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# Enterprise GIS & Architecture

Nevin Gaudet

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# ENTERPRISE GIS & ARCHITECTURE



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Masters of GIS  
GEOG 4993 Capstone  
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## Abstract

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Enterprise GIS solutions are becoming more attractive to companies to implement because of the ability to leverage system of record portals. Information is largely regarded as a company's competitive advantage enabling organizational capability to operate and build capital and equity within a business. And with good reason large amounts of data and information are difficult to collect and organize within a digital framework. Building a GIS enterprise is a solution for data organization and management. Workflows must be in place to collect, process, calculate, and store data with high regard to timeliness and accuracy. Business decisions are made based on information that a company has access to and thus reflects on the importance of database systems as a medium. How efficient a company organizes its information will easily set it apart from others in the competitive realm. Information is knowledge, and how a company can leverage it within an organization or across business assets, will impact how successful the company operates. Building a GIS enterprise on a central server infrastructure enables the expansion of GIS processes and services to both professional GIS users and non GIS users throughout an organization. This proposal is a framing document of why and how a GIS enterprise would be beneficial to implement within an organizations information technology framework environment.

## Introduction

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Organizing data within a corporate setting is a challenging prospect. Many companies struggle with this issue often leading to wasted resources, lost time and lower productivity. Over the years many alternative software and hardware solutions have been available spanning many industry uses. But many fail due to poor implementation, lack of knowledge, cost and expertise of implementing proper workflows and insufficient infrastructure. Unfortunately, there is no silver bullet or a single solution even with today's availability of software and computer systems. This is a proposed outline specifically covering GIS enterprise solutions and other topics on this subject in the hope that GIS could be used as a tool to implement a GIS enterprise design solution for a variety of industry applications.



A background discussion will review the business need and business case of why a GIS enterprise would leverage existing data. Next, a review of a workflow solution will be reviewed that explains why defined workflows are critical to the success of data flow and storage structures. Key topics of a GIS foundation will also be presented followed with a workflow section that will present steps from a starting point of receiving data to publishing data on a server for end users and stakeholders to view and access the end result in a web based browser. Highlights here will also identify key positions and roles that need to be identified within the company to maintain data flow and maintenance. Building connectivity from a GIS to other database systems will also be reviewed to explore options that enable and leverage existing data sets a company already owns. A thorough discussion of issues that are commonly encountered in setting up a GIS program will also be presented. Other key points will be presented on topics for a GIS foundation that should be in place to ensure success of deliverables to end users including issues of geodesy, data model design, project management and data mining. Suggestions of hardware and software requirements will be reviewed along with cost estimates for the design and implementation of a GIS enterprise. Lastly, a discussion of common issues typically encounter in establishing a GIS enterprise is presented to highlight awareness and present possible solutions.

