Architecting the ArcGIS Platform: Best Practices
What's New (June 2019)

This update includes minor changes to improve clarity.

Modifications

The Prioritization Approach best practice includes minor updates to improve clarity.

The remaining best practices and the Conceptual Reference Architecture were reviewed and remain unchanged in this update.
Introduction

You can maximize the value of the ArcGIS platform, in the context of your organization’s goals, by applying the guidelines presented in these best practices and implementation approaches.

Architecting the ArcGIS Platform

The ArcGIS platform connects maps, apps, data, and people in ways that help organizations make more informed and faster decisions. ArcGIS accomplishes this by making it easy for everyone in an organization to discover, use, make, and share maps from any device, anywhere, anytime. Furthermore, ArcGIS is designed to be flexible, offering these capabilities through multiple implementation patterns and approaches. Together, these capabilities and flexible approaches make it easier for you to extend the reach of GIS across the enterprise.

This document presents some implementation guidelines in the form of a conceptual reference architecture diagram and associated best practice briefs. You can use these guidelines to maximize the value of your ArcGIS implementation and meet your organizational objectives.

Conceptual Reference Architecture

The ArcGIS Platform Conceptual Reference Architecture diagram (found on page 6) illustrates platform capabilities combined with best practices and patterns of business use.

The diagram depicts three distinct computing environments—production, staging, and development—which together represent a best practice known as environment isolation. Each environment has four components, with each section displayed in a different color to highlight the function. Figure 1 identifies those components by color and number.

The Apps section illustrates the components of the platform that most users interact with, including end-user applications such as ArcGIS Pro, Collector for ArcGIS, Story Maps, and Operations Dashboard for ArcGIS. Apps connect people and their business workflows to the platform. Apps are typically used in workflows that follow one or more of the patterns of use (mapping & visualization, data management, field mobility, monitoring, analytics, design & planning, decision support, constituent engagement, and sharing & collaboration). For example, the sharing & collaboration pattern extends geospatial capabilities to everyone in the organization by providing a destination (website and simple apps) where knowledge workers, executives, and field workers can discover, use, make, and share maps. A person capturing data in the field with Collector for ArcGIS is following the field mobility pattern. A decision-maker using Operations Dashboard to observe the real-time information created by field workers is following the decision support pattern.

The Portal component of the platform organizes users and connects them with the appropriate content and capabilities based on their role and privileges within the platform. The portal uses a person’s identity to deliver the right content to the right person at the right time. From a product perspective, the portal is either ArcGIS Enterprise (software) or ArcGIS Online (Software as a Service, or SaaS). The portal provides access controls, content management capabilities, and a sharing model that enables users to share information products across the organization.
The **Infrastructure** component includes the hardware, software, services, and data repositories that are the core of the ArcGIS platform. Numerous best practices—including *load balancing*, *high availability*, *workload separation*, and *publication strategies*—are linked from and associated with the platform infrastructure. Follow the links from each best practice label on the Conceptual Reference Architecture diagram to learn more about how these strategies affect infrastructure decisions. Additional information is also available in the **Infrastructure** best practice brief.

The **External Systems and Services** components include other systems that either provide services to ArcGIS or consume ArcGIS services to geospatially enable their capabilities. The ability to easily geonable other enterprise business systems is a key capability of ArcGIS.

**Best Practices**

There are 18 best practice briefs associated with the ArcGIS Platform Conceptual Reference Architecture diagram.

Eleven of these briefs—*Automation*, *Distributed Web GIS*, *Enterprise Integration*, *Environment Isolation*, *High Availability*, *Infrastructure*, *Load Balancing*, *Publication Strategy*, *Real-time GIS Strategy*, *Security*, and *Workload Separation*—reference technology practices that provide high-level implementation guidelines based on business needs. Following these best practices will help organizations meet requirements for performance, security, and availability.

The best practice briefs for *Application Implementation Strategy*, *Capability Delivery*, *Patterns of Use*, *Managing Identities*, *Prioritization Approach*, and *Workforce Development* focus on people and how they should interact with ArcGIS.

Finally, the **Governance** brief offers a complementary process guideline that suggests ways to minimize risk, improve quality, and increase productivity around ArcGIS solutions.

**How to Use This Document**

The ArcGIS Platform Conceptual Reference Architecture diagram is a clickable graphic that contains links to each best practice brief. You can use the diagram to explore how the individual briefs relate to the platform, or to visualize how the ArcGIS platform will support organizational business needs.

**Comments and Suggestions**

Any comments or suggestions regarding this document can be emailed to **SA@esri.com**.
ArcGIS Platform Conceptual Reference Architecture

**Enterprise Systems**
- CRM
- EAM
- BI
- Microsoft Office

**Other**
- Social
- Weather
- Traffic
- Real-time Feeds
- IoT Sensors

**Associated Best Practices**
- Governance
- Prioritization Approach
- Publication Strategy
- Automation
- Capability Delivery
- Security
- Workforce Development

**Patterns of Use**
- Mapping & Visualization
- Data Management
- Field Mobility
- Monitoring
- Analytics
- Design & Planning
- Decision Support
- Constituent Engagement
- Sharing & Collaboration

**PORTAL**
- Users • Groups • Items • Tags
  (Content and Capabilities)
- Web Maps
- Web Layers
- Tools
- Files

**INFRASTRUCTURE**
- Visualization
- Analysis
- Data Management
- Data and Storage

**EXTERNAL SYSTEMS AND SERVICES**

**Production**

**Staging**

**Development**

**Copyright © 2019 Esri. All rights reserved.**
**June 2019**
Application Implementation Strategy

An application implementation strategy is an approach to delivering capabilities that meet your business needs with technology. An ideal strategy will minimize cost and optimize the use of development resources. By applying a “configure first” philosophy that prioritizes commercial off-the-shelf (COTS) apps and least-effort design patterns, you can reduce the cost and effort needed to deploy and maintain applications for your users.

A Flexible Platform for Implementing Location-Enabled Apps

ArcGIS is a platform for applying the power of geography to improve workflows throughout an organization. Apps provide the user experience that makes ArcGIS capabilities available at the right time on the right device, so users can work more efficiently. Implementing apps, however, can require different approaches, depending on whether the capabilities you need are available out of the box. ArcGIS helps you deliver these capabilities by supporting multiple approaches to application implementation (as shown in figure 2), while also helping you minimize cost and effort.

