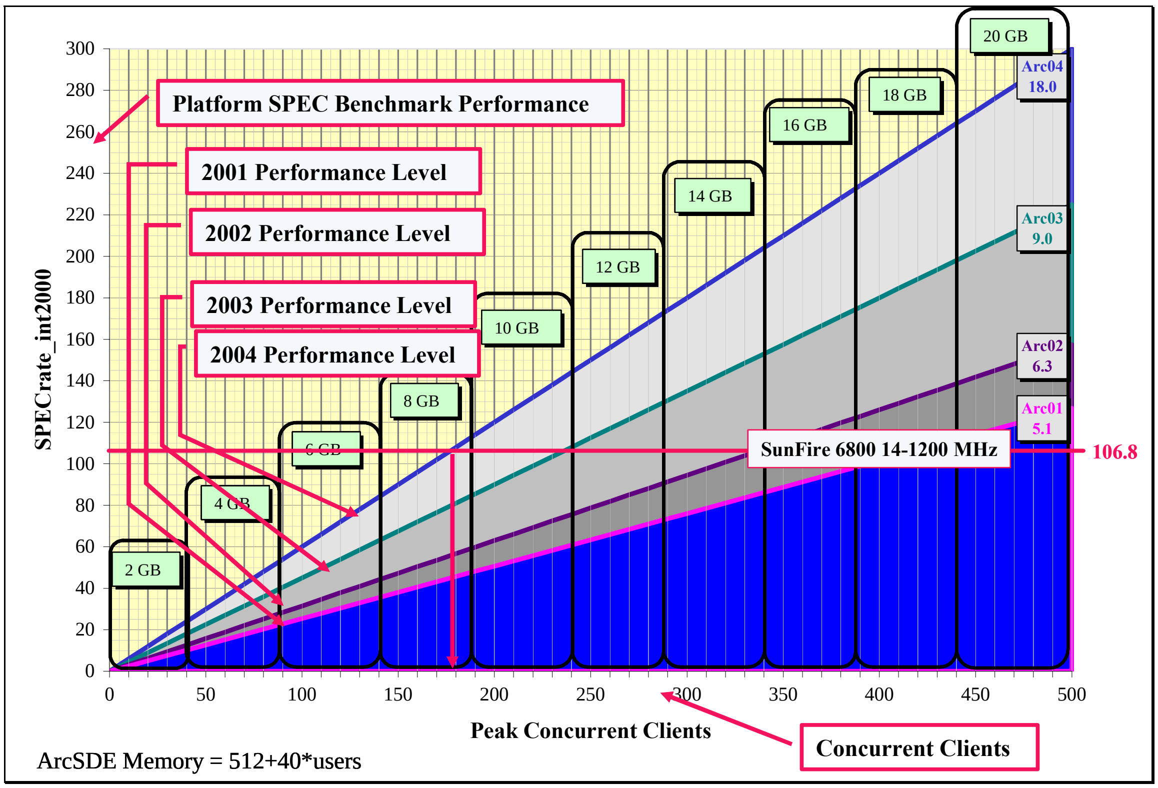
Total life-cycle cost and performance of the system should be the primary considerations in selecting a vendor solution. This section will identify a methodology for establishing vendor configurations with common performance expectations. System solutions with common performance expectations provide a basis for life-cycle cost comparisons.

Once a vendor is selected, a review of the available candidate hardware platforms, along with their associated SPEC benchmark ratings, will provide a basis for satisfying configuration needs. The following information is helpful in evaluating candidate platforms for configuring a system solution.

8.5.1 Platform Sizing Model Format

Figure 8-8 introduces a methodology for presenting the performance models for each of the ESRI product solutions. Understanding how to read and apply this chart will provide a foundation for using the performance models in the rest of this section.

Figure 8-8
Platform Performance Chart Overview



The left side of this chart represents the platform performance based on published SPEC benchmarks for each selected platform configuration. Application compute platforms will use the SPECrate_fp2000 benchmark results, while data server platforms will use the SPECrate_int2000 benchmark results.

This chart provides a plot of performance levels for 2001, 2002, 2003, and 2004 represented by diagonal lines across the chart. These lines are labeled Arc01, Arc02, Arc03, and Arc04 to represent performance baselines for the respective years. The published single-processor benchmark values are identified on each performance line.

The concurrent clients are represented along the X-axis of the chart. Memory recommendations are a function of the concurrent client connects and are represented on the performance chart. The formula used for establishing memory requirements is identified on the bottom left corner of the chart.

A specific platform configuration is represented on this chart by a horizontal line (SunFire 6800 14-CPU 1200-MHz platform is a fourteen-CPU configuration with a SPECint_rate2000 performance benchmark of 106.8). The intersection of the platform performance with the respective baseline performance line identifies the memory requirements and number of clients that can be supported at that performance level by the identified platform configuration. (The example shows 180 clients can be supported at the Arc04 performance level; 14-GB memory would be required to support this number of clients). The same chart can be used to identify configuration requirements for each of the other performance levels (Arc01, 02, 03, and 04) following the same procedure. (The same SunFire 6800 14-CPU 1200-MHz configuration can support close to 340 concurrent clients at the Arc02 performance level; 16 GB of physical memory would be required to support this number of client connects).

8.5.2 Where Can I Find the Performance Benchmarks?

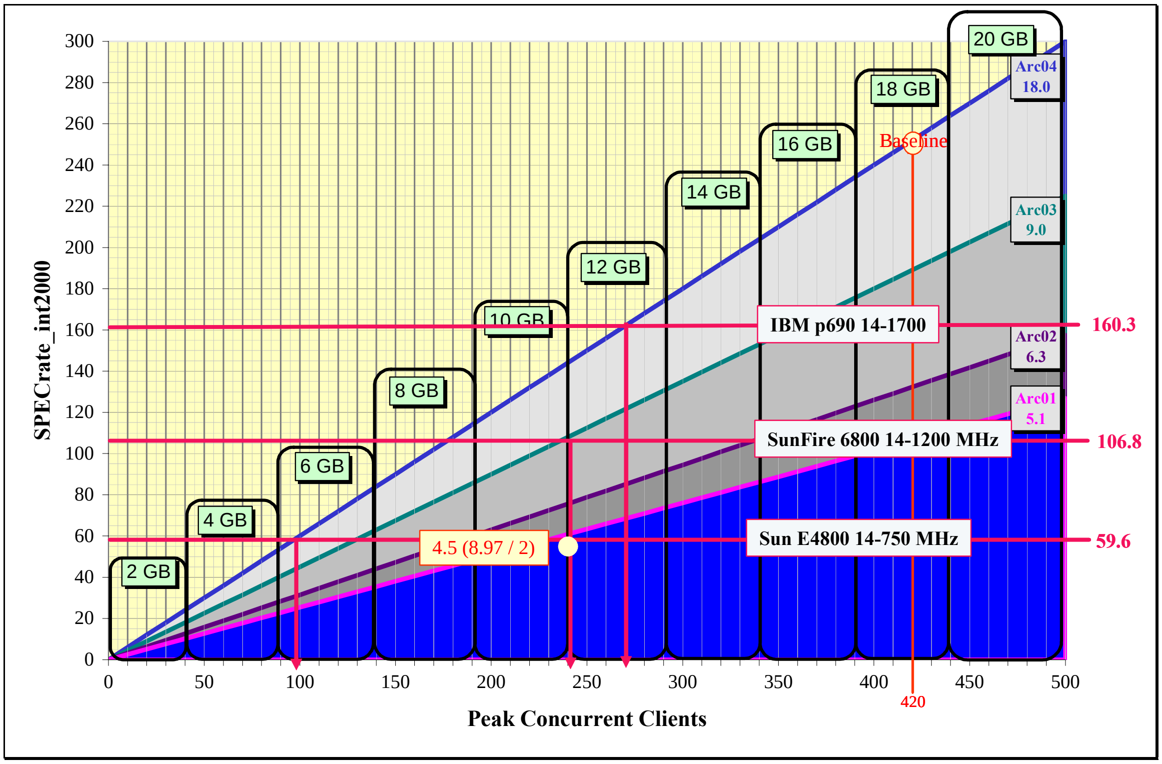
Figure 8-9 provides a summary of Sun Fire 3500 server configurations with 750-MHz processors. This summary was developed from a search function provided on the SPEC Web site, with the results identified on the chart. This is a listing of the SPECint_rate2000 benchmarks published by Sun Microsystems for these platform configurations.

Figure 8-9
Published SPEC Benchmark Results

SPEC2000 Benchmarks (http://www.specbench.org/osg/cpu2000/)					
Company	**System**	**# CPU**	**Processor MHz**	**Result**	**Published**
Sun Microsystems	Sun Fire 280R	2	750	8.97	Jan-01
Sun Microsystems	Sun Fire 3800	8	750	34.5	Jul-01
Sun Microsystems	Sun Fire 4800	12	750	51.3	Jul-01
Sun Microsystems	Sun Fire 4800	14	750	59.6	Jul-01
Sun Microsystems	Sun Fire 6800	24	750	101	Jul-01

The Sun Enterprise 3800 with fourteen 750-MHz processors has a published SPECint_rate2000 benchmark result of 59.6. I will also note on the chart that a single-CPU configuration of this same platform has a benchmark result estimated at 4.5 (8.97/2). I can plot the selected platform configuration benchmark value on the sample chart in Figure 8-10, and use this chart as a sizing tool to identify how many GIS viewers I can support if I use this platform for an ArcSDE data server.

Figure 8-10
ArcSDE Server Sizing Example



The chart above shows the selected Sun E4800 platform configuration intersecting the Arc04 performance line at 100 concurrent users. The chart also identifies a single CPU performance of 4.5, which represents the maximum transaction performance (single user transaction performance) provided by this platform. The transaction performance is slightly slower than the Arc01 performance line (this is an older platform, less than half the performance of the current Arc04 technology). For older technology, it is not possible to support current transaction performance levels. The performance capacity (peak server transaction rate) of this platform can support up to 240 concurrent clients at the Arc01 performance levels, if the server is configured with 12-GB memory and supporting client workstations running at the same performance level. With faster client platforms, the peak transaction capacity will be reached at a lower peak user load.

Arc04 transaction performance levels can be supported by current platform technology, represented by the IBM p690 (SunFire 6800 14-CPU 1200-MHz platform is over one year old). New performance sizing thresholds are established each summer, based on platform technology at that point of the year. New vendor platform technology may provide transaction performance that exceeds last year's performance baseline. Peak capacity performance (maximum transaction rates) for 14-CPU platform configurations will be reached before platforms pass 420 concurrent ArcSDE clients, at which time transaction performance will slow to the Arc04 levels as additional ArcSDE client loads increase. Platform selection should be established based on peak transaction performance since users lose productivity once performance starts to decrease.

8.6 Performance Sizing Charts

The rest of this section will provide individual performance sizing charts for each of the ESRI software solutions identified in Figure 8-11, and include sample platforms plotted on the chart for reference purposes.

Figure 8-11
Platform Sizing Models

- **Workstations (ArcInfo, GIS Viewers, Terminal Clients)**
- **Application Compute Servers**
- **IMS / AGS Map Servers**
- **ArcSDE Servers**

Workstations and application compute servers (Windows Terminal Servers) support application processing. GIS application processing is compute-intensive and traditionally had a preference for floating-point calculations. Recent benchmark testing suggest ArcGIS applications are primarily integer-intensive, and all Arc04 models now use the SPECrate_int2000 benchmark results for sizing purposes. The ArcSDE geodatabase queries are also integer-intensive and will use the same benchmark results for sizing purposes.

8.6.1 GIS Desktop Platforms

Figure 8-12 provides recommended configurations for the GIS desktop platforms.