## Goals

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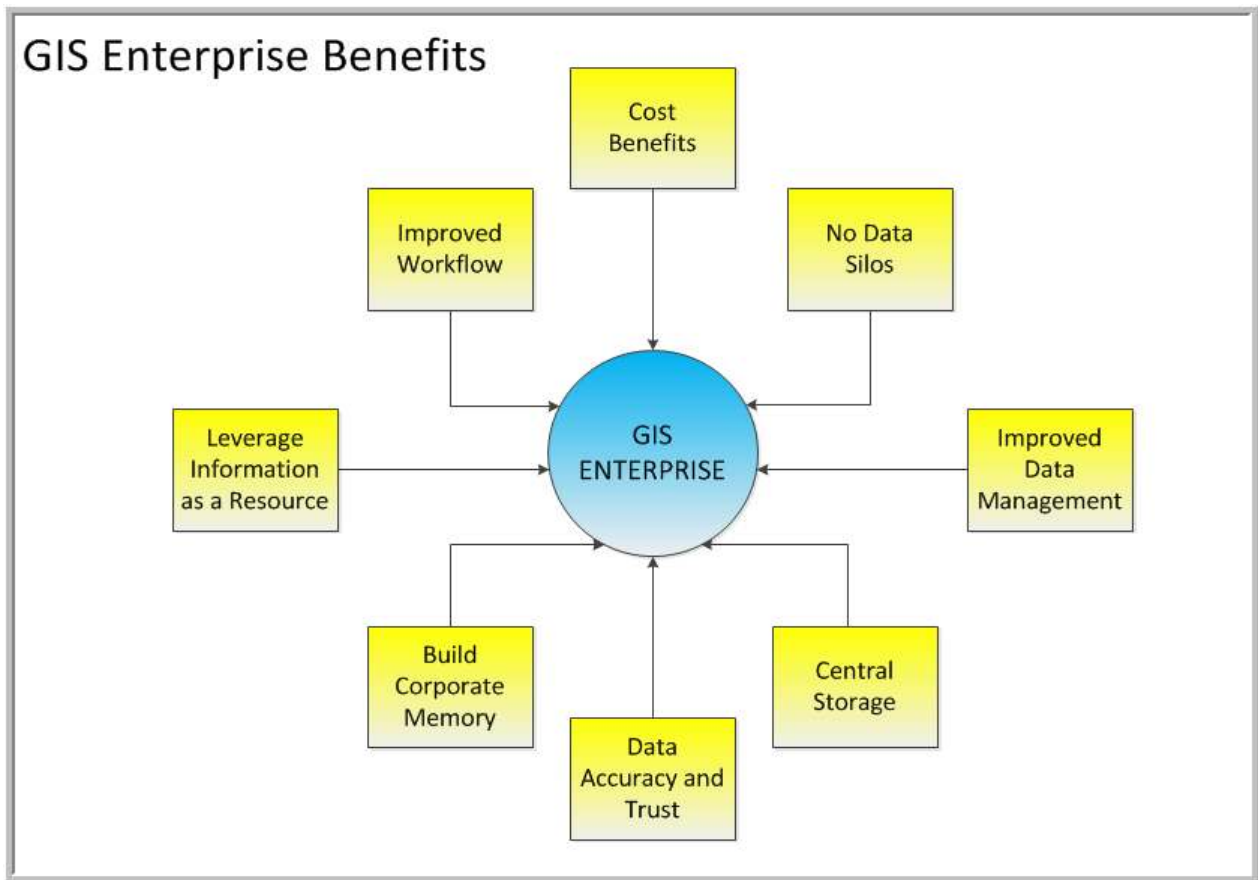
- Provide background and discussion for the business case why an enterprise GIS may be a solution to improve information management
- Define a workflow procedure to manage a GIS enterprise program
- Outline the framework for the deployment of an GIS Enterprise system within a company
- Identify key roles and responsibilities
- Document the required architecture, equipment and software needed
- Highlight best practices given today's technology
- Literature review of other cases, designs and applications of GIS deployed by others
- Provide and discuss a cost benefit framework for the deployment of a basic GIS system
- Discussion of issues and possible solutions



# Background



A GIS enterprise is a data storage and retrieval solution that enables the visibility of information products throughout an organization from a server level infrastructure. Being a GIS however puts a twist on this data structure in that the data being accessed is inherently spatial. Meaning the data itself can be placed on a map and located at a specific location on a map. A lot of information is inherently spatial. And this combined with a solid database structure to organize the information into a framework is what make a GIS a powerful tool. Company assets can now be spatially related to other assets and visually found on a map rather than looking at search lists, tables and charts. Not all data will be spatially attributed, but non spatial data can also be easily added to the GIS database



**Figure 1: GIS Enterprise Benefits**

system as well since the fundamental principle of a GIS is the database structure that stands behind it. A GIS enterprise solution has many components that need to be pulled together to be successful.



Figure 1 above represents a snapshot of some benefits that will be discussed in more detail.

It is fundamental to any project that the scope and deliverables are outlined from the beginning. The project team needs to agree from the beginning what business solutions need to be addressed and define what is in scope and what is not in scope. Put simply, there is one single question that needs to be asked:

*“What will the GIS need to accomplish?”*

Once that question is answered, you can begin to start framing what the project needs to accomplish and what the deliverables will look like in order to achieve the business goal. For any given GIS enterprise solution, a common theme is that users within an organization simply need access to information, typically stored and organized in a central location. Before central database systems existed, data in the form of paper documents were stored in filing cabinets and organized subsequently into folders. The same concept it used today only instead of a paper medium, data is handled in digital format on servers, databases and tables. But the data itself still needs to be processed, uploaded and organized along with a mechanism to allow others within a company to update and access it. Without easy access it would be pointless to store the data in the first place. Busser states that “successful enterprises enable ready exchange of appropriate information (Busser, 2008). His point being that the overall design should be simple to maintain and access.