There are many factors to consider when deciding the best way to deliver new capabilities through apps. These factors include resourcing, initial development effort, ongoing app maintenance, user training, and technical support. In addition, users now expect frequent updates to their apps, which increases demand for resources to develop and maintain custom apps. As a result, it’s best to select the approach that delivers the capabilities you need with the least cost and effort.

Depending on your specific requirements, you can:

1. **Configure COTS apps** to meet your business needs. ArcGIS provides many configurable COTS apps that support key workflows out of the box. Using COTS apps requires the least effort and the lowest ongoing cost.

2. **Extend existing apps**, either by modifying templates or by creating widgets for COTS apps. Esri offers app templates at [arcgis.com](http://arcgis.com) and [github.com/esri](https://github.com/esri) that provide focused solutions for specific problems; you can modify the source code for these templates to add discrete capabilities. In addition, several ArcGIS COTS apps use modular frameworks that let you create custom widgets and plug them into the apps. Extending existing apps lets you develop only the additional functionality you need, saving money and effort.

3. **Customize apps** using ArcGIS APIs and SDKs. These APIs and SDKs provide objects like the Identity Manager to manage credentials within custom apps that expose parts of the ArcGIS platform (such as secure web maps). Because you don’t have to code those parts yourself, you can build business-focused apps to take advantage of ArcGIS COTS capabilities, reducing the overhead for app development and maintenance.

A configure-first philosophy helps you avoid unnecessary cost and effort associated with custom app development, maintenance, and training. Organizations that adopt a configure-first philosophy start by configuring COTS apps, then extend and customize apps only when needed. Using this least-effort approach in your application implementation strategy lets you deliver capabilities faster and reserve your development resources for more complex tasks.

Recommendations

To establish an effective application implementation strategy for your organization:

1. Adopt a configure-first philosophy, configuring COTS apps when possible to deliver the capabilities you need.

2. If you have a requirement that cannot be met with configuration alone, extend existing apps with discrete capabilities and widgets.

3. When you need capabilities that you can’t provide by configuring and extending existing apps, customize apps using ArcGIS APIs and SDKs.
Automation

Automation is the orchestration of tasks, processes, and compute resources to function automatically and efficiently. Automation allows you to streamline administrative workflows and repetitive tasks to improve efficiency, consistency, and productivity, reducing risk and increasing the value of your GIS.

Increasing the Value of ArcGIS Through Automation

Repetitive tasks are common when using GIS to support data management, analysis, map production, and infrastructure deployment and operations. Repetitive manual tasks take a lot of time, effort, and focus; decrease overall productivity; and increase risk. These impacts are compounded as the number of tasks grows.

You can mitigate these impacts through automation. Automation allows technology to create and maintain infrastructure and programatically execute the steps of a well-defined workflow while limiting human interaction. Common tools for automation include APIs and scripts.

Automation maximizes your investment in ArcGIS by improving:

1. **Efficiency.** Information is most useful to the decision-making process when it is delivered in a timely manner. Because automating tasks and resource allocation improves efficiency, work can be completed faster and new information can be delivered to stakeholders sooner. This boost in efficiency allows ArcGIS to return greater value to the business.

2. **Consistency.** When tasks are executed manually, errors are more common and outcomes can be inconsistent, unreliable, and costly. Once developed and properly tested, automated processes are highly dependable and can be replicated with identical and predictable results. Automated processes save time, minimize duplicated efforts, and increase confidence in business operations.

3. **Productivity.** Automation can improve all areas of a GIS including deployment, administration, and end-user workflows. By using automation to execute more GIS tasks and complete them faster, you can increase overall productivity. This lets you apply ArcGIS to additional business initiatives (such as strategic projects, research and development efforts, and other high-value projects) that might otherwise go unfulfilled.

With automation, you can improve administrative workflows and process data more efficiently, consistently, and routinely. This improves operational efficiency and the effectiveness and timeliness of decision-making, freeing resources for other tasks and boosting the value of ArcGIS in your organization.

Recommendations

To maximize the benefits of automation and reduce risk in your organization:

1. Automate tasks where human error can impact reliability and consistency in outcomes.

2. Automate lengthy tasks so processes can be completed in less time.

3. Schedule automated tasks so they run continuously within set time windows, without human interaction.
Capability Delivery

Delivering capabilities that support key requirements, goals, and initiatives helps you improve business outcomes. By working with stakeholders to define the capabilities you deliver, you can better align your solutions with real business needs. In addition, establishing a regular cadence for capability delivery lets you continuously improve your maps, apps, services, and information products, so they can provide additional value and meet evolving requirements.

A Business-First Approach to Delivering New Capabilities

Delivering capabilities that support your business requires smart resource investments. Organizations that spend years on expensive, complex development projects often end up with solutions that are difficult to use or that don’t align with current requirements. To maximize the value of your investments and better support the evolving demands of your business, you can work with stakeholders to identify areas where you can provide the most value in the least time. This business-first approach helps you establish a cadence for rapidly delivering high-impact capabilities and information products that meet business needs.

For effective capability delivery, you should:

1. **Collaborate with business stakeholders** to envision their capability needs. Engaging stakeholders early in the planning process helps you identify the business value a capability will provide, balance value against risk, and set development priorities. You can then apply a configure-first approach, deploying low-effort capabilities first. This delivers value quickly and builds toward long-term success. Once you have a final product, you can invite stakeholders to test it and offer feedback.

2. **Iterate rapidly on existing solutions** so you can deliver new value quickly and often. By focusing on incremental enhancements that provide clear value, you can avoid spending development time on functionality that adds unnecessary complexity. A rapid release cycle should be 30 days or less, with each iteration producing a usable deliverable. To meet this short release schedule, you can keep requirements simple and focused, and leverage COTS and configurable solutions when possible. With each new release, you can solicit stakeholder feedback to drive the next iteration.

3. **Adhere to a capability delivery lifecycle** with a regular cadence, like the lifecycle shown in figure 3. This helps you continue iterating on your solutions as long as the business gains new value from each iteration. Once you satisfy your stakeholders’ needs, you can suspend further iterations, then resume them if future business needs require additional enhancements. When a solution no longer provides value, its lifecycle is complete. Deprecating these legacy solutions lets you avoid consuming resources unnecessarily.