Figure 8-12
ArcInfo and ArcView Platform Recommendations

Application	Platform	Memory	SPECfp2000
ArcGIS Desktop	Intel Xeon 3200+	512	1620
ArcEngine Desktop	Intel Xeon 2400+	256	850
Terminal/Browser Clients	Pentium Pro 200+	64	50+

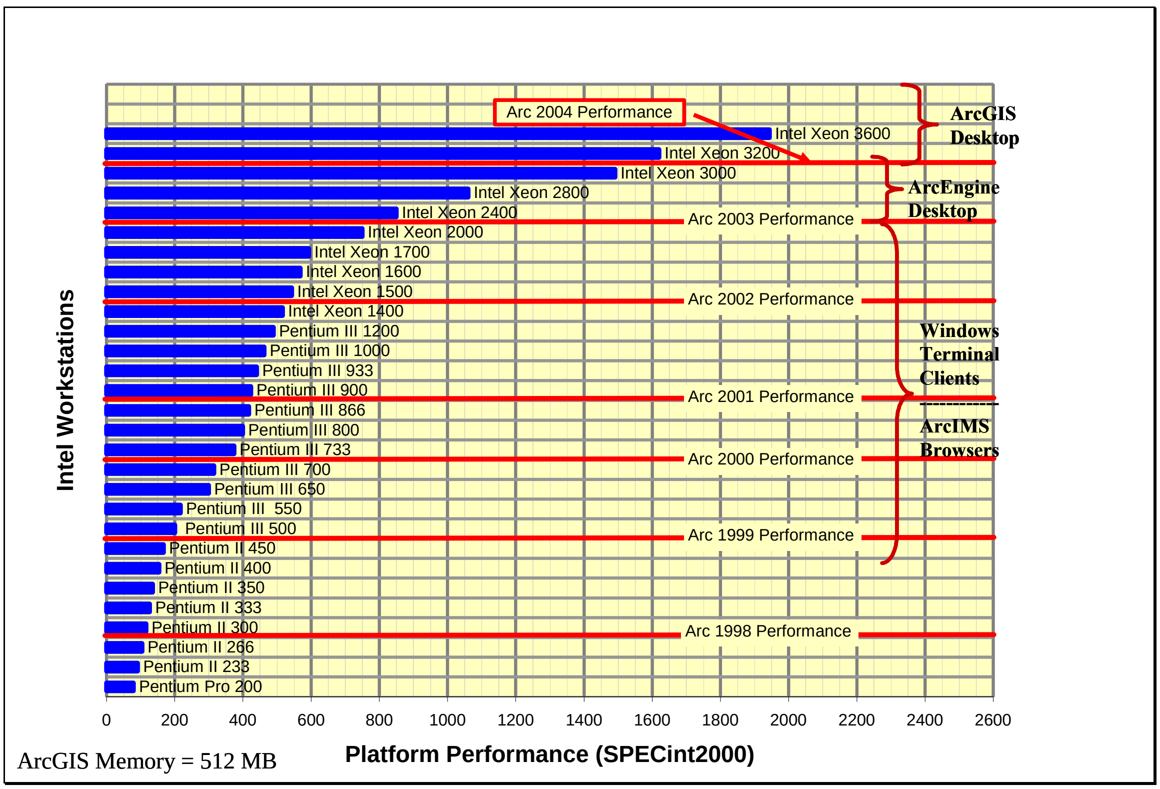
There are two categories of GIS user workstations. A high-performance configuration is required to support ArcInfo Workstation and the ArcGIS desktop applications (ArcInfo, ArcEditor, and ArcView). Smaller applications such as ArcView 3 and custom ArcEngine 9 desktop applications can support similar productivity with last year's performance platforms. Standard Windows Office desktop environments can support terminal and browser clients.

ArcInfo Workstation and ArcGIS Desktop Specifications. ArcInfo and ArcGIS desktop platform requirements include a Pentium 4-class processor (current processor is Intel Xeon 3200+) with 512-MB physical memory and 20-GB SCSI hard disk (40-GB disk would provide additional local storage for large project files). Minimum 17-inch display (20-inch preferred for heavy users). Video display card should include 32-MB VRAM supporting minimum of 1280 x 1024 resolution and full color (additional VRAM will provide higher resolution and better display performance for 3-D applications). Platform should include a CD ROM, 1.44-MB floppy disk, and 10/100-Mbps Ethernet controller. Include Windows operating system.

ArcObjects Engine Custom Client Workstation Specifications. Lighter custom applications developed with the ArcGIS 9 ArcObjects Engine development environment may be supported by Intel Xeon 2400 platforms (current processor is Intel Xeon 3200) with 256-MB memory (512-MB preferred) and 20-GB SCSI hard disk (40-GB disk would provide additional local storage for large project files. Minimum 17-inch display (20-inch preferred for heavy user). Video display card should include 32-MB VRAM supporting minimum of 1280 x 1024 resolution and full color (additional VRAM will provide higher resolution and better display performance for 3-D applications). Platform should include a CD ROM, 1.44-MB floppy disk, and Ethernet controller. Include Windows operating system.

Figure 8-13 provides a performance overview for current Windows platform environments. Recommended performance thresholds are identified for ArcInfo workstations, GIS viewing workstations (ArcView GIS and MapObjects applications), and Windows Terminal clients (this would include Web browser clients).

Figure 8-13
Workstation Platform Recommendations



8.6.2 Application Compute Servers

The application compute server supports execution of the primary ArcGIS applications. This platform can be used as a user workstation as well as a compute platform for a number of users with display and control supported by terminal clients.

The total number of concurrent users supported by a specific application compute server platform can be calculated by dividing the published SPECrate_int2000 performance rating by the associated SPECrate_int2000 performance baseline platform rating and multiplying by a factor of 6 for a file data source, and 7.5 for an ArcSDE data source. This identifies the number of users who can be supported by each candidate platform.

Once the number of users is identified for each candidate platform, memory requirements can be established based on software specifications. For ArcGIS desktop sessions, physical memory requirements are roughly 512 MB for the first user and 256 MB for each additional user.

Windows Terminal Servers. There are two charts provided to support configuration recommendations for Windows Terminal Servers. Figure 8-14 provides general guidelines for configuring Microsoft Windows Terminal Servers when accessing a file data source.

Figure 8-14
Windows Terminal Server Sizing
(File Server Data Source)

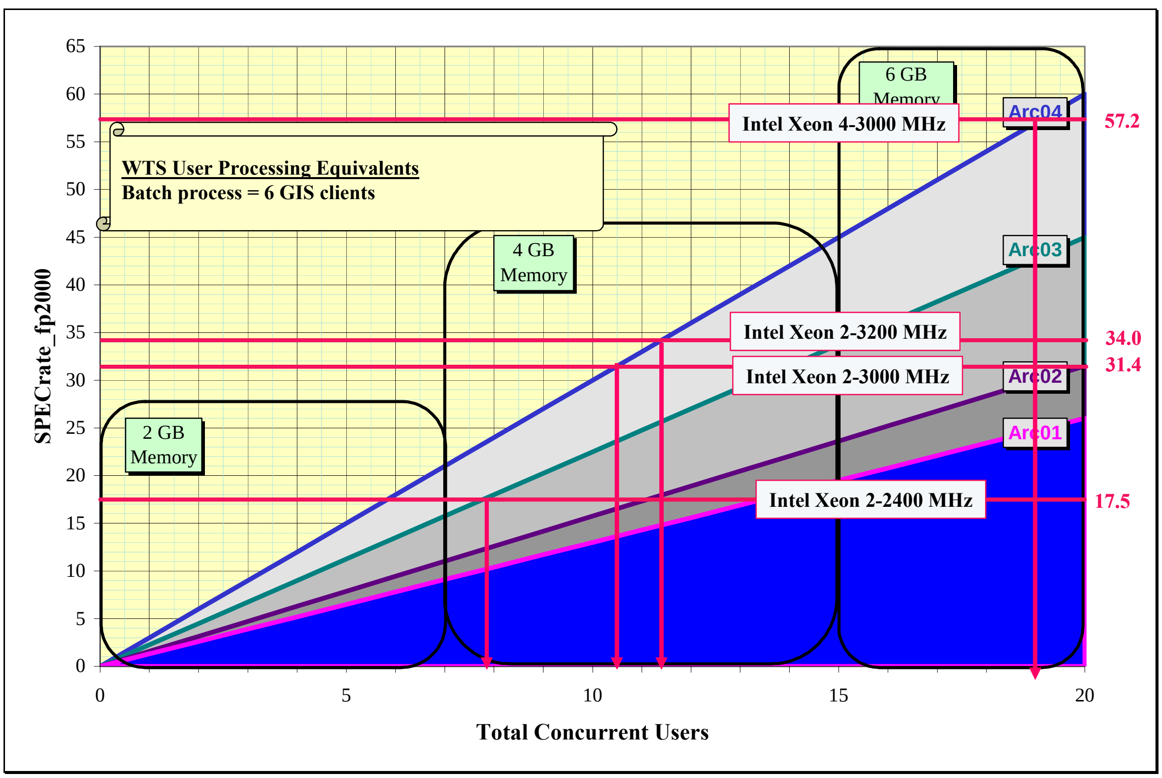
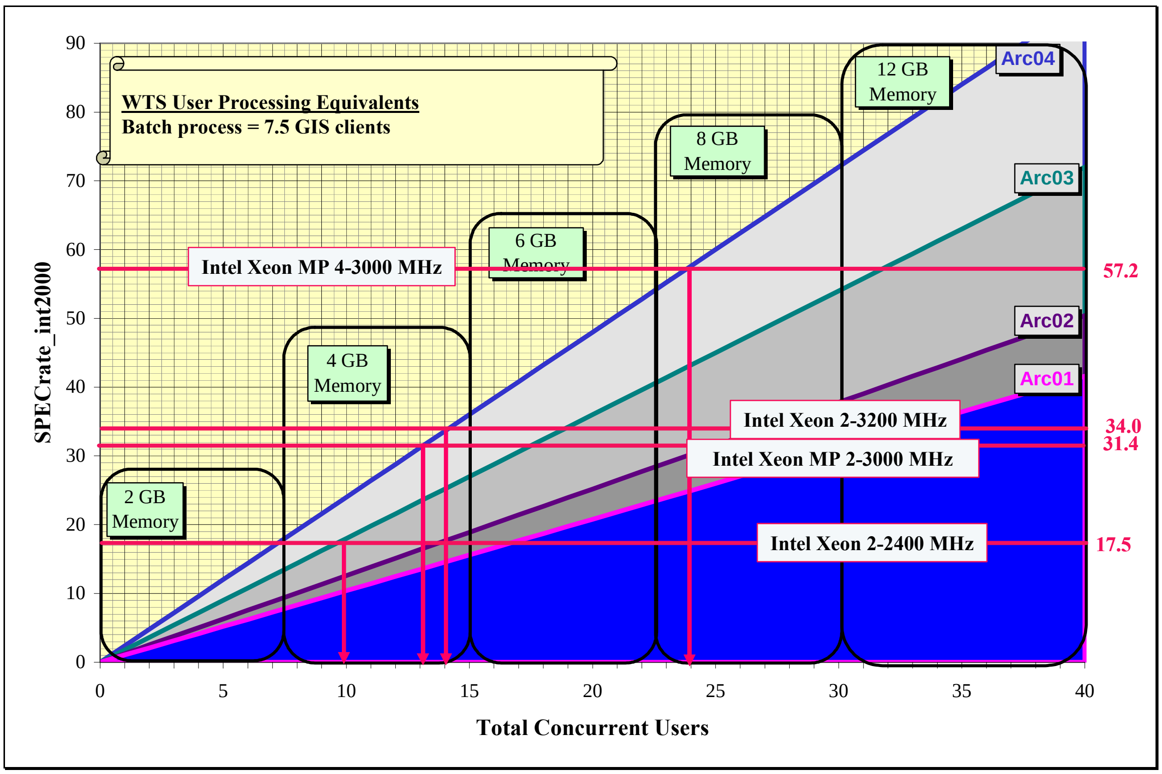


Figure 8-15 provides recommendations for Windows Terminal Servers when accessing a separate ArcSDE data source. Application servers with a separate ArcSDE data source will off-load query processing to the ArcSDE server and, as a result, can maintain performance levels with up to seven or eight ArcInfo users for each CPU. Additional users supported by the same application server will result in reduced application performance.

These charts can be used as a quick reference for selecting the appropriate platform CPU and memory requirements. Memory and performance requirements are provided as a function of peak concurrent users. Platform should be configured with the appropriate number of CPUs required to support peak user performance needs, since users will generally be disappointed with a performance loss even if this loss is predicted in the system design.

New technology may outperform Arc04 performance levels supporting higher user productivity. Peak platform capacity may be reached at the same level indicated by the Intel Xeon 2-CPU 3200-MHz platforms. After reaching peak user capacity, performance is expected to slow gradually to Arc02 performance levels as the platform line intersects with the Arc02 performance line.