Unfortunately, in a lot of cases, company personnel that receive data or create new data will end up keeping it on their personal workstations, CD ROM’s or other storage mediums. The problem with this model is that no one else has access to the information. It becomes lost and as a result company resources are allocated to continuously searching, recreating or purchasing the information. This in turn creates redundancy of data sets in multiple locations.

The concept of an enterprise GIS is to make spatial data and maps accessible to other employees within a company. Build one source rather than having data reside either on a single workstation with limited access, or multiple versions on multiple workstations. If a





single central location is used the information is distributed throughout the organization by simply using a database server and a software solution to deliver information products from one central location to individuals throughout an organization. What is key with this concept is that decisions are now made on relevant and trustworthy data.

So what does a GIS enterprise look like? Ultimately in a very simple form it needs the following components:

- Data products and data collection
- Data organization
- Central Storage (Server)
- Computer hardware for storage and interface for data retrieval and updating

Each of these four components obviously needs a well-defined workflow to support each step to maintain and update the data products over time. One additional critical function is that the system must be simple and easy to maintain. The best thing about GIS is its inherent structure and ability to provide flexibility that supports many business needs (Babinski, 2009). Fundamentally, the GIS itself must be built to support the business need. If it provides no service or end user needs, its use will slowly disappear in the depths of the IT department black box that has no incentive to support it.

### **Lost Information**

For large corporations data collection itself is not necessarily the difficult task, however, storing and organizing data is typically lost because of poorly defined workflows and processes. Many larger corporations have a dedicated file server for employees to save their information on. But these folder structures are typically created in ad hoc fashion and data ends up placed randomly in hundreds of little yellow folders. This often starts from the beginning of the process where data is either generated or collected in the field. From here, there are dozens of paths a data set can follow. If no workflow is in place to capture this data it will eventually be lost. This in turn becomes a cost burden on company assets and resources. Time will be spent in searching for the data, regenerating or collecting it again or outright purchasing it again. In some cases lost data will be impossible to acquire or generate



a second time. The only effective solution to lost information is to have a well-defined data collection procedure in place, followed by a workflow that organizes data into a central storage location. This ensures that the data is collect within company approved procedures, and the method or workflow is understood as to where it should end up.

The difficult task in designing a workflow for data collection and storage is the sheer volume of handling different data formats (Anonymous, 2009). Data governance and data interchangeability will largely have to be handled by internal workflows within a company's organizational structure. With the proliferation of software tools and packages the number of file formats has proliferated. The key solution to lost information is organizing all data in one location with a workflow to update and maintain it.

Richard Newhouse, a professional surveyor that works for an engineering survey company, handles countless offshore surveys projects for oil and gas clients. Richard states that countless times a month he is contacted by clients requesting maps and reports that had been delivered previously. "They have no control or idea where their data goes. It goes to a single project manager that was in charge and is never seen again."(Newhouse, 2010). As a result their clients are often forced to return to the contractor that collected the data to get the information again. "In most cases large companies like this only work at the project level. There is no data center that manages their data or data management. When the project is over, the project data is packed into boxes and sent to a warehouse for storage." Data is delivered from vendors but there is no mechanism where it can be found again. The frustrating part is someone within the company needs this information and has no idea where to find it. And has no means of searching for it or knows who collected the data in the first place. Newhouse also states that "...in other cases, a client will contact him looking for survey data from a project that his company never worked on in the first place."



## **Building Corporate Memory**

An ongoing issue that continues to haunt organizations is the loss of corporate memory. This is the key knowledge that experienced employees have and are the subject matter experts that eventually move on to other positions, start retirement or leave their position for a job at another organization. One method used commonly in the industry to solve this is developing mentoring programs where processes and lessons learned are passed on to newer employees, however, this typically only benefits a small segment of the organizations population (Chosnek, 2010). In addition to this, resources are often stretched thin and time is a critical commodity in most situations. Most professionals don't have the time to train others. Additionally others simply have no interest in training others. But people tend to learn best by example or if they have access to proper documentation that is simple and straightforward. Chosnek proposes a document management system (DMS) along with an established workflow that maintains its organizational structure for training and onboarding of newer employees. Chosnek states that "This workflow becomes the essential tool for corporate memory retention."