Recommendations

To deliver capabilities that maximize business value and make effective use of development resources:

1. Collaborate with business stakeholders to define, prioritize, and test new capabilities.

2. Keep iteration cycles short and focus on supplying incremental business value with each new release.

3. Establish a regular cadence for new iterations until you satisfy all identified business needs, and deprecate solutions that no longer provide value.
Distributed Web GIS

A distributed web GIS is an integrated set of GIS deployments working together and sharing content as part of a trusted collaboration. By implementing a distributed web GIS, you can more effectively leverage authoritative data, foster engagement and communication, and glean insights from data. A distributed web GIS lets you preserve departmental control over data and workflows while contributing to and supporting the needs of the entire organization.

A Modern Approach to Sharing Information

Distributed web GIS is a modern implementation pattern that supports a new type of sharing. It allows you to connect multiple GIS deployments together, so users from each deployment can share content with each other. With this integrated approach, each department controls access and the level of detail in shared items, but shares content as needed to support the broader business needs of the organization. The result is a truly collaborative environment—an integrated set of deployments working toward shared goals.

For example, an organization might have multiple business units, each with its own GIS deployment and supporting different business functions. In a city, the police department, fire department, public works department, and municipal water utility might each deploy their own GIS to support their individual workflows. With distributed web GIS, you can connect those deployments so people across departments or outside the organization can work together using authoritative data. Figure 4 illustrates these relationships.

Distributed web GIS expands a modern GIS by making its capabilities and data easier to access across the enterprise. A distributed web GIS creates an organizational network where content can be shared in a simple and controlled manner. This enables business units to share select information with the broader enterprise while maintaining control of sensitive data.

To implement a distributed web GIS, you can use simple out-of-the-box tools available with ArcGIS to create a distributed collaboration. You can invite multiple ArcGIS Enterprise deployments and (optionally) an ArcGIS Online organization to the collaboration, and then share data and content with the participants. No custom coding or special permissions are required.

Each GIS deployment within a collaboration maintains its own maps, apps, and data, continuing to deliver the capabilities needed for that particular business unit or function. Each participating GIS deployment chooses which data and content to share with members of the collaboration; updates can be shared either in real time or at scheduled intervals. Importantly, a collaboration uses each GIS deployment’s existing security model.

With distributed web GIS, you can help multiple GIS deployments support and achieve larger organizational goals through distributed collaborations, well-defined sharing processes, and automation, all within ArcGIS.

Recommendations

To fully leverage distributed web GIS within your own organization:

1. Model your distributed web GIS after your organization’s structure.

2. If you have departments or business units that need to control sensitive data, allow each to work in its own GIS deployment as part of a trusted collaboration.

3. Establish distributed collaborations between GIS deployments based on business need, enabling the right people to have access to the authoritative content they need.
Enterprise Integration: Application Patterns

Application integration patterns describe different approaches to incorporating location intelligence into applications. You can use these patterns to identify how users will interact with geospatial content, and how capabilities from GIS and other business systems should integrate.

Patterns for Integrating GIS with Business Applications

Application integration lets you deliver solutions that combine data and tools from disparate systems—including your GIS as well as business systems like permitting, licensing, and asset management systems. With integrated solutions, you can improve cross-functional business processes and provide decision-makers with integrated views of your organization’s information.

How you integrate GIS with other systems will depend on which system you use as the hosting framework. ArcGIS helps you meet varying integration needs by supporting multiple application integration patterns (as shown in figure 5). These patterns include:

1. **Geocentric applications**, which enhance GIS applications with business data and capabilities to automate or inform location-centric activities. Geocentric applications are dominated by geospatial content and capabilities, while delivering business content and capabilities secondarily. This pattern typically uses a GIS application as the hosting framework. It is best suited for staff who are familiar with GIS applications, for situations where GIS activities are central, or for cases where a user-friendly GIS template or configurable app provides most of the needed functionality.

2. **Geoenabled applications**, which enhance business applications with GIS data and capabilities to automate or inform business activities. Geoenabled applications are dominated by business system content and capabilities that are supplemented by GIS capabilities. This pattern typically uses the business system as the hosting framework. It is best suited for staff who are familiar with the business system that automates the related workflows, or when an extensible business system provides most of the needed functionality.

3. **Composite applications**, which integrate capabilities from multiple systems in situations where no existing system can or should serve as the hosting framework. This pattern typically uses web services to integrate data and logic from multiple systems to derive new functionality. Composite applications are conceptually comparable to mashups, and they represent a contemporary trend in enterprise application development.

No single application integration pattern fits all situations. You can use the application pattern that best combines capabilities from ArcGIS and your business system to deliver the greatest impact.

**Recommendations**

The following guidelines can help you determine which application integration pattern best suits your situation:

1. If most of the capabilities you need are delivered by your GIS, deploy a geocentric application.
2. When you need to access GIS content and capabilities within a business system or application, deploy a geoenabled application.
3. When you need a discrete application that integrates content and capabilities from both your GIS and existing business systems, build a composite application.
Environment Isolation

Isolating computing environments is an approach to maintaining system reliability and availability. This approach involves creating separate systems for production, testing, and development activities. Environment isolation reduces risk and protects operational systems from unintentional changes that negatively impact the business.

Deploying Isolated Environments to Safeguard Operational Systems

Unintentional system changes can cause operational systems to fail to deliver the capabilities and performance that users expect. Environment isolation insulates different computing environments from the risk of unmanaged change, helping you better maintain their functionality, stability, and performance.

Users within your organization have expectations for system reliability. In some cases, your users’ expectations may be documented in a Service Level Agreement (SLA), a contract between business stakeholders and technology service providers that defines the level of reliability expected by stakeholders. You should consider your users’ expectations when you decide on the level of environment isolation and governance required to manage system changes.

To effectively manage enterprise systems and meet expectations for system reliability, organizations typically implement at least three isolated computing environments (as shown in figure 6):

1. A production environment is the live system that supports end users. Uptime requirements are defined by an SLA and met through effective change management and governance. Software, application, configuration, or network changes should never be made to a production system without being tested in a staging environment.