Figure 8-15
Windows Terminal Server Sizing
(ArcSDE Data Source)

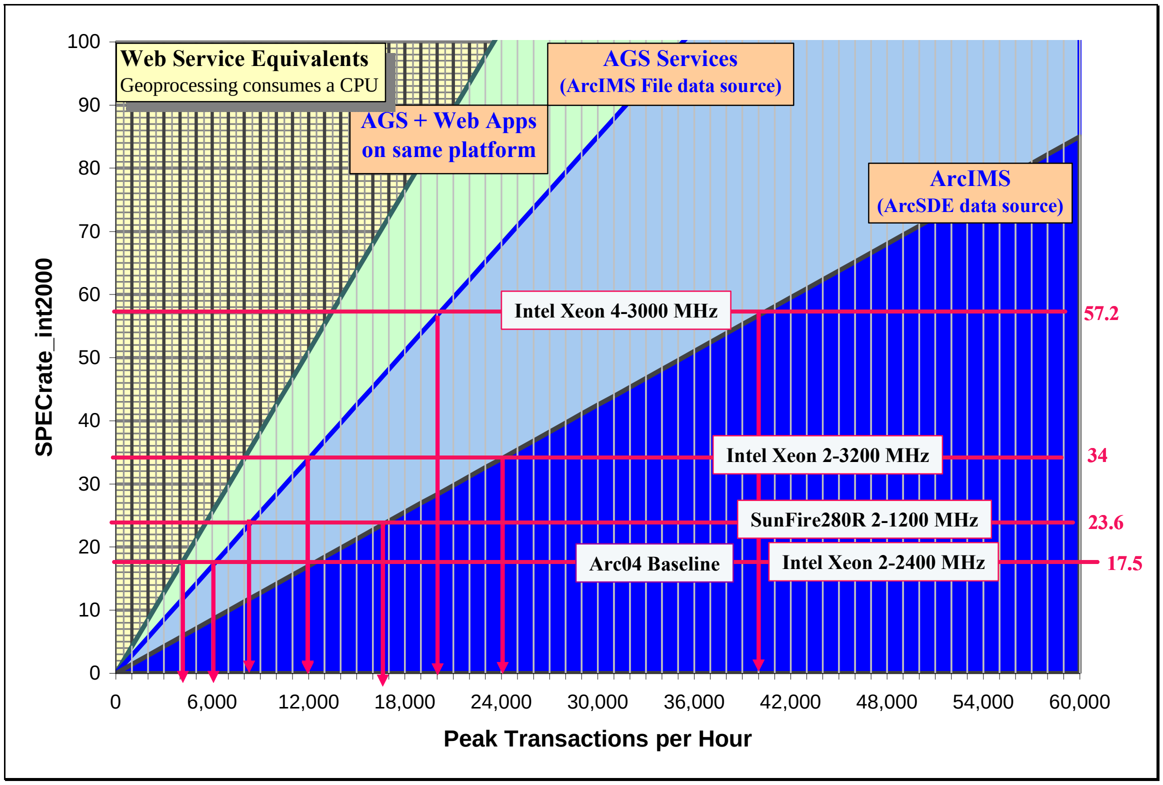


8.6.3 Internet Web Services

ESRI Web services provide the technology to publish map products to browser clients throughout the internal enterprise environment or over the public Internet. The Web site includes several components that support the Web services. These components can be installed on a single platform, or configured on separate platforms for optimum performance and high availability. A complete discussion of the ArcIMS and ArcGIS Server architecture and sizing models were presented in Section 7.

Figure 8-16 provides sizing recommendations for ArcIMS and ArcGIS Server.

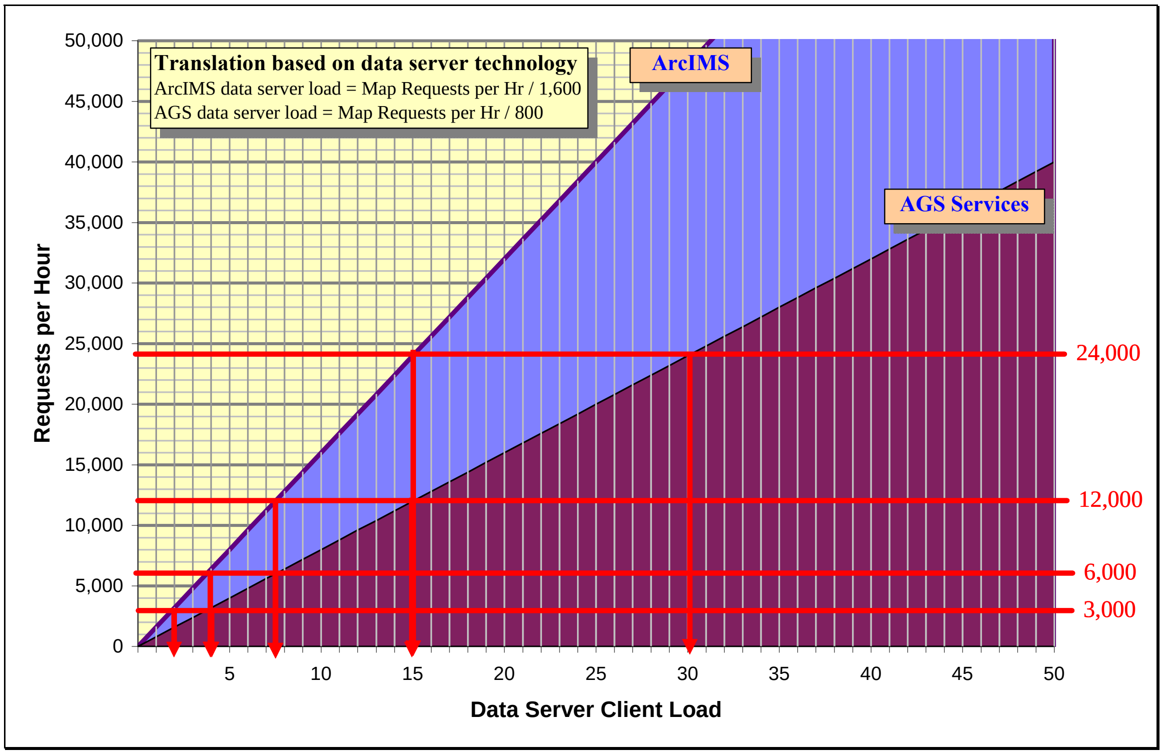
Figure 8-16
ArcIMS/ArcGIS Server Sizing



Sample platforms are included on the performance chart to demonstrate current capabilities. Map server platforms are represented by a horizontal line on the chart (based on their SPECrate_int2000 performance benchmark). The ArcGIS Server (AGS) and Web application server on same platform supports peak loads of 4,000 TPH, the AGS services container machine supports peak loads of 6,000 TPH, and the ArcIMS map server supports peak loads of 12,000 for the Arc04 baseline. Performance baseline is established for these platforms based on the Intel Xeon 2-CPU 3200-MHz server performance (Arc04 single CPU performance is 50% of the dual-processor server).

Figure 8-17 identifies ArcIMS and AGS equivalent data server loads. This chart is required when the source data is located on a separate data server platform. Enter the chart from the left side with the required peak transaction rate (map requests per hour). The equivalent data server load is provided on the horizontal axis, and is identified by the intersection of the peak transaction rate line with the appropriate service line on the chart.

Figure 8-17
ArcIMS/AGS Data Server Processing Loads



ArcIMS/AGS Memory Requirements. Platform memory requirements are normally established to support required executables in physical memory. During peak operations, memory paging of executables should be minimized. Paging is required when there is not enough physical memory to support the required program executables, and executables must be swapped to disk to make room for processing requirements. This extra executable loading is a negative contribution to the overall processing workload, and uses CPU cycles that do not contribute to program execution. With many of the current operating systems, a certain percentage of physical memory is used for data cache in an effort to optimize data processing. Executables may swap to disk even when there appears to be plenty of memory available to retain the code in memory. Sufficient physical memory should be provided to minimize paging on executables during peak processing loads.

ArcIMS map server memory requirements are driven primarily by the number of spatial servers launched to support the published services. Each published map service connections are established on the map server, although these database connections are relatively small compared to the size of the spatial servers. Physical memory requirements are roughly twice what is required to support the deployed spatial server processes.

ArcGIS Server container machine memory requirements are driven primarily by the number of server object containers published to support peak workloads. Each service configuration requires dedicated SOC instances, and sufficient instances must be deployed to support peak transaction loads. Low-isolation SOC configurations require less memory, allowing that each SOC can support four instances before deploying more SOC executables on the same container machine.

Figure 8-18 identifies recommended ArcIMS and AGS physical memory requirements.

Figure 8-18
ArcIMS/AGS Memory Requirements

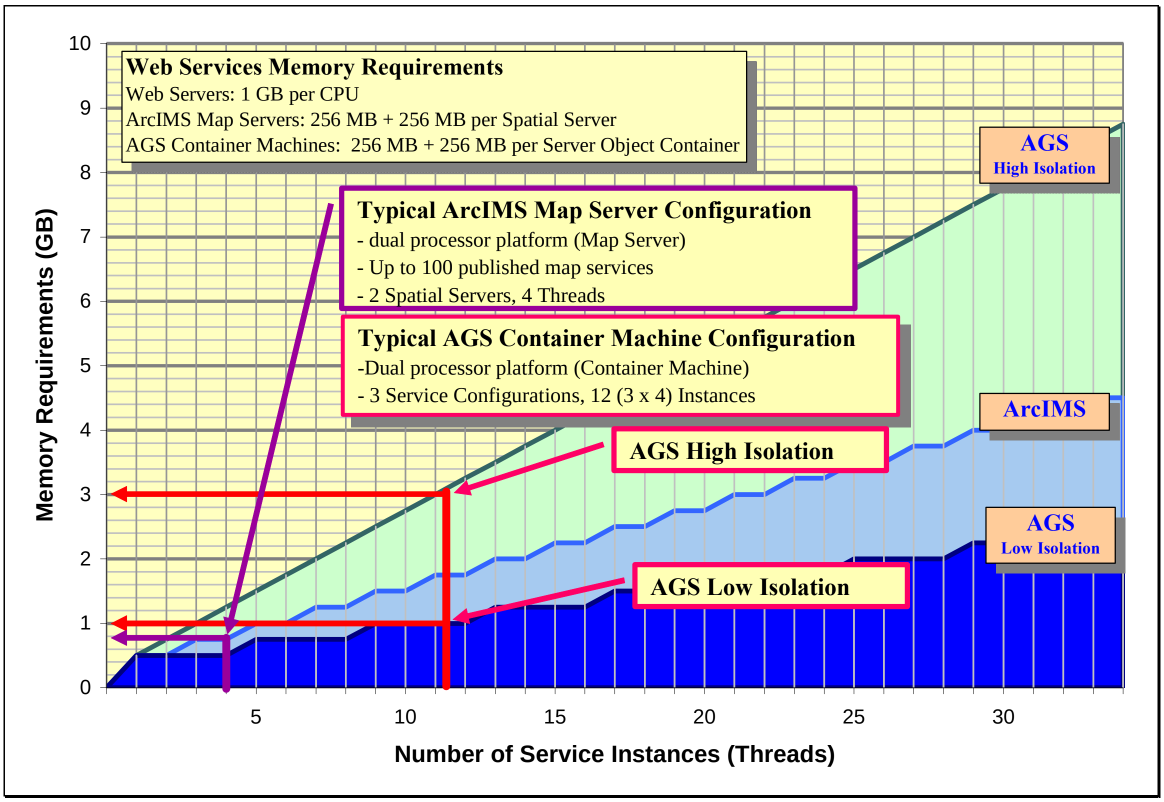
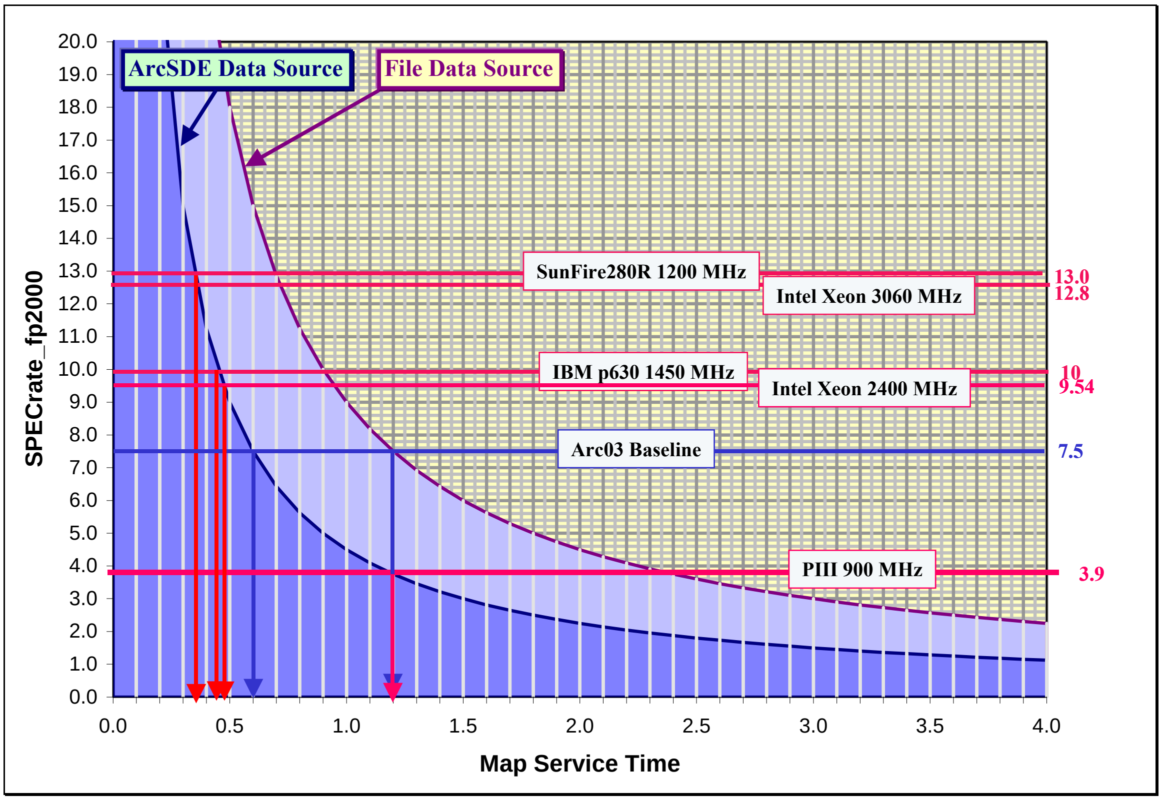


Figure 8-19 can be used to translate map service rates measured on one platform to expected service rates on another platform, based on published relative performance benchmarks. For example, a map service rate of 0.45 seconds on an Intel Xeon 2400-MHz platform would require roughly 1.2 seconds on a Pentium III 900-MHz platform, or 0.35 seconds on a SunFire 280R 1200-MHz platform.