Company procedures, regulations, policies, standards, best practices, audits, inspection reports, event monitoring, safety reports and design criteria can all be captured in such a DMS. This helps to prevent reinventing the wheel and adds efficiency by saving resources and preventing mistakes. Access and security can also easily be built into an electronic DMS providing users relevant documents for the processes they manage or work on.

This concept can also be adapted to a GIS enterprise design where documents are linked or imbedded into the digital map itself. An engineer looking for operating procedures for a particular equipment asset can spatially search for the documents. This may prove to be efficient for search purposes as the documents would be specific to the feature location on the map. Rather than doing a cursive search from a table on "Oil Wells" that would return hundreds of possible related documents. Accessing a specific well on a map would only link to specific documentation of that well.

A defined workflow that all employees follow and know where to send data when updates or changes are received from past or future projects is important. This would likely introduce a



culture change from current operations, but once the workflow is understood the process becomes another routine that employees are expected to follow. With a well thought out workflow the information becomes reliable and trustworthy and ad hoc methods of finding company information are no longer required. End users as customers will be making business decisions based on the information available in the system that is purposely in place to be used. Further discussion of document management systems is presented in the section “Building Connectivity”.

### **Information as a Resource**

Many employees will spend time looking for information they need to assist in making decisions, incorporate results for reports, or update existing data with newly acquired data. Exploration Geologists that I have talked to spend upwards of 4 hours a day looking for well information because the information is spread across multiple business units. This requires time spent finding the person within the company that has the data. This is especially taxing if the company is particularly large with many departments. In some cases data that is difficult to access or find within a corporation may not be used at all simply because the time and resources to find it is just too overwhelming. Information in a well-organized data structure that is simple and easy to access will readily be used to support business processes and decisions. If the information is reliable and valid it will quickly become a central resource for many to use. This is where a company can turn information into a resource rather than being a loss.

Centralizing data within a corporation is important but even more daunting is what to do with the data once you have it. Patrick Desrouleaux, a professional survey manager in the offshore oil and gas industry, notes that, “Within large corporations it’s hard to find someone to take responsibility for data management unless the role itself is clearly defined and assigned to a person that is responsible for carrying out that task” (Desrouleaux, 2010). “Once that role is clearly defined within the organization, data will quickly pile up. And you need a workflow and method to organize it all to handle the onslaught of project related data that is generated.” Desrouleaux continues that “people in large corporations often move to new positions and data is just lost. Additionally management has no time to overlook operations at this level.”



In some fields, like offshore exploration, technology advancements are pushing the limits new equipment designs, drilling procedures, laser scanning, acoustic devices and multibeam with side scan sonar systems. Data storage used to be an issue just 10 years ago where a gigabyte was considered a lot of data. Multibeam sensors simply were not practical because the data storage requirements couldn't be met. Today multibeam sensors and other acoustic systems generate data sets that fill several terabytes of data in a single day. The big challenge for GIS and IT departments now is where to store such huge data sets and how to create an interface where data managers and processors have access to these data sets.

Once this is accomplished organizations quickly find they are sitting on a gold mine of information if it's organized in a way that pertinent information can be recovered from the system. The gold mine then becomes a system of record and a valuable resource that others in the company can depend on. Data sitting on a disconnected storage medium where no one can access it is not a resource. It just becomes a burden.

### **Reduce Costs and Increase Productivity**

Enabling a GIS Enterprise would shorten the time spent wasted looking for the information needed. It will also enhance business decisions or complement existing management processes. A GIS could also support regulatory reporting, emergency response and audits. If anything it's an efficient method of storing information needed by the business in one location, with easy access and should become the system of record. Another hidden cost to company bottom lines are data silos and over redundant systems that maintain multiple copies of the same data in multiple locations (Bails, 2002). Instead of having multiple copies of data sets spread across multiple file folders on a network, they could all be centralized to one location on a managed server. This also reduces the chance of data errors and greatly reduces the effort of updating, thus increasing efficiency and turns into cost savings. Documenting a data's source will also greatly be easier to maintain and update metadata.