2. A staging environment is a mirror of the production environment that lets you vet system changes before deploying those changes to production. You can perform user acceptance testing, performance testing, load testing, and training in a staging environment to avoid risk to your production system. If needed, you can even implement multiple staging environments for different testing and training activities.

3. A development environment is a workspace where developers and analysts can manage content and make changes without impacting a large audience. This dedicated server environment is typically used for unit testing, constructing business workflows, or creating new capabilities such as applications, services, data models, or geoprocessing models. The size and complexity of the environment will depend on the level of risk generated by changes, the number of creators, and the potential impact of system outages and downtime.

Implementing these isolated computing environments helps you deliver a stable, extensible, and high-performing system. By leveraging these environments to support effective change management, you can shield your system from unexpected failure and avoid disruptions to business operations.

Recommendations

To best maintain system reliability and availability for your users:

1. At a minimum, implement isolated production, staging, and development environments.

2. Test system changes in a staging environment before making changes to the production environment.

3. Use a development environment to develop new capabilities without impacting users in other environments.
Governance: Leverage the IT Framework

Information technology (IT) governance is a subset of corporate governance, focused on maintaining IT systems, maximizing their positive impact, and managing risk to business operations. IT governance helps organizations effectively build and manage IT solutions. By applying IT governance to the ArcGIS platform, you can deliver clear benefits and achieve long-term success with your ArcGIS solutions.

Key Components of Effective IT Governance

IT governance is a framework, culture, and set of owned responsibilities that ensure the integrity and effectiveness of an organization’s use of IT. Organizations implement IT governance by monitoring, managing, and steering their IT landscape to achieve required business outcomes. Since GIS is part of the IT landscape, IT governance should also be applied to GIS. Doing so lets you maximize the benefits of deploying and using the ArcGIS platform.

Key areas where IT governance can improve your use of GIS include:

1. **Software change management.** A software change management plan lets you mitigate operational risk when implementing new software. An effective plan covers both software testing and the upgrade process. As part of your plan, you should run functional, performance, and user acceptance tests in a staging environment. This helps maintain business continuity for production workflows. Once testing shows that the software works as expected, schedule an upgrade to the production system in advance. This lets you ensure that essential staff are available and have the privileges needed to perform the upgrade. In addition, document the upgrade process and establish a rollback strategy, so you can recover more easily if issues occur.

2. **Data governance.** A data governance approach involves exercising control over data quality, accessibility, usability, and security. You can integrate spatial data in your broader data governance approach, rather than treating spatial data as a separate concern. With an integrated data governance approach, spatial data is maintained by data stewards within your business units and delivered to end users through centrally managed web services (for example, through distributed web GIS). Data stewards are responsible for data quality and usability, while IT staff manage data accessibility and security. By managing and serving spatial data in this way, you can provide useful, high-quality data resources to anyone that needs them. This helps people more easily access, use, and share maps and data that support their work.

3. **Technology alignment.** By aligning technology to your business needs, you can help the organization overcome challenges that impede its mission and goals. To identify these challenges, speak with business leaders and decision-makers to get a clear picture of their organizational initiatives, goals, and pain points. Explore ways that GIS can help them complete their objectives and alleviate their challenges. By providing GIS solutions that support key organizational goals, you can amplify the value your GIS and your team provide to the enterprise.

By extending IT governance across the GIS domain, you can implement new GIS software more effectively, access and share useful GIS data across the organization, and increase the value of your GIS program. This improved governance helps you increase your long-term success with ArcGIS.

Recommendations

To effectively apply IT governance to ArcGIS within your organization:

1. Implement a software change management plan to mitigate the risk associated with upgrading your GIS.

2. Incorporate GIS data in your broader data governance approach, so anyone can access useful, high-quality maps and data in their work.

3. Align technology to overcome business challenges and amplify the value of your GIS.
High Availability

High availability is a design approach that helps a system meet a prearranged level of operational performance over a specific period of time.¹ Highly available systems provide customers with a reliable, high-performing environment that meets or exceeds their business requirements for service delivery.

Strategies for Maximizing System Performance and Reliability

High availability is a set of strategies for minimizing service downtime and maximizing system performance and reliability. Because GIS is part of critical business operations and workflows, it is essential for organizations to apply high availability strategies to GIS. By using high availability designs for their ArcGIS deployments, IT managers and system architects can mitigate the risk of system and component failures.

Before designing a solution for high availability, it is necessary to determine your organization’s acceptable level of system downtime. This information is typically described in a Service Level Agreement (SLA). An SLA quantifies the percentage of required service uptime (also known as the “number of nines”). For example, an organization may want their systems to be available at a rate of 99.9% (three nines), which equates to 8.76 hours of downtime annually or 10.1 minutes weekly. Your SLA will define the amount of uptime your high-availability design must support.

To maximize your system’s performance and uptime, you should:

1. **Reduce single points of failure** through duplication and load balancing (as shown in figure 7). Duplication involves implementing multiple instances of a specific system component. Load balancing is a technique for distributing client workload traffic requests across multiple system components.

2. **Develop and execute test plans** to evaluate the system’s ability to meet a prearranged level of operational performance. These plans should include, but not be limited to, stress, performance, and failover functions and activities. At least one test plan should be developed and executed before going live. All testing plans and associated activities should be part of your overall system governance.

3. **Monitor the health of the system** and have a plan in place to correct problems before they cause a widespread or unrecoverable outage. A variety of system monitoring tools are available from Esri and third-party vendors.

By designing your ArcGIS implementation for high availability, you can improve performance and reliability, meet your SLA commitments, and satisfy your users’ expectations for service availability.

Recommendations

To implement a high-availability design for ArcGIS:

1. Use duplication and load balancing to reduce the number of single points of failure.

2. Test the system regularly to assure that it can meet performance requirements.

3. Monitor your system to catch issues early, and have a plan in place to address issues quickly when they arise.

---

¹ High Availability (HA), while related to Disaster Recovery (DR), is a separate concept. Generally, HA is focused on avoiding downtime for service delivery, whereas DR is focused on retaining the data and resources needed to restore a system to a previous acceptable state after a disaster. When DR plans are executed, it is typical for service delivery to be disrupted until the system has been restored.
Infrastructure

GIS infrastructure is GIS technology deployed on standard IT infrastructure components. The server-side infrastructure components of the ArcGIS platform let you deliver, access, and use data and capabilities wherever and whenever they’re needed.