Figure 8-19
ArcIMS Map Service Time



8.6.4 GIS Data Server Sizing (ArcSDE and File Servers)

Data resources typically represent the largest and most valuable asset supporting GIS operations. GIS applications provide tools to support management and analysis of GIS data. The configuration and location of GIS data resources is a primary consideration for any GIS system design.

There are several data formats and storage strategies that can be used to support GIS data resources. Data can be stored in user directories on local workstations or application servers for individual GIS projects or studies. Shared GIS data resources are normally located on a GIS file server or ArcSDE DBMS server. Enterprise data server solutions are normally supported by an ArcSDE DBMS server. Web services can be supported by data replicated on the ArcIMS spatial server or by a central file server or ArcSDE DBMS server.

The data location will impact system performance. Data located on a data server must be transmitted across the network to the application to support processing (minimum of 100-Mbps bandwidth is recommended between the application processing platform and the GIS data source). Larger bandwidth capacity may be required when using a file data source or supporting larger ArcSDE server client environments. The GIS application will support query processing when data is stored locally or on a file server. The ArcSDE server will support query processing for data located in the ArcSDE DBMS.

Data server sizing charts are provided for workgroup and enterprise environments. Both of these charts are based on the same sizing model, and can be used for selecting file server or ArcSDE data servers. There is no additional performance penalty for application access to data on local disk (this is supported by the application server and workstation performance charts).

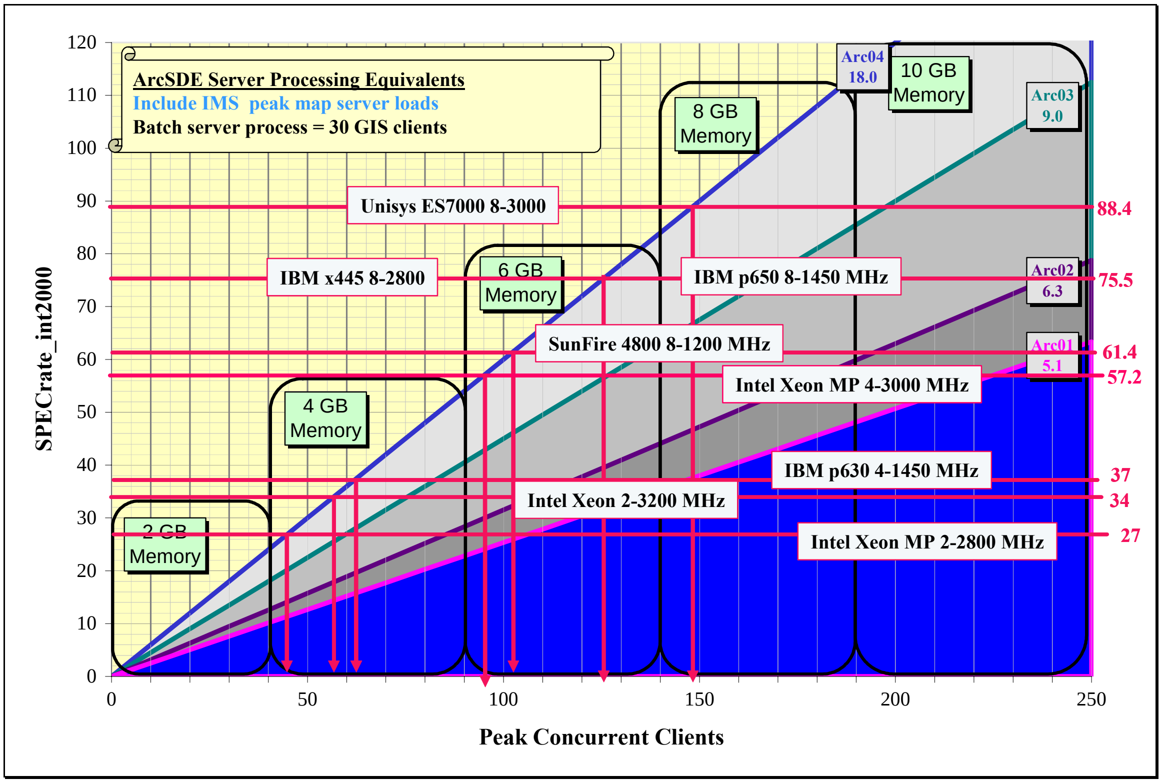
The GIS data server provides an environment for GIS spatial data and associated server processes. The GIS data server must be configured to support the maximum number of concurrent clients. Any additional processes running on the server platform must also be accounted for in the sizing analysis.

The total number of concurrent GIS clients that can be supported by a specific GIS data server platform can be calculated by dividing the published SPECrate_int2000 performance rating by the associated performance baseline platform rating and multiplying by a factor of 30. This identifies the maximum number of users supported by the recommended candidate platform configuration.

In some configurations, the GIS data server will also support additional application or server processes. These additional processes must be included in determining the total compute load on the server. Additional client application processes (ArcInfo or ArcView GIS) running on the server take roughly the same CPU resources as five data server clients. Any batch processes running on the server will consume a CPU, which is equivalent to the resources required to support 30 data server clients. These adjustments can be made to estimate the total number of equivalent concurrent GIS clients.

Memory and performance guidelines for dedicated GIS data server sizing are displayed in Figure 8-20. These charts can be used as a quick reference for sizing GIS data servers.

Figure 8-20
Workgroup Data Server Sizing
(ArcSDE and File Servers)

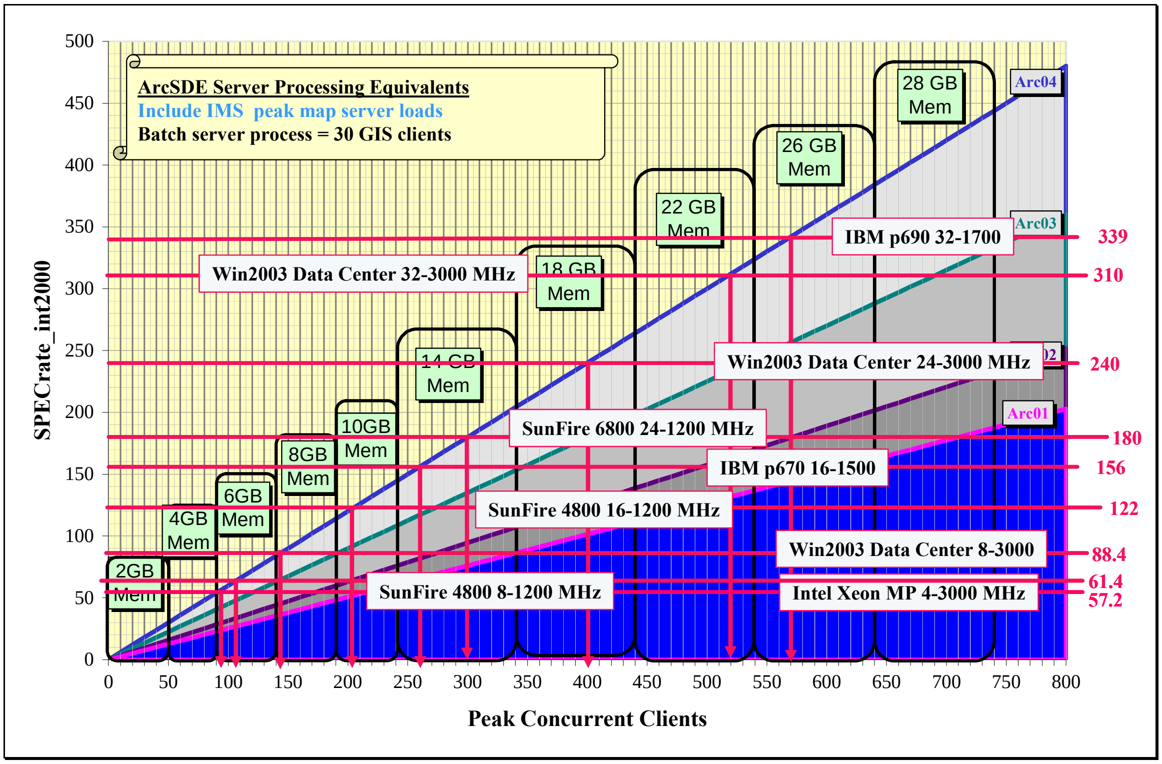


The ArcSDE data server provides client/server data management integrated with standard commercial DBMS product solutions. ArcSDE provides GIS transaction management on the server platform and supports network communication with the GIS client application. The ArcSDE server should be configured to support the peak number of concurrent ArcSDE clients. Any additional processes running on the server platform should also be accounted for in the sizing analysis. This would include any DBMS clients in addition to the GIS users.

The ArcSDE solution is supported on a variety of DBMS platforms including Oracle, Informix (incorporated in the Informix Spatial Datablade), DB2 (incorporated with the DB2 Spatial Extender), and Microsoft SQL Server. Communications between client and server are supported by the ArcSDE application programming interface (API). Both spatial and attribute data are stored in the DBMS. Standard DBMS administration and performance tuning features apply to both the spatial and attribute data. An alternative DBMS Direct Connect option is available for which supports the ArcSDE processing load on the client and using the DBMS network client to communicate with the DBMS server.

Memory requirements are identified to support standard DBMS and ArcSDE server processing and should be increased to support planned data caching needs. Increasing memory cache can significantly improve server performance. These charts can be used as a quick reference for sizing GIS data servers.

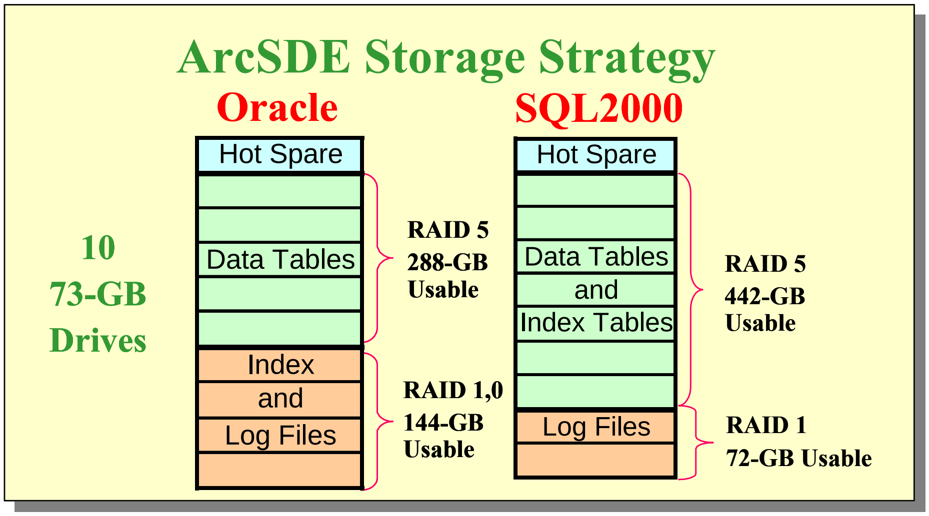
Figure 8-21
Enterprise Data Server Sizing
(ArcSDE and File Servers)



Data storage is becoming a growing consideration in supporting enterprise ArcSDE server environments. Storage requirements have increased from several 10s of Gigabytes to over a Terabyte of data within the last couple of years, and data storage requirements are continuing to increase as spatial data resources grow. It is common to find the cost of the storage solution to exceed the cost of the enterprise server, both in terms of initial hardware and overall administrative cost.

There are several basic considerations that must be addressed in selecting the appropriate storage solution. Standard storage practices recommend storage of DBMS index and data files on separate disks. Microsoft SQL Server recommends locating the SQL log files on a RAID1 mirrored pair of disks, with index and data files on RAID5 (striping with parity disk) volumes. Oracle recommends the more intense index and log tables located on RAID1,0 storage (mirror and striping) and data tables on RAID5. For best practice, the RAID5 volumes should be supported on 5 (4+1) or 9 (8+1) disk volumes (5-disk RAID5 supports highest peak capacity). Storage recommendations are summarized in Figure 8-22.

Figure 8-22
ArcSDE Storage Best Practices



Several factors contribute to disk access performance. Data striping along with the array data cache improves access performance. Too few disks in the array (with lots of concurrent client queries) can result in disk contention (I/O performance bottlenecks). Small database environments with a large number of peak user loads present the highest probability of disk contention. As a general guideline, a minimum of 5-disk RAID5 array should support the ArcSDE data files.