### **Accuracy and Trust**

When information is published as a resource to company users, there is often a belief that the data being provided has some validity to it. In other words the assumption is that the data



is truth and must be correct. Non GIS users will assume that the position of a feature on the map will be correct and make decisions based on this information. However, sometimes, features presented on a map may only be an estimate, based on information that was available at the time. Or worse case it was entered incorrectly from the beginning. Low end GPS equipment will collect data with accuracies of +/- 100 feet. But more expensive GPS equipment can collect positions to within sub foot accuracies. But, unless this accuracy is documented, the assumption is the end position on the map is “good”. This is an example of why positioning or survey methods that are used to collect the data is fully documented within GIS attributes tables or metadata.

Google earth imagery for example can vary in position over hundreds of feet from one collection year to the next. And there are several reasons for this.

1. Geodesy

Google Earth and other internet map services use a modified auxiliary spheroid to place their imagery on a mapping surface. This WGS84 auxiliary spheroid is different from the standard WGS84 mapping datum that is used in the surveying and GIS worlds for coordinate based calculations. As a result, data collected in the field may not line up correctly when placed on the Google Earth map.

2. Imagery will vary from different years of when it was collected. This change is often reflective of the resolution, method and equipment that are used to collect the imagery.

To see this change with a real world example consider Figure 2 below





**Figure 2 - Imagery Shift – Source Google Earth, 2012**

The feature in the middle of the imagery on the left is a baseball field located on Governor's Island south of New York. The pitcher mound location is located at latitude of  $40.687275^{\circ}$  and longitude of  $-74.022384^{\circ}$ . The imagery on the left is from the year 2005. When the imagery in the background is changed to the year 2009 (on the right) the pitcher mound shifts by 35 feet. The original coordinate position has not changed. It's important to note that there is no way to tell if either image is more accurate than the other without knowing a true position located within the images.

As Foody states, "The failure to recognize uncertainty, whatever its source, may lead to erroneous and misleading interpretations." With GIS systems becoming more popular and easier to implement within an organization, more non specialists will have access to these data sets (Foody, 2003). As such, caution should be used in the interpretation of the data for what it represents and the decisions based on it. This is why metadata is critical to document which explains the accuracy limits the GIS information inherently has.

There are four main components that will dictate how accurate a particular data set is or the confidence level that can be associated with trusting the data to be used for a given purpose. These components include the following:



- The equipment was used to collect the data
- Resolution of the equipment
- Method used to collect the data or create it
- Source of the data

A good example is the case of GPS equipment that is popular with field surveying for data collection today. A simple hand held GPS unit will typically collect spatial locations around +/- 10 meters without differential corrections. A more expensive GPS set up can collect data within about 1 meter to 5 centimeters depending if differential calculations and or post processing is performed. Highly accurate lasers on an electronic distance measurement instrument (EDM) can measure down to several millimeters.

### **Risk Management**

The risk of equipment failures and planned maintenance for many companies can be a challenging task to mitigate. The power of a GIS and central data storage system can easily show events over specified time periods. Pulling data from multiple source can highlight and support risk assessment analysis that otherwise would not be possible with data in separate locations.

A good example is the case where pipeline companies are tasked with maintenance and repairs on pipeline distribution systems. Under regulatory compliance requirements, pipeline companies are required to perform minimum maintenance and repairs on their distribution systems over certain time frames. Risk for pipeline systems will also change over time due to urbanization and future building construction. A pipeline that was built in the 1950's may have been installed in a farmer's field at the time. However, as a small town or city grows, today there may be a church and a school located within several hundred feet of the pipeline. Pulling data layers for land use, building locations, the pipeline location and the wall thickness of the pipeline will dictate the risk associated of public exposure to the pipeline location. So in cases like this elevated risk can be readily identified as change occurs in the environment. As long as the information to identify the risk is organized in a central location and leverage to find such high risk occurrences.





## Time and Trend Analysis

With data consistently being managed and updated in a central server location, it would also be possible for data sets to be viewed over a specified time frame. This builds on the power of spatial data analysis in that layers of information can be compared over time to identify where and when events happen and at what frequency they occur. Trend analysis and similar techniques can be leveraged and used for prediction analysis using statistical techniques to anticipate events before they happen. Such systems are often referred to as models in the industry and take advantage of complex algorithms and statistical calculations.