An Infrastructure for Serving Data and Capabilities to Users

ArcGIS platform capabilities are delivered by server-side infrastructure components, represented conceptually in figure 8 and described below. You can host these components on premises or in a cloud environment like Amazon Web Services or Microsoft Azure. By leveraging these components, you can expose GIS content and capabilities as web services and consume those services in your apps. This enables users to access and apply useful GIS resources in their work.

SDKs/APIs let developers build custom capabilities for specific needs. At the infrastructure level, they reference objects and interfaces for your GIS servers, allowing you to extend, consume, and manage GIS services. For example, you can use ArcGIS Enterprise SDKs to add new operations to map services and extend the functionality of ArcGIS. In addition, with Esri’s other SDKs and APIs, many client and server technologies can be integrated with the ArcGIS platform.

Data Management represents server-side capabilities, exposed as web services that allow end users to create, maintain, and transform geographic data. For example, you can use a mobile app to access a web service for data editing, allowing you to gather location data in the field. Key server-side data management capabilities include short and long transaction editing, data replication, and extract, transform, load (ETL) procedures.

Analysis represents web services for performing GIS analytics. These analytics can range from simple geometric functions (like point-in-polygon) to complex geoprocessing models for site selection. You can run analytics on many kinds of data including vector data, raster data, linear networks, imagery, 3D data, real-time data, and big data.

Visualization represents web services for creating and consuming visual information products like 2D maps and 3D scenes. These products can be dynamically generated on demand, or pre-rendered and cached.

Data and Storage represents the stored geographic information leveraged by GIS servers. ArcGIS supports multiple storage models for various data types, formats, and uses. One storage model is the data store managed by ArcGIS. There are several data store types, including relational data stores (for vector data), tile cache data stores (for map and 3D scene caches), and spatiotemporal big data stores (for big data). Another model is the geodatabase, an object-relational model for storing geographic data in a relational database management system (such as Microsoft SQL Server, IBM DB2, or Oracle), a file-based structure (a file geodatabase), or an in-memory columnar system like SAP HANA. A third model is to connect to externally managed data sources like Hadoop, IBM Netezza, and Teradata.

Recommendations

To make the most of your ArcGIS platform infrastructure:

1. Store and connect to your data using the storage models that best support your data and business needs.
2. Expose data management, analysis, and visualization capabilities as web services so people can access and use those capabilities in their daily work.
3. Use ArcGIS apps, SDKs, and APIs to incorporate ArcGIS capabilities and services in your apps and systems.
Load Balancing

Load balancing is a technique for distributing client workloads across multiple computing resources, such as physical servers, virtual servers, or clusters. Load balancing helps you balance system utilization, reduce risk, simplify service delivery and growth, and improve backend server security.

Technology for Optimizing System Resource Utilization

The ArcGIS platform can scale to support both small and large deployments. As the number of users increases, so will the deployment size and the number of GIS servers. To accommodate this growth effectively, ArcGIS supports load balancing techniques and technologies. With load balancers in place, you can distribute client workload traffic across multiple server-based resources to optimize performance and resource utilization. Load balancing algorithms, used to dispatch client requests, can vary from simple round-robin approaches to more complex algorithms that consider factors such as current connection counts, host utilization, or real-world response times.

A properly load-balanced system improves scalability by allowing you to add and subtract machines without modifying client applications or removing those applications from use. Also, with load balancing in place, typically only one IP address is exposed to the internet or intranet. This greatly reduces security risks because the internal topology of the network and systems is hidden, and the number of breach points is reduced in case of attack. This method also simplifies service delivery and consumption by providing a single access point (such as a URL).

In its simplest configuration, a single-machine ArcGIS Enterprise base deployment uses two ArcGIS Web Adaptors to manage traffic to the ArcGIS Enterprise portal and to the ArcGIS Server. In more complex configurations, you can deploy third-party load balancers in front of your ArcGIS Servers (as shown in figure 9).

ArcGIS Web Adaptor is an application that integrates ArcGIS Server with an existing web server. It also serves as a load balancer, providing a single endpoint that distributes incoming requests and enables web-tier authentication. Client traffic is forwarded to your ArcGIS Servers via a round-robin algorithm. ArcGIS Web Adaptor is easy to install and configure, and it is required for an ArcGIS Enterprise base deployment.

Third-party load balancers are often used by more advanced site and network administrators. As with ArcGIS Web Adaptor, client traffic is directed to the load balancer, then forwarded to available servers or ArcGIS Web Adaptors. However, third-party load balancers also offer special capabilities including asymmetric load management, priority queuing, added HTTP security, SSL offload and acceleration, and TCP buffering. These additional features help organizations address advanced business and technical requirements.

Recommendations

To optimize system performance and resource utilization for your GIS deployment:

1. Implement load balancing to distribute client workload traffic across multiple computing resources.
2. If you have a simple ArcGIS configuration or require web-tier authentication, use ArcGIS Web Adaptor as your load balancer.
3. If you have advanced load balancing requirements, use a third-party load balancer that provides the capabilities you need (along with ArcGIS Web Adaptor, if you also need web-tier authentication).
Managing Identities

An ArcGIS identity provides a unique credential that lets a user securely access maps, apps, data, and analysis tools. You can manage ArcGIS identities using the built-in security features in ArcGIS or using a third-party identity provider. By effectively managing ArcGIS identities for your users, you can enable people across your organization to access, use, and participate in the ArcGIS platform.

Delivering the Right Content and Capabilities to Every User

An ArcGIS identity allows a person to participate in the ArcGIS platform. With an ArcGIS identity, users can access, create, and share GIS content and capabilities. This enables them to collaborate with others across the organization.

Each ArcGIS identity is managed as a named user credential. With this credential, users can sign into ArcGIS on any device, at any time, and access the maps, apps, and capabilities they have permission to use (as shown in figure 10). For example, they can access their saved maps and items, content and apps that have been shared with them, and data from other participants. The named user model allows you to securely extend geospatial capabilities to everyone who needs them.

Administrators can configure roles that define the privileges users have in ArcGIS. You can tailor roles to individual users and their responsibilities. The privileges associated with these roles govern the capabilities the user can access.