8.7 Platform Selection Criteria

There are several factors that must be considered in supporting proper hardware selection. These factors include the following:

- **Platform Performance**. Platform must be configured properly to support user performance requirements. Identifying proper platform configurations based on user performance needs and the ESRI design models establishes a solid foundation for proper hardware platform selection.
- **Purchase Price**. Cost of hardware will vary depending on the vendor selection and platform configuration. Pricing should be based on evaluation of hardware platforms with equal performance capacity.
- **System Supportability**. Customer must evaluate system supportability based on vendor claims and previous experience with supporting vendor technology.
- **Vendor Relationships**. Relationships with the hardware vendor may be an important consideration when supporting complex system deployments.
- **Total Life-Cycle Costs**. Total cost of the system may depend on many factors, including existing customer administration of similar hardware environments, hardware reliability, and maintainability. Customer must assess these factors based on previous experience with the vendor technology and evaluation of vendor total cost of ownership claims.

Establishing specific hardware performance targets during hardware source selection significantly improves the qualtify of the hardware selection process. Proper system architecture design and hardware selection provides a basis for successful system deployment.

9 System Implementation

Successful system implementation requires good leadership and careful planning. A good understanding of every component of the system is critical in putting together an implementation strategy. Enterprise IT environments involve integration of a variety of vendor technologies. Interoperability standards within IT environments are voluntary, and even the most simple technology integration must be validated at each step of the integration process.

Enterprise GIS environments include a broad spectrum of technology integration. Most environments today include a variety of hardware vendor technologies including database servers, storage area networks, Windows Terminal Servers, Web servers, map servers, and desktop clients all connected by a broad range of local area networks, wide area networks, and Internet communications. All of these technologies must function properly together to support a balanced computing environment. A host of software vendor technologies include database management systems, ArcGIS desktop and server software, Web services, and hardware operating systems all integrated with existing legacy applications. Data and user applications are added to the integrated infrastructure environment to support the final implementation. The result is a very large mixed bag of technology that must work together properly and efficiently to support user workflow requirements.

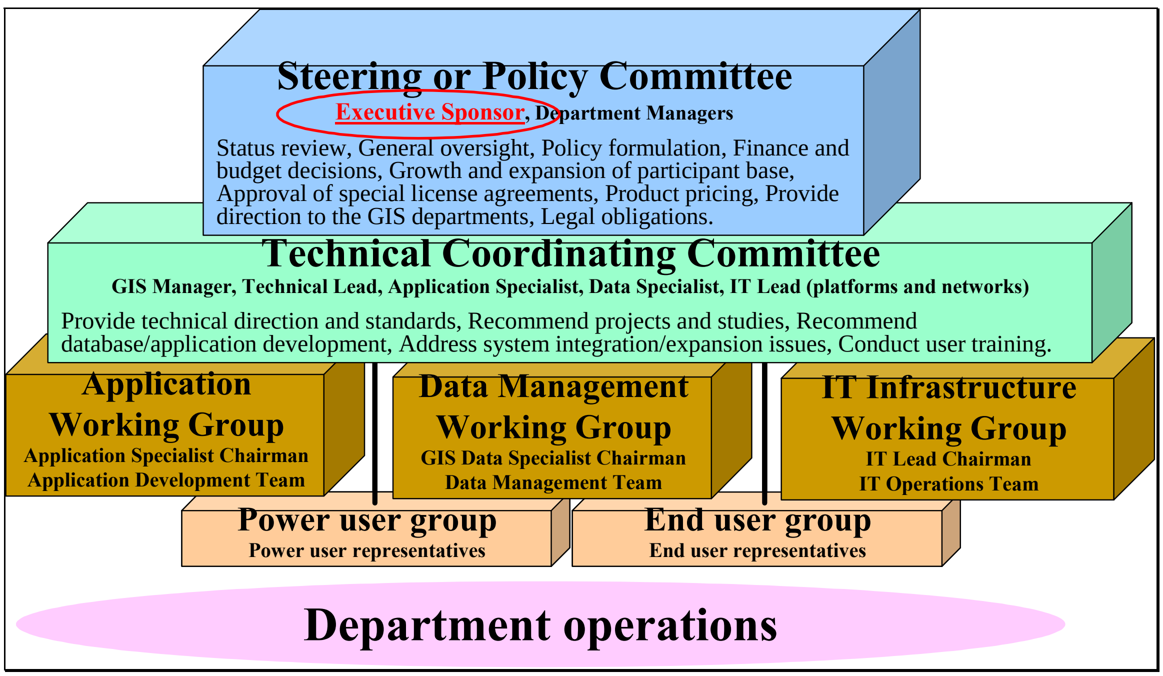
The integration and implementation of distributed computer technology has become easier over the years as interface standards have matured. Over the same time, enterprise environments have become larger and more complex. The complexity and risk associated with an enterprise system deployment is directly related to the variety of vendor components required to support the final integrated solution. Centralized computing solutions with a single database environment are the easiest environments to implement and support. Distributed computer systems with multiple copies of the same database environment can be very complex and difficult to deploy and support. Many organizations are consolidating their data resources and application processing environments to reduce implementation risk and improve administrative support for enterprise business environments.

9.1 GIS Staffing

Good leadership begins with proper staffing. Successful GIS enterprise deployments are normally supported by an executive business sponsor, and the GIS manager should report to senior management.

Figure 9.1 shows an overview of a traditional GIS organization structure. Enterprise GIS operations are supported by an executive committee with influence and power to make financial and policy decisions for the GIS user community. A technical coordinating committee is responsible for providing technical direction and leadership. Working groups are assigned, normally aligned with each technical discipline, to address organizational issues and report on system status. The user community should be represented throughout the overall review process.

Figure 9-1
Traditional GIS Organizational Structure



A formal organizational structure provides a framework for establishing and maintaining long-term support required for successful enterprise GIS operations. This basic organization structure can be useful in managing small to large organizations, and the same type of organizational structure can be effective in managing community GIS operations.

Several technical disciplines are required to support successful GIS operations. Figure 9-2 provides an overview of functional responsibilities required to support enterprise GIS operations.

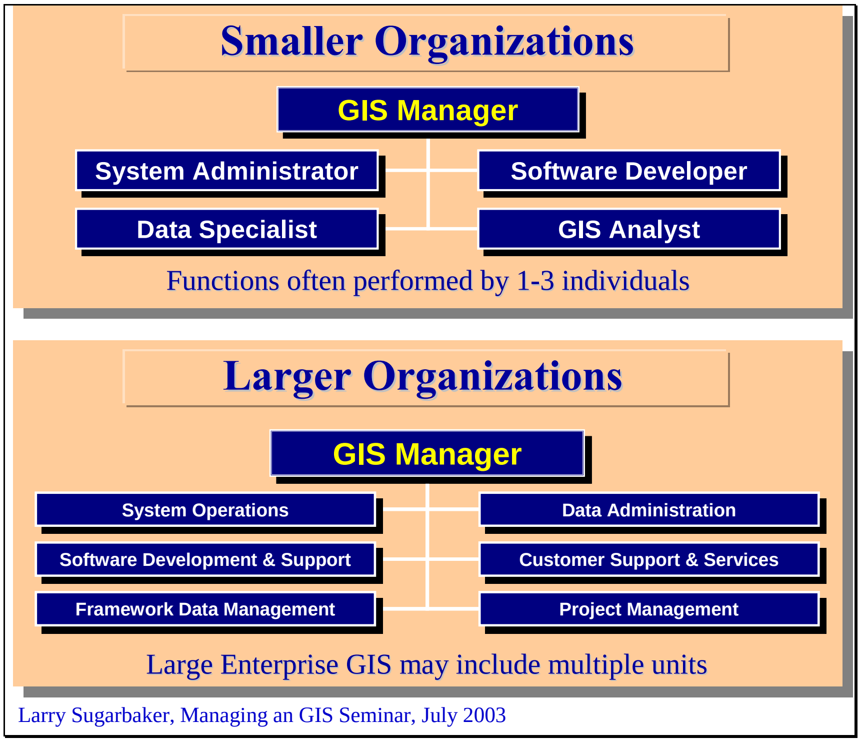
Figure 9-2
GIS Functional Responsibilities

STAFF	ROLE	RESPONSIBILITIES
GIS Manager / Coordinator	Enterprise GIS Operations Management	Provide planning and direction for GIS growth to serve multiple departments Chairman of the Technical Coordinating Committee Provide overall management for all GIS implementation tasks Manage setting of priorities for database and applications development Act as liaison to other departments and outside agencies Provide overall management for all contracted work
GIS Analyst / Technical Lead	GIS technical lead	Technical leadership to GIS users Executive secretary of the Technical Coordinating Committee Project implementation services Interdepartment technical coordination GIS technical support services Coordinate project work for departments and outside agencies Provide user training services Perform troubleshooting on custom application problems
System administrator	System Manager	Hardware - procurement, installation and configuration Network infrastructure - installation and configuration System performance tuning / troubleshooting Operating System System backup and recovery Related software (upgrades and service packs)
Database administrator (DBA)	DBMS manager	Database configuration Data model implementation Database security Performance tuning Data backup and recovery Data replication DBMS software upgrades and service packs
ArcSDE database administrator	ArcSDE manager	ArcSDE installation and software upgrades Ownership and management of ArcSDE and geodatabase schema objects Manages the ArcSDE service Compresses a geodatabase
Data administrator	Data and geodatabase manager	Data model design Data validation and quality - topology, domains Version management Spatial data management - data loading, spatial index tuning, DBMS statistics
GIS Application Programmer	Desktop application development and support	Develop and enforce programming standards Desktop application development and code maintenance Desktop client application support Desktop application performance tuning
ArcIMS Application Specialist	Web services development	Web services development and maintenance Web services application and system performance tuning

The complexity of these responsibilities will vary with the size and extent of each individual GIS implementation, although every organization will need some level of support and expertise in each of these areas.

The GIS manager of each organization will have a dedicated staff to support central GIS operations. In smaller organizations, members on the GIS staff may perform multiple roles. In larger organizations, responsibilities may be more specialized and expanded to support additional levels of coordination and support activities. Large enterprise operations may require additional GIS support staff reporting at various business unit manager levels.

Figure 9-3
GIS Staffing Recommendations



9.2 Building Qualified Staff

Training is available to help develop qualified staff and support GIS user productivity. Organizations should make sure their teams receive required training. Figure 9-4 provides an outline of recommended ESRI training courses established to support qualification of the required staff functions.

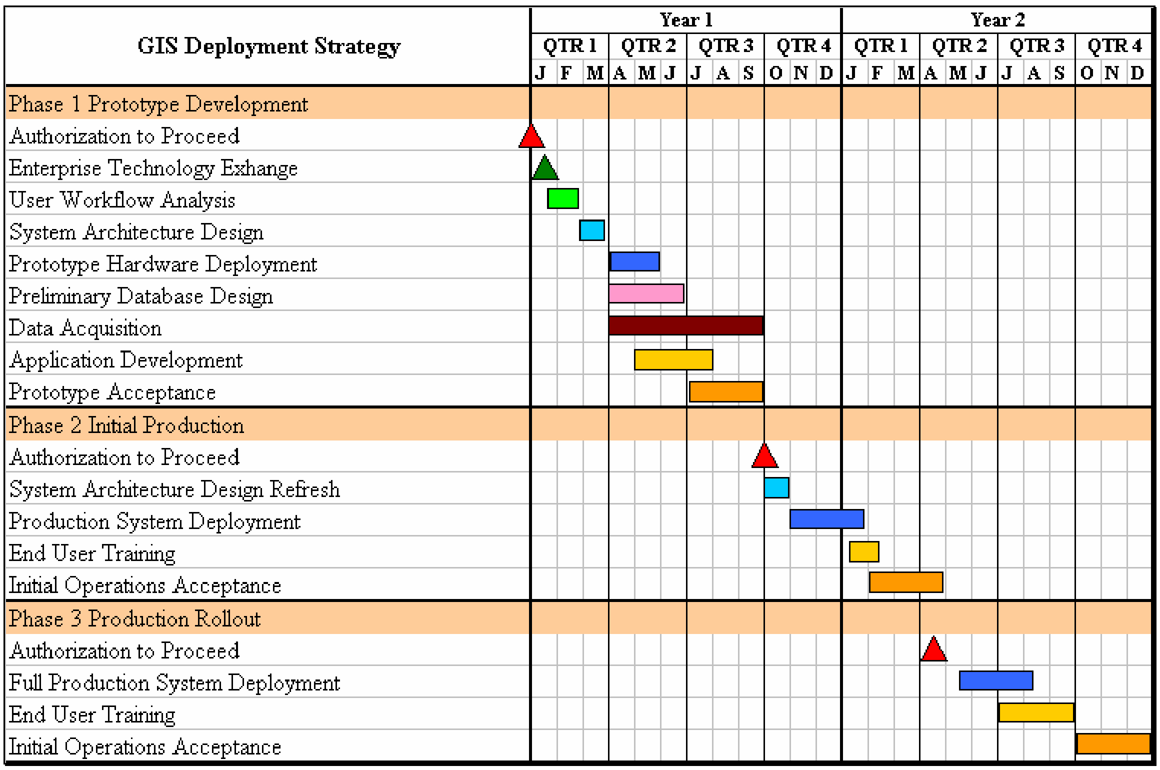
Figure 9-4
Training Opportunities

Training for GIS Operational Staff	GIS Manager / Coordinator	GIS Analyst / Technical Lead	System administrator	Database administrator (DBA)	ArcSDE database administrator	Data administrator	GIS Application Programmer	ArcIMS Application Specialist
GIS Software Training								
What's New in ArcGIS 8.3/9.0	○	○	○	○	○	○	○	○
Introduction to ArcGIS I	●	●	●	●	●	●	●	●
Introduction to ArcGIS II	●	●	○	○	●	●	●	●
Customizing ArcGIS (Web course)	○	●		○	○	●	●	
Introduction to Programming ArcObjects	○	●		○	○	●	●	
Advanced ArcObjects Component Development I & II	○	●		○	○	●	●	
Geodatabase Design Concepts	○	●	○	●	○	○	○	
Building Geodatabases I & II	○	○	○	●	○	○	○	
Modeling Geodatabases using CASE Tools	○	○	○	●	○	○	○	
System Architecture Design for GIS	●	●	●	○		○	○	●
GIS Procedures Training								
Storing Raster Data in ArcSDE Geodatabase		○		●	●	○	○	○
Understanding ArcSDE Table Relationships		○		●	●	○	○	
Understanding the ArcSDE Spatial Index		○		●	●	○	○	
Introduction to ArcIMS		●	○					●
ArcIMS Administration			○					●
Introduction to ArcSDE		●	○	○	●			○
ArcSDE Administration for DB2/SQL/Oracle			○	○	●			○
● Recommended Training								
○ Optional Training								

9.3 System Architecture Deployment Strategy

Planning is normally the first step in supporting a successful system deployment. A system design team should review current GIS and hardware system technology, review user requirements, and establish a system architecture design based on user workflow needs. A deployment schedule should be developed to identify overall implementation objectives.