Some common uses of this technique include weather prediction and analysis, oil spill response, tidal measurements, plate tectonics and earthquake modeling. In nature, events that happen very infrequently but consistently over long geological periods of time are difficult to model. But, with good record keeping events can sometimes be linked to a measurable frequency pattern. And some events may prove to have no frequency pattern at all. Although, natural events that occur in the real world are more often not that easy to model or predict.

GIS for the most part is a static model, in that the features on the map are not moving over time in a real sense. However, more and more software today is developing tools to visualize models with a time component. The biggest problem is the vast amount of information that is currently out there today, lacks any time component. In most cases, in order to capture data with a time component requires equipment and more resources to set up and establish, thus, increasing costs. Change detection over time can also vary greatly from just a few seconds, to years and decades.



## The GIS Foundation

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How GIS is implemented within an organization will be guided by many factors. However, common to best practices, a GIS enterprise should accomplish what the business reasons were for implementing it. Sharif states that any enterprise system should incorporate the following characteristics:



- People focused
- Performance balanced
- Pervasive
- Productivity enhancing
- Polymorphically adaptable

Following these key points Sharif states that "...balancing the requirements of the organization as a whole with the needs and aspirations of its employees is so vital and crucial, to ensuring the success of such systems" (Sharif, 2004).

Other key points to successfully establishing a GIS enterprise is using a phased approach (Somers, 2005). In this manner the organizations' priorities can be addressed first, while other processes and operations can be implemented at a later time. Somers also identifies the importance of flexibility of the system to allow for adjustments and having a specific, and realistic design plan.

Limitations of the GIS enterprise are also important to identify. Trying to build a system that has unrealistic goals is not a strategy to follow.

### **Information is Knowledge**

In the modern world of corporate business and operations, information is critical to maintaining, competing, building and designing new products. It supports research, consulting, communications, exploration and many other business objectives. Information for the most part is the competitive advantage that companies use for cost reduction and increased efficiency. Whether operations are private industry, university research, or



government most organizations are tasked with data management and data processing in one form or another. The sheer proliferation of information management technologies being embedded within these organizations and government over the last 20 years or more exemplifies the importance of information assets. Having a well-organized data structure is critical for business operations. If data is lost, missing or incorrect, the result is often translated to wasted resources, lost time, loss of investment, poor decisions, opportunity costs, and ultimately will burn through precious cash resources. If data is organized correctly and efficiently, information can be readily leverage by an organization and lead to cost savings, increased productivity, and support safer operations. Needs of the users will vary and as a result may impact what data is collected and how. As the number of GIS consumers increases, the number of GIS applications and data needs will also increase (Derby, 2004).

Maps and spatial data are also a critical part of the information world that many companies and governments rely on for supporting operations. As with any data structure or information management process it will initially require investing time, resources and labor to build a GIS system. However, the cost benefits would hopefully outweigh the initial costs over time. And with ongoing updates and maintenance it becomes an evergreen process.

One tendency for project related work is the established workflow of amassing data quickly, then store it ad hoc fashion and send the report to waiting clients. The task itself becomes central to accomplishing the deliverables. Little regard is given to the long term documentation and archiving requirements (Keating, 2003). As a result the information is lost soon after a project is completed. Although this meets the immediate requirements of producing results, in the long term it harms the ability of an organization to leverage this information at a later time.

### **End User Requirements and Needs Assessment**

The GIS data model and structure should be designed to support the needs of the business and end users. No one will use the system if it doesn't provide the information or support that the business users require. If end users can use the system to get information they need, it would prove to be a valuable resource to leverage within the organization. The model should store information that would be useful and readily available.



Interviews and communication with stakeholders should be done to design the enterprise GIS from the beginning (Elliot, 2012). Designing a system that few in the company would find useful would be a waste of resources. Determining what solutions the GIS needs to deliver or what functionality it should provide is critical to deliver a successful implementation. Pinakin Jaradi, a GIS project manager, explains that "...extensive interviews should be conducted with stakeholders within a company that intend to use the GIS to clearly define what business processes they support and identify what their business needs are." (Jaradi, 2012). This will guide what your needs assessment is about and what functionality the product needs to deliver.