Users can also join and participate in groups. A group is a collection of maps and apps that is typically related to a specific area of interest (such as a business unit, initiative, or team). Groups help you organize content and control access. If a group is private, only members will see the group and its content. Members of a group can update maps and apps that have been shared with the group. You can also create public groups that are viewable by anyone.

Depending on the needs of the organization, ArcGIS identities can be managed with the ArcGIS platform’s built-in security, or with a third-party identity management system. For small implementations, administrators can leverage their ArcGIS portal’s built-in security to add and configure users. They can then use a simple web interface to manage these users, the roles they’re assigned, and the privileges they’re granted. For larger implementations, organizations can use externally managed identities and groups to control access to the platform.¹ These implementations can integrate enterprise credentials from a Lightweight Directory Access Protocol (LDAP) server, an Active Directory server, or any identity provider that supports Security Assertion Markup Language (SAML) 2.0 web single sign-on.

Recommendations

To effectively manage ArcGIS users in your organization:

1. Provide an ArcGIS identity to everyone in the organization that needs to use GIS content and capabilities.
2. Create roles and groups to control who can access specific capabilities and content.
3. If you don’t need to integrate ArcGIS with existing enterprise credentials, use the built-in security in ArcGIS; otherwise, use an external identity provider.

¹ Specific capabilities related to identities and groups differ between ArcGIS Enterprise and ArcGIS Online. The ArcGIS Enterprise and ArcGIS Online help topics provide details about these differences.
Patterns of Use

The patterns of use describe common geospatial functions that re-occur across organizational business models and environments. These patterns give you a framework for tracking current and future GIS utilization in a business context.

Understanding and Planning Your Use of ArcGIS

A common set of GIS usage patterns exists across industries, independent of business models or environments. Because these patterns describe both geospatial capabilities and business capabilities, you can use them to understand how ArcGIS aligns with your needs. Organizations that apply all the patterns in their location strategy reap the greatest business benefits and return on their GIS investments.

Mapping & Visualization is how people understand locations and relationships through visual representations. 2D and 3D maps and charts bring data to life and provide context, so people can share and understand information.

Data Management is how people collect, organize, and maintain accurate locations and details about assets and resources. It is important to persist spatial data within storage models optimized for its unique characteristics. Storage models include the geodatabase, spatiotemporal big data store, relational data store, and tile cache.

Field Mobility includes managing and enabling a mobile workforce to collect and access information in the field. This lets you improve visibility into the operational aspects of an organization, enhance workforce scheduling, reduce issues caused by stale data, and empower personnel with information needed to perform tasks while on the move.

Monitoring allows people to track, manage, and monitor fixed and mobile assets and resources in real time. This lets organizations tap into, analyze, and display streaming data from many sensors, devices, and social media feeds.

Analytics involves applying analytical techniques to transform data into actionable information. You can use analytics to discover, quantify, and predict trends and patterns to empower decision-making and improve business outcomes.

Design & Planning enables people to evaluate alternative solutions and create optimal designs. This supports the design workflow by enabling users across organizations and communities to collaborate on design decisions.

Decision Support involves combining data, metrics, and operational and analytical layers on a map or dashboard to better understand activities, projects, and operations. This produces valuable information for decision-makers.

 Constituent Engagement includes two-way sharing of information with the public, partner agencies, or other external stakeholders. By improving engagement and collaboration with communities of interest, you can promote more informed decision-making.

Sharing & Collaboration provides self-service capabilities, so people can discover, use, make, and share maps. This lets you extend the value of location information to the entire organization or community.

Recommendations

To better understand how GIS capabilities can meet your current and future business needs:

1. Apply the patterns of use as a framework for tracking your use of GIS in a business context.
2. If you identify gaps in pattern adoption, consider leveraging ArcGIS capabilities to fill those gaps and maximize the value of your GIS investment.
Prioritization Approach

You can maximize the success of your ArcGIS platform adoption by prioritizing easy and manageable projects that deliver high business value.

Deliver Ongoing Value to Your Organization

When implementing new GIS capabilities, organizations should apply a simple method of selection and prioritization to improve their overall return on investment. The goal should be to mitigate implementation risks and improve adoption by balancing challenges with business benefits. By embracing this approach, you can continuously deliver high business value and high returns on your GIS investments.

One effective prioritization approach uses a matrix to plot both business value and ease of launch. The benefit aspect relates to the value derived from completing an activity (such as increased productivity, reduced costs, or more informed decisions). The ease of launch aspect focuses on the level of effort, challenge, or risk required to deliver a capability (including considerations like the technology skillsets required, time to delivery, and level of difficulty).

You can evaluate potential new capabilities by plotting them on a matrix like the one shown in figure 12. You can then pursue the activities with the appropriate mix of value and risk:

1. The green oval represents activities that provide clear benefits and are easy to accomplish (for example, configuring COTS templates). You can embrace these kinds of activities to develop a cadence of delivery that produces ongoing value to the organization.

2. The blue rectangle represents high-value capabilities that are challenging to deliver. Typically, these are long-term projects that require careful planning. They may require additional resources, planning, or mitigation actions. The additional effort to manage risks may also lengthen the project duration.

3. The purple diamond represents tasks that are good for developing skills, thanks to manageable challenges. You can use these types of activities to learn new technologies or approaches in an isolated development environment. Experimentation can lead to greater understanding and help reduce future risk.

4. The red hexagon represents efforts that are challenging and offer little business benefit. Trying to implement these types of capabilities will be costly and will distract from the overall value of the platform.

Organizations that employ this simple but effective prioritization approach derive high value from their ArcGIS investments and achieve greater success in their platform implementation.

Recommendations

When deciding how to prioritize new activities in your organization:

1. Consider using a matrix to help qualify new capabilities based on business value and ease of launch.
2. Prioritize the capabilities that offer the greatest benefit with the lowest risk, so you can deliver rapid value.
3. Develop a delivery cadence of easy, high-value capabilities, and take time to plan more challenging projects.
4. Avoid low-value, high-risk efforts altogether.
Publication Strategy: Geospatial Content Delivery

A publication strategy describes how you deliver data, services, and applications to users. By considering the needs of your users, you can identify a strategy that delivers geospatial content in a well performing, reliable, and secure manner.