Figure 9-5
GIS System Deployment Strategy



Phased implementation strategies can significantly reduce implementation risk. Computer technology continues to evolve at a remarkable pace. Integration standards are constantly changing with technology and, at times, may not be ready to support immediate system deployment needs. New ideas are introduced into the market place every day, and a relatively small number of these ideas develop into dependable long-term product solutions. The following best practices are recommended to support successful enterprise GIS implementation.

Pilot Phase

- Represent all critical hardware components planned for the final system solution
- Use proven low-risk technical solutions to support full implementation
- Include test efforts to reduce uncertainty and implementation risk
- Qualify hardware solutions for initial production phase

Initial Production Phase

- Do not begin until final acceptance of pilot phase
- Deploy initial production environment
- Use technical solutions qualified during the pilot phase
- Demonstrate early success and payoff of the GIS solution
- Validate organizational readiness and support capabilities
- Validate initial training programs and user operations
- Opportunity to qualify advanced solutions for final implementation

Final Implementation Phase

- Do not begin until final acceptance of initial production phase
- Plan a phased rollout with reasonable slack for resolving problems
- Use technical solutions qualified during previous phases
- Prioritize roll-out timelines to support early success

9.4 System Testing

Proper test conduct can contribute to implementation success. Functional component and system integration testing should be conducted for new technology during the initial pilot phase. Performance testing should be delayed until the initial production phase.

Figure 9-6 identifies best practices for planning and conducting functional system testing.

Figure 9-6
Functional System Testing Best Practice

- **Test Planning**
  - Complete a Risk Analysis: Identify functionality that requires testing.
  - Identify test objectives and establish configuration control plan
  - Identify test hardware/software configuration
  - Develop test procedures
- **Test Implementation**
  - Identify implementation team and establish implementation schedule.
  - Order hardware and software and publish installation plan
  - Conduct test plan and validate functional acceptance.
  - Collect test performance parameters (CPU, Memory, Network Traffic, etc)
- **Test Results and Documentation**
  - Document the results of the testing
    - Include specific hardware/software/network components that were tested
    - Include installation and test procedures that were followed, test anomalies, and final resolution.
    - Complete test compliance matrix identifying validation of functional requirements
  - Publish the test results for reference during system implementation

"Complete prototype integration testing before production deployment"
"Test in production environment (configuration control)"
"Document functional requirements and test procedures"

Functional system testing should be completed for all new technology that will be integrated into the production system. A test plan should be developed to identify test requirements, establish configuration control (software versions, operating system environment), and provide test procedures. Testing should be completed before production deployment. Testing should be conducted using the software versions and operating system that will be deployed in the production environment.

Figure 9-7 identifies some cautions and warnings associated with system performance testing.

Figure 9-7
Performance Testing Pitfalls

- **False Sense of Security**
  - Tendency to accept test results over analysis
  - Problem 1: Test results are a function of input parameters often not understood
  - Problem 2: System bottlenecks in testing can generate false conclusions
- **Simulated Load Testing May Not Represent Real World**
  - Load generation seldom represents actual user environments
  - Relationships between load generation and real world are seldom understood
  - Several system configuration variables can contribute to test anomalies
- **Performance Testing Best Practices**
  - Model system components and response parameters
  - Validate models based on real-world user loads testing
  - Predict test results from models (hypothesis) before conducting testing
  - Evaluate test results against models and original hypothesis
  - Update models and hypothesis, repeat testing until reaching consensus

"TEST ONLY WHEN YOU THINK YOU KNOW THE ANSWER"
"TESTING ONLY CONFIRMS WHAT YOU ALREADY KNOW"
"TESTING DOES NOT TEACH YOU WHAT YOU DON'T KNOW"

Performance testing can be expensive and the results misleading. Initial system deployments normally need to be tuned and optimized to achieve final performance goals. System performance bottlenecks are normally identified and resolved during the initial deployment. Early application development focuses primarily on functional requirements, and performance tuning is not complete until the final release. Actual user workflow environments are difficult to simulate, and test environments seldom replicate normal enterprise operations.

The scientific method introduced with grade school science fair projects demonstrates fundamental best practices that directly apply to system performance testing. Performance testing should only be conducted to validate a hypothesis (something you think you know). The primary objective of a performance test is to validate the hypothesis (confirm what you know). The test is a success only if it proves the hypothesis (testing does not teach you what you don't know).

Initial performance testing results often fail to support the test hypothesis. With further analysis and investigation, test bottlenecks and/or improper assumptions are identified that change the test results. Performance testing is only successful if it validates the test hypothesis.

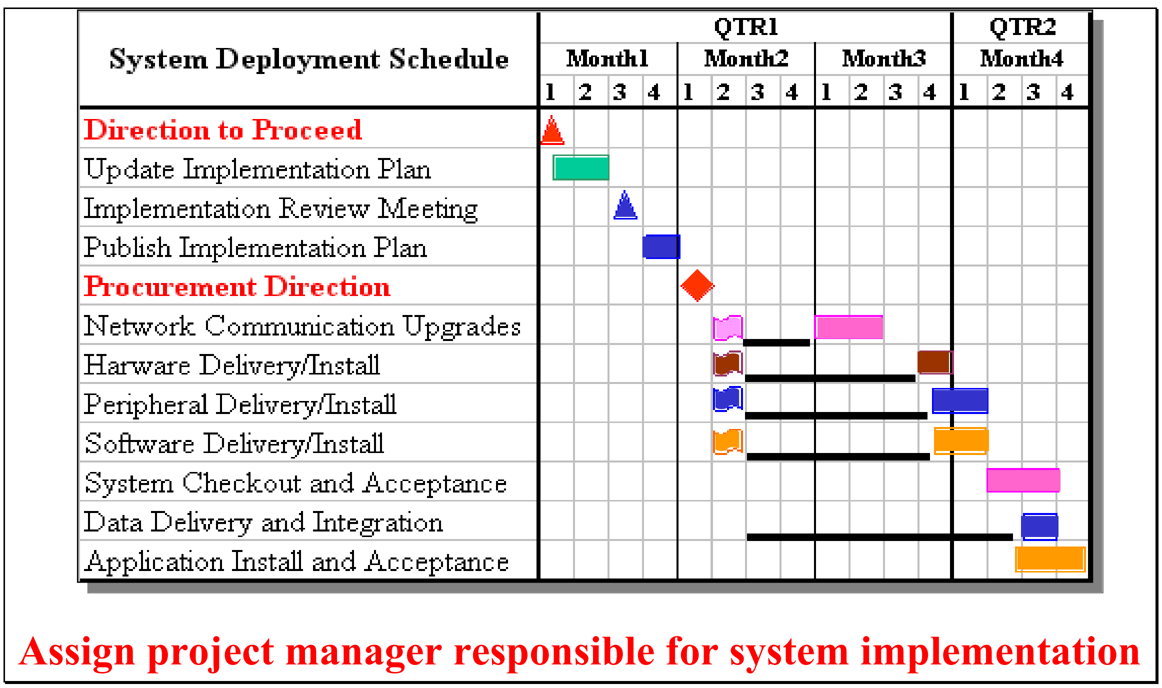
Performance testing is best conducted during the initial production deployment. During this phase, real users doing real workflow can generate a real user environment. Critical system components should be monitored during the initial deployment to identify processing bottlenecks and resolve system conflicts. Initial deployment acceptance should include validation that user workflow performance needs are met.

9.5 System Implementation Management

Basic project management practices promote implementation success. Project teams should be established, individuals should be assigned specific responsibilities, task plan should be developed to support implementation planning, configuration control plan and change control process should be established, and an implementation schedule should be published to support project deployment milestones.

A system architecture design can provide the framework for establishing an implementation plan. The implementation plan should be developed after final selection of the hardware vendor solution. Figure 9-8 provides a typical system deployment schedule. Specific decision milestones should be included on the schedule, and each major task effort clearly identified. An implementation project manager should be assigned to make sure all tasks are well defined and every participant has a clear understanding of their responsibilities. A clear set of acceptance criteria should be developed for each implementation task, and a formal acceptance process followed to ensure integration issues are identified and resolved at the earliest opportunity.

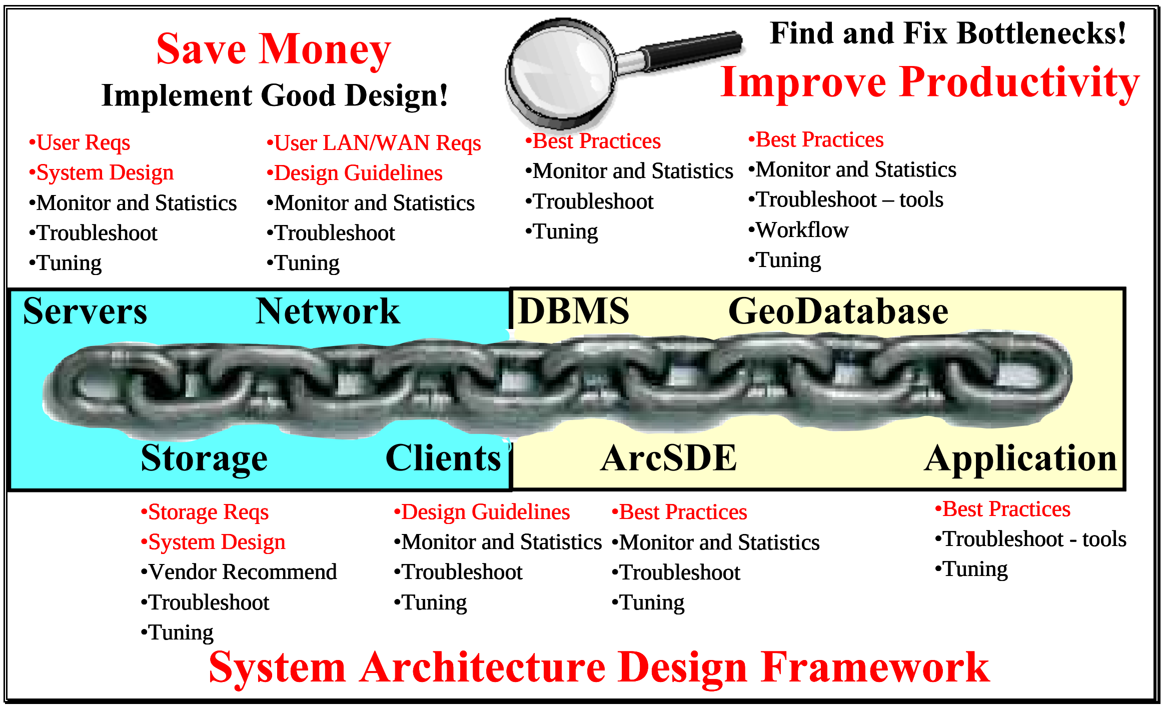
Figure 9-8
Systems Integration Management



9.6 System Tuning

System tuning is a critical part of final system integration and deployment. Initial user requirement planning is the first opportunity to begin performance tuning. Heavy batch processing efforts should be separated from interactive user workflows and supported through a separate batch process queue. System backups and heavy processing workloads should be planned during off-peak workflow periods. System component performance metrics should be monitored on a periodic basis, particularly during peak workflow periods, to identify performance bottlenecks and address system deficiencies. Figure 9-9 provides an overview of the components supporting an enterprise GIS environment. Any component has the potential to introduce a weak link in the overall system performance equation.

Figure 9-9
System Performance Factors



9.6.1 ArcIMS Server Performance Tuning

There are variables within the ArcIMS architecture that can be measured and modified to improve site performance. Figure 9-10 identifies the associated performance measurements and configuration variables available in tuning an ArcIMS configuration.