GIS business planning according to ESRI should incorporate at least 3 factors: Users, applications and GIS data ( Busser, 2008).

### **GIS Data Model**

The foundation for any GIS design is the architecture of the model that is built to store and organize the data it contains. A detailed discussion will be developed using an example GIS data model for an offshore oil and gas exploration company. Data from the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) will be used to build an example model. BOEMRE was formally known as the Minerals Management Service (MMS).

This section will explore why a GIS model needs to incorporate and support the findings from the needs assessment and what information is important. The purpose of the GIS model in this context is to capture all of the company assets in an organized database at a table structure level. Montello and Sutton state simply the definition of a model as being "...a simplified computer representation of the spatial, temporal, and thematic attributes of geographic information." (Montello, Sutton, 2006). This then becomes the system of record or an asset registry that holds the data deemed important for the business to utilize. The USEPA defines an asset registry as a "systematic recording of all assets an organization owns for which it has responsibility" (Baird, 2010).



Data collection will require company resources over time to collect. So it's important to have a detailed knowledge of "what" data needs to be collected to support business processes. Collecting data that is not useful is a waste of resources that could be spent collecting or processing more important information that will have more impact on the efficiency and business processes of other business units. Data storage for most companies is a burden. And the storage of data itself has an inherent cost, so defining the GIS model from the outset what data it needs to retain is due careful consideration and planning. The return on investment and operational costs can be reduced greatly if the GIS model is simple, and well designed (Baird, 2010). Once the GIS model is in place it can also be used to support regulatory reporting requirements, support timelines when equipment needs to be inspected, support for audits, or become a valuable resource for emergency response.

Other issues to consider for a GIS model are how the system will interact with other existing database platforms within a company. This is where the flexibility of a GIS database system can be used to extensively leverage other data collection events and support standardization of data organization within a database structure. This method would also help reduce data redundancy by integration of other data sources as linkages into existing GIS databases. Or the GIS database itself becomes a data source for other database services within a company.

Another critical function of the GIS model is to standardize how data is delivered from third party vendor or contractors that perform surveying or data collection operations. It's been well documented in the industry that many vendors have their own data formats and data collection methods. This often results in different reporting formats in reports or electronic datasets from PDF's, ASCII files, Cad files, units (meters/feet), and stationing directions being delivered to the client. This is further complicated when multiple vendors are used on a project over a period of time. Each vendor typically has its own schema of data formats. As a result the end client is required to invest significant time and resources to convert disparate data formats into their own internal standard formats (McDonald, 2012). With a well-designed GIS model the vendor can populate the tables and fields in a geodatabase template that is expected by the end client. Thus, the data entry is done while data collection is ongoing from the beginning of the project. By the end of data collection the data model is delivered to the



end client in the form of a geodatabase that can easily be migrated to the client's existing data structure that matches the geodatabase. Minimal time is now spent on data conversion and re-formatting.

An example GIS model in the form of an ESRI Geodatabase will be used as a demonstration to explain how a model is built and how it supports both data collection methods and data processing to update the central data stored on a server. The assets and features of the GIS model theme will be built on an offshore subsea oil and gas operation for platforms and well fields on the seabed from BOEMRE.

### **Pilot Project**

Once the requirements are documented, a preliminary pilot project should be built and designed to get an idea of what issues would need to be taken care of. It would also facilitate what other requirements are needed to be put in place if these were overlooked during the needs assessment. Once the big picture is defined and the processes are in place the pilot project will be useful to find where deficiencies exist and allow time to correct them. The pilot project here will also borrow heavily from the project management processes that are in place as discussed earlier. Another benefit of a pilot project is to identify other processes within an organization that could be updated and standardized to support the new process.

### **Geodesy**

Not realizing what the underlying datum and projections your data is in is a set up for mistakes and poor decisions. GIS data for the most part has spatial attributes. And all spatial data that is referenced to a real world coordinate system must be understood and processed to show on the map in the correct location. The biggest issues here are non GIS professionals that handle or report data incorrectly. Data will be coming from multiple sources and as such is likely collected with a multitude of different data collection methods and sensors. It's critical to understand the underlying geodesy the data has.