Give Your Users the Access They Need—Securely

An effective geospatial content delivery strategy must address performance, reliability, and security. By addressing these three areas, organizations can make certain that content will be available and delivered in a manner that is suitable for consumers to use. This strategy should balance user expectations for performance and availability against security and load on the infrastructure. This will mitigate risk while meeting audience needs and expectations.

One common publication need involves sharing internal information with people outside the organization—for example, a city sharing land ownership information with the public. A typical strategy involves creating a publication geodatabase (as a hosted service) deployed to a cloud environment, which is separated from internal systems. As discussed below, this strategy addresses the elements of performance, reliability, and security:

1. **Performance** is addressed by separating information consumers from operational or transactional systems. In the city’s example, the public consumes information from ArcGIS Online, a cloud-hosted software-as-a-service (SaaS) environment. This approach reserves the city’s internal resources for transactional editing, which in turn reduces resource contention and increases the resources available for editors. In addition, the resources available to consumers can grow in response to demand (for example, to support a suddenly popular map), because the SaaS environment is scalable and more elastic than the city’s internal resources.

2. **Reliability** can be expressed as a Service Level Agreement (SLA) or as an expectation of when the system will be available (for example, during work hours, or during a crisis). You can address reliability by following other best practices like High Availability, Load Balancing, Workload Separation, and Security. You can also leverage cloud capabilities to meet reliability expectations. In the city’s example, reliability is addressed for the public, since ArcGIS Online has a 99.9% SLA. The city’s SLA for editors is less strict and doesn’t need high availability.

3. **Security** means exposing the right content to the right consumers while protecting the enterprise. In the city’s example, consumers can view published land ownership information but cannot update property boundaries. Because property boundaries should be maintained in a secure system of record and edited only by authorized experts, a separate internal publication environment is appropriate for other departments. The city might also consider a separate internal publication environment for decision support, as shown in figure 13.

An effective geospatial content publication strategy addresses performance, reliability, and security. Your strategy should deliver content that meets the needs and expectations of consumers, while minimizing the impact on operations and protecting internal systems and data.

Recommendations

When devising your own publication strategy, consider the following recommendations:

1. For better performance, consider separating information consumers from operational or transactional systems, and consider using a cloud-hosted SaaS environment for scalability and elasticity.
2. To improve reliability, implement the infrastructure necessary to support the SLA expectations of your users.
3. For better security, use separate publication environments to support audiences with different needs.
Real-time GIS Strategy

Real-time GIS allows organizations to analyze and display streaming data from sensors, devices, and social media feeds. With real-time GIS, maps and databases are continuously updated, trends are observed as they form, and key personnel are alerted the moment activity or performance reaches a critical threshold. By embracing location in your real-time capabilities, you can quicken decision-making and responsiveness.

A Core Capability for Operational Awareness and Decision-Making

Real-time location data is increasingly important in modern enterprises. Organizations that treat real-time GIS as a core capability can track the location, performance, and status of relevant assets and environments, as well as manage, analyze, and disseminate this data in real time. This enhances an organization’s operational awareness and maximizes the impact of its decisions. Your real-time GIS strategy should allow you to ingest and manage real-time data, transform that data into actionable information, and disseminate the intelligence to the right people.

1. **Ingest real-time data** from a wide variety of locations and sources, so decision-makers and operations teams can access information as events occur. You can consume real-time data streams for immediate display and persist the data for later analysis and use. ArcGIS ingests data about the location, performance, and status of teams, assets, products, environments, and services from Internet of Things (IoT) sensors and devices, as well as social media feeds and web APIs. With ArcGIS, you can broadcast live data with stream services for visualization, as well as archive data to a relational database or spatiotemporal big data store.

2. **Filter and analyze incoming data** on the fly so decision-makers can address changes as they occur. You can use location-based and attribute-based filters to evaluate high-volume and high-velocity data and determine its relevance and importance. For example, a spatial filter based on a geo-fence can verify if an asset is inside, outside, entering, or exiting an area (see figure 14). Additionally, you can analyze and enrich incoming data using mathematical, spatial, and geometric analysis tools. Analysis can make real-time data more relevant and actionable.

3. **Disseminate actionable information** to enhance decision support through notifications, which let you send information to appropriate users, applications, or systems for action. For example, the location of moving assets (like snow plows) or the status change of stationary assets (like radiological sensors) can trigger a notification to key personnel (via text message) and/or to another system (via a web API).

Real-time data from moving and stationary assets can help you optimize business performance and improve decision support. By embracing the location aspect of your real-time data, you can react more quickly to dynamic situations and make faster, more informed decisions.

**Recommendations**

To maximize the value of your real-time data:

1. Ingest real-time data from a range of locations and sources to deliver better situational awareness to users.
2. Use analysis tools and filters to evaluate incoming data and determine its relevance and importance.
3. Configure notifications so the right users, applications, or systems can respond to incoming data.
Security

ArcGIS platform security should be addressed early in the design process, since the techniques and approaches may vary by business need and environment. Storing and delivering information securely will improve availability and reduce risk. ArcGIS supports common security frameworks and can be configured to work within your established security model.

Key Technical Security Mechanisms

ArcGIS can meet an organization’s security and privacy challenges through a secure enterprise solution. Typically, the security configuration involves integrated functions within Esri products, third-party solutions, and implementation approaches. Key technical security mechanisms to consider include user authentication and authorization, filters, encryption, and logging/auditing:

1. **Authentication** involves verifying credentials to confirm the identity of a user or application attempting to access the system. The authentication process confirms the identity, and then an authentication process directs the user or application to the items and datasets they are permitted to access. To help you secure resources using a single sign-on experience (reducing the number of user credentials you need to manage), ArcGIS can leverage centralized authentication stores like Lightweight Directory Access Protocol (LDAP), Integrated Windows Authentication, or Security Assertion Markup Language (SAML). Depending on the identity store, authentication may require specific technology configurations to authorize access to items.

2. **Filtering** hardware and software can intercept invalid or attack requests before a server can execute them. You can use firewalls to prevent unauthorized access to private resources, or to inspect packets and accept or reject them based on defined rules around acceptable levels of risk. Reverse proxies obscure details of the internal network; you should configure them for content filtering, URL rewriting, and load balancing. ArcGIS Web Adaptor can forward client requests to ArcGIS Enterprise machines in a site, obscuring machine and port information and filtering access to ArcGIS Server Manager and Administrator directories.