Figure 9-10
Web Mapping Services Performance Profile

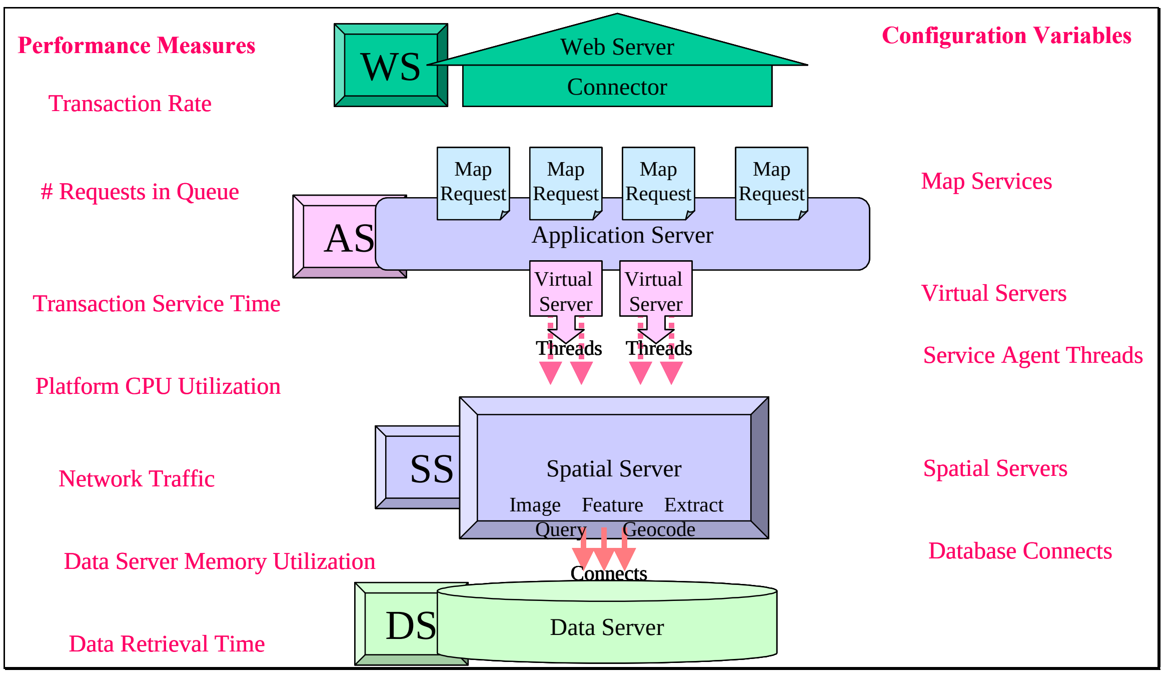


Figure 9-11 identifies things you can measure, and how you can modify ArcIMS map services or component variables to optimize site performance.

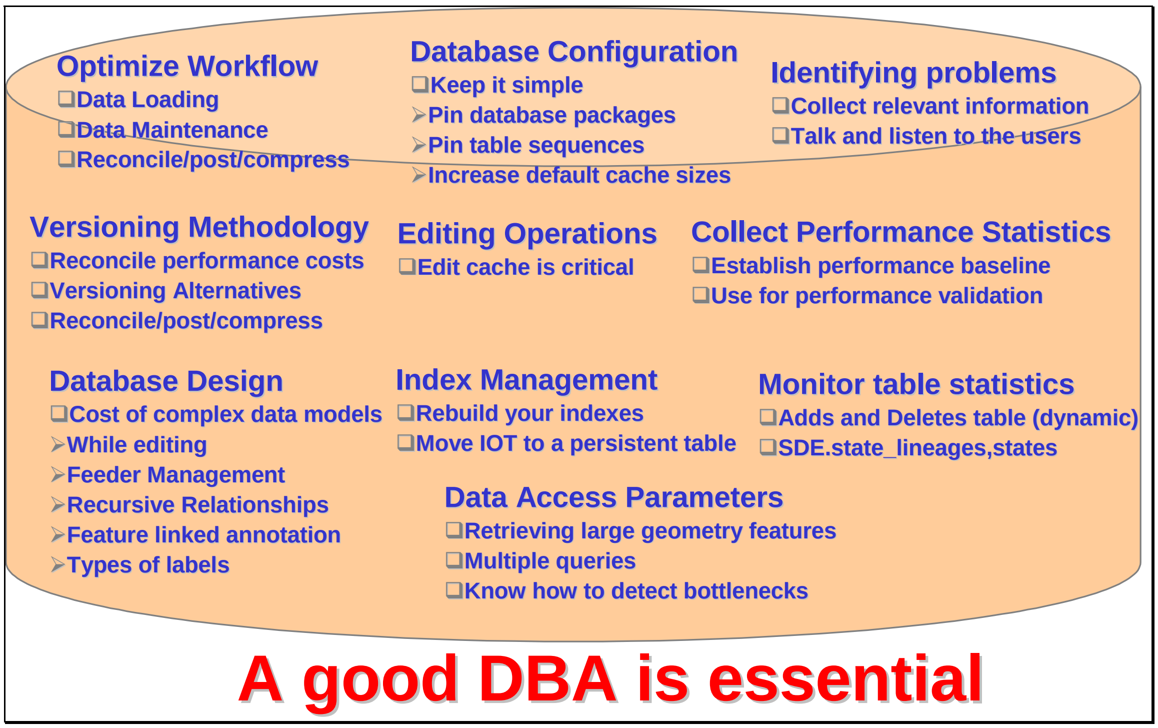
Figure 9-11
Web Mapping Services Performance Tuning Guidelines

Performance Measure	Tuning Options
Transaction Rate	Transaction rate identifies the number of requests supported by the site configuration. Peak transaction rate is the maximum capacity of the site to support incoming requests. Peak capacity can be increased by reducing the time required to generate each map service (simpler information products) or by increasing the number of CPUs (more processing power). Sufficient service agent threads should be included to take full advantage of the available CPUs (usually 2-3 threads per CPU is sufficient). Once CPUs are fully utilized, additional threads will not improve site capacity.
# Requests in Queue	Each virtual server acts as a processing queue for inbound requests. Requests are held in the queue until there is a service thread available to process the request. If a request arrives and the virtual server queue is full, the browser will receive a server-busy error. Queue depth can be increased to avoid rejecting browser requests.
Transaction Service Time	CPU time required to process the published service, once it has been assigned to a service agent for processing. Long service times can significantly reduce site capacity, and should be avoided if possible. Simple map services (light data and minimum number of layers) can significantly improve site capacity.
CPU Utilization	Sufficient threads should be configured on the public service agents to support maximum CPU utilization. Peak site capacity is reached with CPU utilization reaches a peak level (close to 100% utilization). Increasing service threads beyond this point without increasing number of CPUs will increase average client reponse time, and is not recommended.
Network Traffic	Sufficient network bandwidth must be available to support information product transport to the client browser. Network bottlenecks can introduce serious client response delays. Bandwidth utilization can be improved by publishing simple map services, keeping image size from 30 KB to 50 KB, and ensuring sufficient bandwidth to support peak transaction rates.
Data Server Memory	Sufficient physical memory must be available to support all processing and adequate caching for optimum performance. Memory utilization should be checked once the system is configured to insure more physical memory exists that what is being used to support the production configuration.
Data Retrieval Time	CPU processing time on the ArcSDE server. Query time can be optimized by proper indexing and tuning of the ArcSDE database.

9.6.2 ArcSDE Performance Tuning

The ArcSDE database provides the data source for clients and Web services supporting the enterprise environment. Performance issues on the ArcSDE server can impact the entire system environment. Figure 9-12 provides an overview of factors to consider in tuning the ArcSDE database environment.

Figure 9-12
ArcSDE Performance Tuning

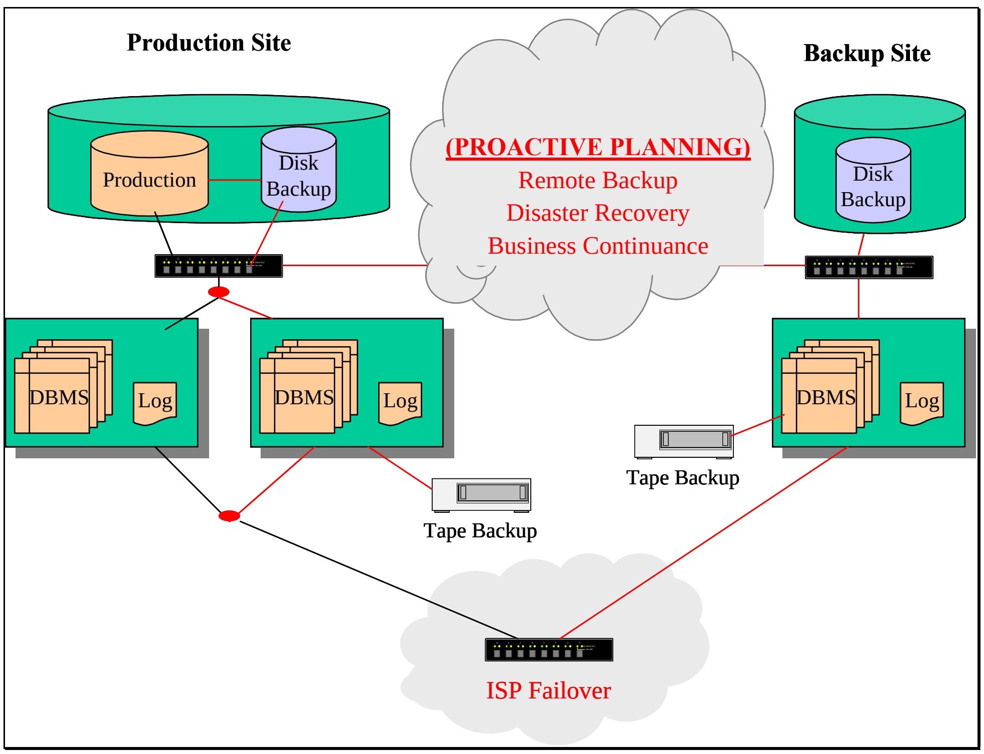


Some database performance factors relate directly to workflow management, initial database design, and the versioning methodology. Other performance problems can be resolved through rebuilding database indexes, using edit cache during long transactions, or monitoring performance or table statistics to support timely data administration and maintenance functions. In all cases, it is extremely important to have the support of a qualified database DBA to support standard performance tuning and administration of the database environment.

9.7 Business Continuance Plan

Every organization should carefully assess the potential failure scenarios within their system environment, and protect critical business resources against such failures. Enterprise GIS environments require a significant investment in GIS data resources. These data resources must be protected in the event of a system failure of physical disaster. Business recovery plans should be developed to support all potential failure scenarios. Figure 9-13 provides an overview of the different system backup strategies. A business continuance plan should be developed to address specific organizational needs in the event of a system failure or disaster recovery.

Figure 9-13
Plan for Business Continuance

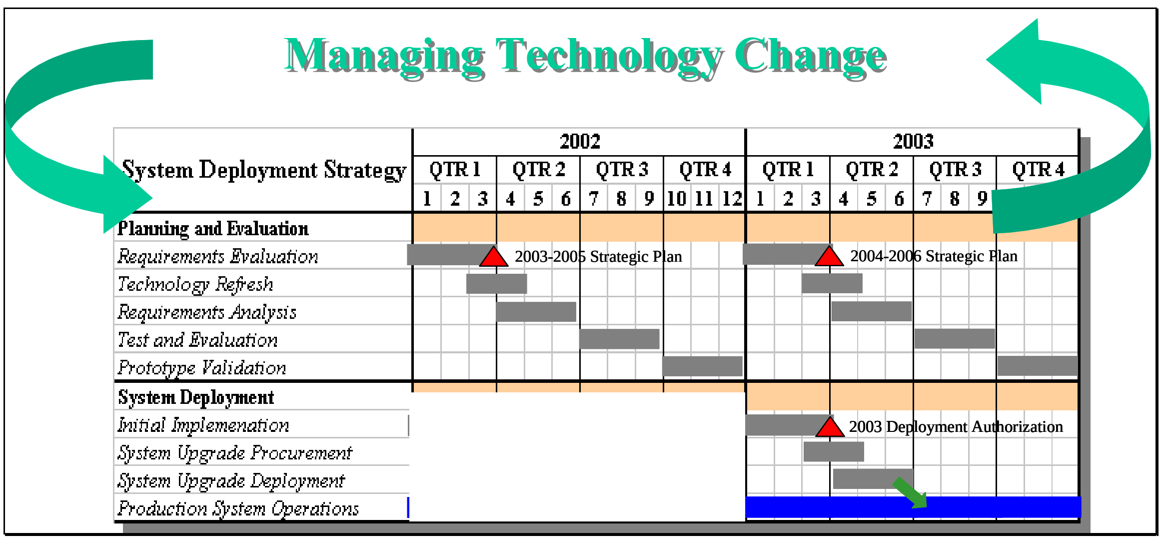


9.8 Managing Technology Changes

Enterprise GIS operations require a combination of strategic planning and a continued investment in technology. Technology is changing very rapidly, and organizations that fail to manage this change fall behind in productivity and operational cost management. Managing technology change is a major IT challenge.

Enterprise operations should include a periodic cycle of coordinated system deployment. The planning and technology evaluation should occur one periodic cycle ahead of technology deployment, and these efforts should be coordinated to support operational deployment needs. Figure 9-14 identifies a conceptual system architecture planning and deployment strategy for technology change management.

Figure 9-14
System Architecture Design Strategic Planning



- **Planning and Evaluation**. Planning activities should be established on a periodic cycle, coordinated to support the organizations operational and budget planning needs. Strategic plans should be updated to support a multi-year deployment strategy, and published on an established periodic basis (normally on an annual cycle).

  The planning and evaluation process should include a requirements evaluation (strategic plan update), technology refresh (training and research), requirements analysis (process and requirements review), test and evaluation (evaluate new technology alternatives), and prototype validation (pilot test programs). Efforts should be planned on a schedule to support the annual system deployment upgrade cycle.

- **System Deployment**. Operational system upgrades should be planned on a periodic cycle, scheduled to implement validated operational enhancements from the planning and evaluation program. System deployment phases should include initial implementation (implementing changes in an operational test environment) to support deployment authorization. The program should include planned schedules for new technology procurement and deployment on a periodic schedule (normally on an annual cycle). All production system upgrades should be planned and scheduled with full support for ongoing operations.

9.9 Conclusion

Successful implementation depends on a good solid design, appropriate hardware and software product selection, successful systems integration, and careful incremental evaluation during installation. A phased approach to implementation reduces project risk and promotes success, providing the opportunity for early success and flexibility to incorporate new technology at low risk prior to final system delivery. Guidelines are available to support a successful system design, even for large complex systems. Final purchase decisions are influenced by both operational requirements and budget limitations, introducing unique challenges for system design.

Figure 9-15 provides an overview of ESRI lessons learned in supporting GIS system implementations over the past 12 years. Good leadership, qualified staff, and proven standard practices support successful deployments.

Figure 9-15
System Implementation Lessons Learned

- **Establish project management responsibilities and authority**
  - Include systems integration project management
- **Complete user needs and system architecture planning**
  - Establish a 3-5 year deployment strategy to support budget planning
  - Obtain executive sponsor and funding for GIS implementation strategy
- **Establish deployment schedules**
  - Implement phased system deployments to control installation risk
  - Establish deployment timelines for each installation task
- **Build a qualified technical staff**
  - User and administrative training
- **Manage system performance and tuning**
  - ArcSDE database administration monitoring and tuning
  - ArcIMS configuration, services management, and site tuning
- **Conduct required system testing to reduce implementation risk**
  - Functional integration testing during initial validation phase
  - system performance validation testing during initial implementation phase

Attachment A

System Architecture Design Consulting Services

A-1: Agency System Architecture Design
These services are most appropriate for large agencies with several organizations that need consulting support in establishing a specific system architecture strategy for supporting integrated agency-level GIS operations. All organizations should be represented in the system design process. A current user needs assessment and clear understanding of user deployment objectives is a prerequisite for this effort, and will be required as an input to the system architecture design process.

A-2: Enterprise System Architecture Design
These services are most appropriate for larger organizations with several departments or workgroups that need technical support in establishing a specific system architecture strategy for supporting their enterprise GIS deployment needs. All departments should be represented in the system design process. A current user needs assessment and clear understanding of user deployment objectives is a prerequisite for this effort, and will be required as an input to the system architecture design process.

A-3: Departmental System Architecture Design
These services are most appropriate for smaller organizations or workgroups that need technical services in establishing a specific system architecture strategy for supporting their GIS deployment needs. GIS users and IT staff should be represented in the system design process. A current user needs assessment and clear understanding of user deployment objectives is a prerequisite for this effort, and will be required as an input to the system architecture design process.

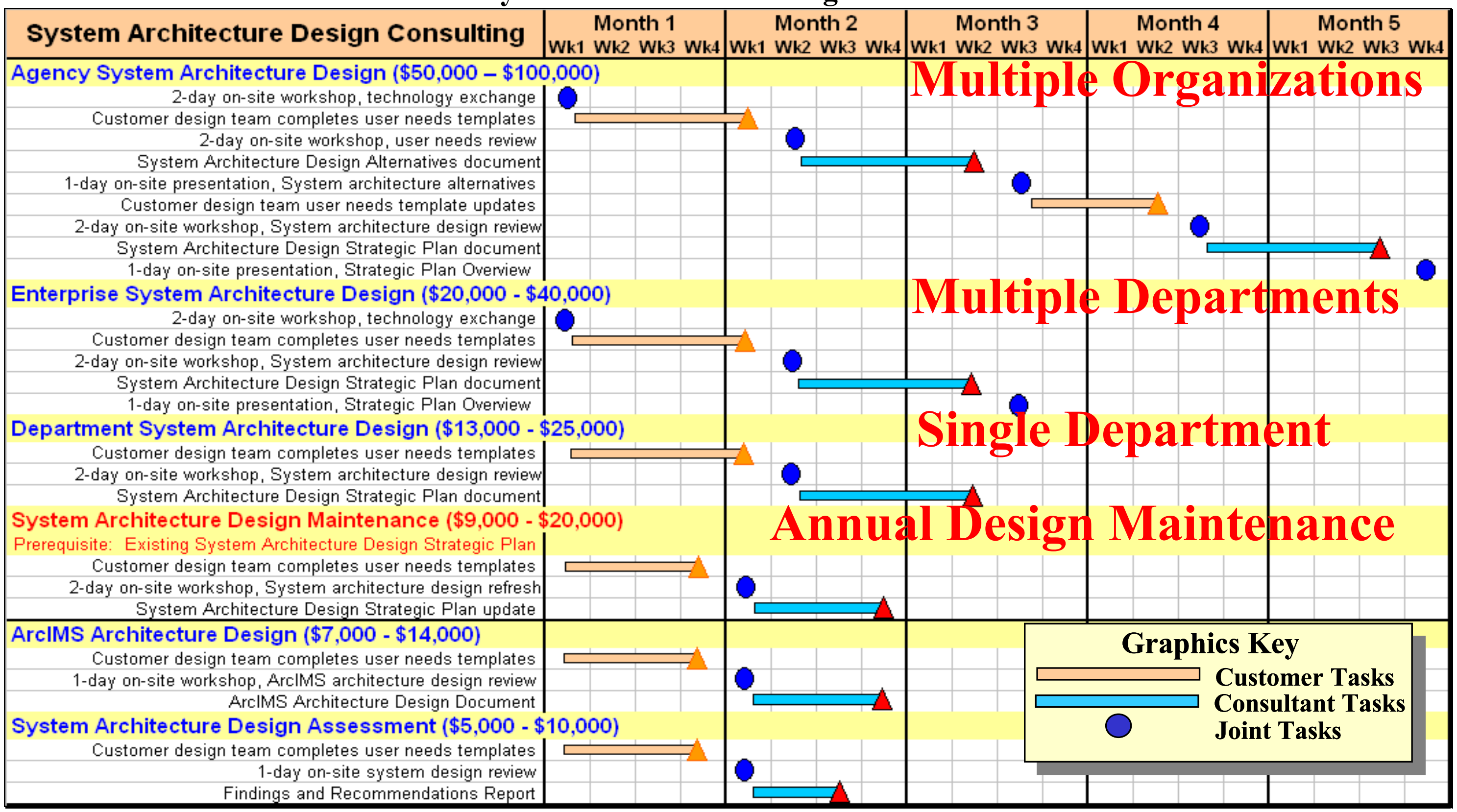
A-4: System Architecture Design Maintenance
These services are for maintaining current system architecture design recommendations for a customer's enterprise-wide GIS. To take advantage of these services, a customer must have an established system architecture design strategic plan prepared by ESRI as a prerequisite for supporting this design maintenance consulting effort.

A-5: ArcIMS Architecture Design
These services are most appropriate for organizations that need technical support in establishing a specific system architecture strategy for supporting their ArcIMS deployment needs. A current business needs assessment and clear understanding of Web services deployment objectives is a prerequisite for this effort, and will be required as an input to the ArcIMS architecture design process.

A-6: System Architecture Design Assessment
These services are most appropriate for organizations that need technical support in establishing a specific system architecture strategy at a point in time for their enterprise GIS or ArcIMS environment. A clear understanding of GIS operational workflow requirements is a prerequisite for this effort, and will be required as an input to the system architecture design review.

This figure provides an overview of the standard system architecture design services supported by the ESRI Systems Integration team. It is our goal to provide the quality support you need to promote your own success. A broad range of services is provided to address the specific needs of our customers.

System Architecture Design Services



Attachment B

System Architecture Design for GIS Class Description

J-6017

System Architecture Design for GIS

Overview

This two-day course introduces a proven system architecture design methodology for developing successful GIS design and implementation techniques. This methodology was developed and tested during years of successful ESRI system design consulting efforts. The objective of this course is to share this methodology to help users improve performance of existing and future GIS environments. The system design models and configuration guidelines discussed provide class participants with a proven path to successful GIS solutions. Lectures and hands-on exercises help those responsible for GIS system architecture decisions select a system design that will support GIS user performance requirements.

Audience

System Architecture Design for GIS will appeal to those in charge of developing and maintaining hardware or software systems designs and to those in the business of supporting software or application development and technical marketing for system design, testing, and configuration of client solutions. It also provides an excellent conceptual framework for anyone in the position of supporting and securing GIS hardware or software solutions. Senior architecture consultants will benefit from the GIS design methodology presented, while GIS managers will come away with a better understanding of system architecture and hardware selection criteria.

Goals

- Understand the relationships that are available to support successful GIS solutions
- Learn where ESRI software solutions fit in an evolving GIS environment
- Learn how to integrate ESRI software in a distributed enterprise environment
- Learn how to provide high-performance remote user access requirements
- Learn how to integrate GIS applications with legacy data sources
- Understand the prerequisites and recommendations that must be completed before selecting hardware solutions
- Learn how to identify user locations and existing network communications
- Learn how to summarize user requirements to support system architecture design
- Identify system components that contribute to application performance
- Learn how to select an optimum enterprise design solution
- Learn how to identify relative performance of Windows and UNIX platforms
- Apply practical sizing models for selecting central application and data servers
- Learn practical design guidelines for network communications
- Understand the process for conducting a system design review and distributed GIS hardware solution

Topics covered

- System design strategies
- GIS software solutions
- Network communications
- GIS product architecture
- GIS user needs
- System sizing fundamentals
- System sizing tools
- System implementation

Prerequisites and recommendations

Registrants should have an interest in understanding GIS product architecture and how today's computer technologies can support successful GIS solutions. It may also be helpful to review the white paper titled *System Design Strategies* at www.esri.com/library/whitepapers/pdfs/sysdesig.pdf.

Cost: $850 (Two days)

Classes can be taught onsite at a client's facility (up to 12 participants) for a fixed price of $6,650.* Special pricing is available to the United States federal government and to qualifying educational institutions, libraries, and museums. Contact the ESRI Learning Center for eligibility requirements. Prices are subject to change without notice. *For on-site training of fewer than three days, add $500 to the total charge.

J-6017

Course Outline System Architecture Design for GIS

DAY ONE

System design process

- What is system architecture design
- Why is system design important
- System design process overview
- Supporting technologies overview
- System design support efforts

GIS software solutions

- Overview
- GIS workstations
- Local area networks
- Remote access clients
- Web map products
- Distributed data solutions
- GIS migration strategies
- ArcInfo license management
- GIS high-availability solutions
- *Review questions*

Network communications

- GIS network impact
- Types of networks
- Client/Server communications
- Client/Server performance
- Network configuration guidelines
- Network technology overview
- *Network sizing exercise*

GIS product architecture

- GIS multi-tier architecture
- GIS applications
    - *ArcInfo, ArcView GIS, MapObjects*
- Data management solutions
    - *GIS file servers, ArcStorm, Spatial Database Engine*
- Remote Access Solutions
    - *UNIX application servers, Windows Terminal Servers, Internet Map Servers*
- *Review questions*

GIS user needs

- Total GIS environment
- Application needs assessment
- System architecture review
- User needs assessment
- WAN communications overview
- User application requirements
- Configuration strategies
- Selecting a system solution
- Identifying platform loads
- *Project planning exercise*

DAY TWO

System sizing fundamentals

- System performance profile
- Performance testing
- Client/Server models
    - *Batch processing performance*
    - *Terminal server performance*
    - *Data server performance*
    - *Web services*

System sizing tools

- GIS performance history
- How do we handle change?
- SPEC benchmark suite
- Platform performance charts
    - *GIS workstations*
    - *Application servers*
    - *Internet Map Servers*
    - *File servers*
    - *SDE servers*
- Platform vendor selection
- *Platform sizing exercise*

System implementation

- Phased implementation
- Project management
- Installation schedule
- Lessons learned

Putting it all together

System design exercise

- System design review
- User needs assessment
- System architecture solution
- Platform sizing evaluation
- Platform vendor selection
- Network design specifications