3. **Encrypting** data in transit enforces the security and privacy of data. To prevent the interception of secure data communications, you should configure ArcGIS to use the Transport Layer Security (TLS) encryption protocol. You should also employ strong encryption methods like Advanced Encryption Standard (AES) and Secure Hash Algorithms (SHA) to encode data and detect whether it has been tampered with or modified.

4. **Auditing** and analyzing system and application logs on a regular basis can provide a baseline understanding of the ArcGIS platform’s use in regular operations. You can then use anomalies in the baseline to identify security incidents or provide information on system problems or unusual conditions. Application logs can also provide event-level details around specific security incidents and policy violations within the enterprise.

The most up-to-date information about ArcGIS security, privacy, and compliance is available at trust.arcgis.com.

Recommendations

To address security requirements within your environment:

1. Consider and identify the appropriate security measures necessary to meet your enterprise business requirements and security/privacy needs, as early in the ArcGIS design process as possible.

2. Use your organization’s existing centralized identity management system to simplify user access and centralize credential management.

3. Use filtering hardware and software to inspect requests and obfuscate internal network components.

4. Encrypt data in transit and at rest, balancing the most secure methods possible with acceptable levels of risk.

5. Regularly audit application and system logs to understand baseline operations and identify anomalies.
Workforce Development

Workforce development is meant to equip an organization’s most valuable asset—its people—with the knowledge and experience needed to effectively use and expand the reach of the ArcGIS platform. Devoting resources towards workforce development will help an organization achieve greater value and a faster return on investment from ArcGIS.

Cultivate Expertise for a More Effective Workforce

Organizations use ArcGIS to execute daily operations, engage with customers and constituents, and create products and services that improve business outcomes. But many organizations are unable to fully leverage ArcGIS because their staff is not current on the latest technology advancements. This makes it difficult for organizations to meet business demands, and it may cause them to use inefficient legacy workflows or rely on consulting services to accomplish goals.

Workforce development is critical to a successful ArcGIS platform implementation because it improves awareness of contemporary workflows and methodologies, encourages the use of appropriate methods and approaches for solving problems, and reduces reliance on external resources. For example:

1. New workflows and processes are developed as technology evolves, improving efficiency and productivity. Esri training helps an organization’s employees understand these more efficient modern workflows.

2. By using appropriate methods and approaches to problem-solving, you can minimize wasted time and unlock the full value of ArcGIS. Once your staff knows when and where to use the right tools and workflows, they can reach their goals more quickly and more efficiently.

3. Third-party consultants often help organizations develop new capabilities. These consultants are more efficient and more effective if the staff they’re working with have the proper expertise. Trained staff are better prepared to lead new teams and can retain better control over consultants’ activities. Trained staff are also more receptive to knowledge transfer, helping them take ownership of consultants’ work.

Esri provides training resources to better equip your workforce and achieve your strategic goals (see figure 15). Esri offers instructor-led training, web courses, training seminars, videos, conferences and user groups, professional services, and business partner knowledge transfer. If you have a qualifying Esri product with a current maintenance subscription, you have unlimited access to self-paced e-Learning resources. Your staff can develop their expertise by using these training resources and practicing what they learn, which will help them utilize ArcGIS capabilities.

Workforce development should be a part of every ArcGIS platform implementation, because it allows you to achieve greater value and return on investment from ArcGIS. With a trained workforce, you can use ArcGIS efficiently and effectively, set and achieve your organization’s goals, and build a culture of self-reliance and expertise.

Recommendations

To increase the return on investment from your ArcGIS platform implementation:

1. Invest regularly in workforce development, so you can improve operations and meet new business needs.

2. Build a training plan for each GIS role in your organization, so your staff can develop appropriate expertise.
Workload Separation

Workload separation is a design approach that aligns your technical implementation with your organization's business requirements. You can use this approach to maximize system performance, reduce risk, and improve reliability.

Provide Better, More Reliable Service

Different business functions impact the performance of the ArcGIS platform in different ways. By allocating workloads to appropriate server resources organized by business function, you can maximize performance, reduce risk, and meet business-defined Service Level Agreements (SLAs). By implementing geospatial function isolation, you can reduce the risk that high-intensity processes will consume cycles needed to support critical applications, or that an abnormal spike in requests will disrupt service for all users. You should:

1. **Maximize system performance** by directing service requests to compute resources in a way that optimizes the use of your hardware and reduces resource contention. For example, you can direct processor-intensive analysis tasks to an ArcGIS Server site containing machines with fast processors, while directing less intensive tasks to more modest machines. This makes the best use of your compute resources to achieve the highest level of performance.

2. **Reduce the risk of service interruption** by routing user requests to the appropriate sites through load balancers. This enhances system stability by preventing overloaded machines from affecting other machines, which in turn protects critical tasks from resource contention.

An example of workload separation involves the isolation of analytic tasks from decision support tasks. Back-office analytics are typically CPU-intensive, executed sporadically, and maintained by lower SLAs. Because analysts use geoprocessing tasks in an ad hoc fashion, the CPU may sit idle but then spike when several tasks are executed. On the other hand, decision support activities simply consume map-based information products to drive operational business decisions. They are typically less CPU-intensive, executed more consistently, and maintained by higher SLAs. Because these tasks and workflows are so different, you can use workload separation to accommodate each set of activities.

Recommendations

To take advantage of workload separation in your environment:

1. Consider different business workflows to understand how each workflow impacts compute resources, and then use segregated and preplanned resource allocation to meet the needs of each workflow.

2. Allocate hardware around core GIS capabilities, as shown in figure 16.

3. Use GIS Patterns of Use, SLAs, and performance expectations to determine how to best direct workloads to appropriate compute resources.

4. Direct CPU-intensive service requests to sites containing machines with faster processors, and direct less intensive requests to more modest machines.
Esri, the global market leader in geographic information system (GIS) software, offers the most powerful mapping and spatial analytics technology available.

Since 1969, Esri has helped customers unlock the full potential of data to improve operational and business results. Today, Esri software is deployed in more than 350,000 organizations including the world's largest cities, most national governments, 75 percent of Fortune 500 companies, and more than 7,000 colleges and universities. Esri engineers the most advanced solutions for digital transformation, the Internet of Things (IoT), and location analytics to inform the most authoritative maps in the world.

Visit us at esri.com.