Transformation methods performed on a coordinate system are also dangerous because not many in the GIS profession are aware of how transformation methods are used or applied on data sets that requires conversion from one coordinate system to another. Common



coordinate transformation methods used in North America include Molodensky, Bersa-Wolf and NADCON.

Although the defined GIS model can work on any predefined set of geodesy parameters, the largest source for errors is the conversion of new data into the required geodesy the model has or needs. All spatial data using real world coordinate systems must be defined on a given datum. If the data is to be projected to an XY grid format, the data also needs a projection applied. Mathematically most projections will use a cylinder, cone or plane (Zeiler, 2010). Often spatial data that is collected in one datum and projection will require transformation to another datum and or projection. In addition to XY grid formatted coordinates, features on a map can also be located using geographic coordinate based systems, often known as angular latitude and longitude based coordinates.

Another issue with positioning science that is often overlooked is key understanding of direction relative to north. As such there are several “north” directions that can be used to determine orientation including grid north, true north and magnetic north. Additionally, convergence is the difference between true north and grid north. Grid north is based on the projection being used (Desrouleaux, 2012). Direction and headings are critical to document for some positional operations such as offshore drilling rigs or building construction. Surveyors often have more training with these calculations than GIS users. Thus it’s important to have the right subject matter experts involved in data processing and calculations.

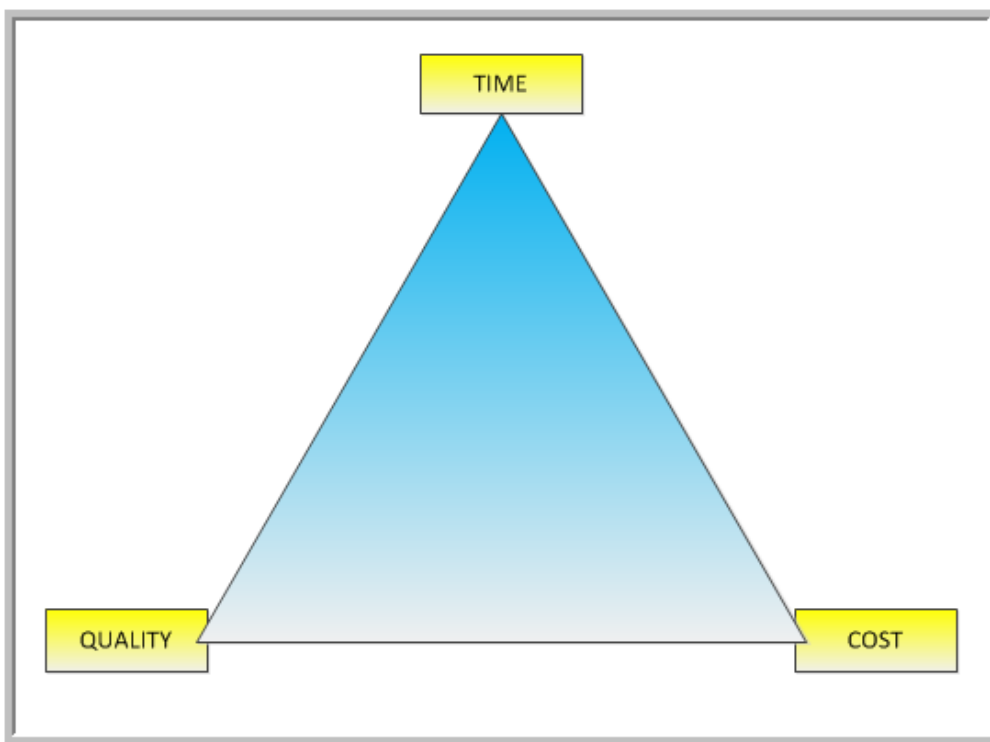
Software is available to handle many kinds of geodesy and coordinate calculations such as Blue Marble’s Geographic Calculator; however a skilled professional that understands transformation methods need to be involved. Applying the incorrect transformation could lead to critical errors in placing the spatial data in the wrong location on the map. As a result further calculations can lead to more incorrect decisions by compounding previous errors. It is proposed that a discussion on geodesy settings within a GIS model and mapping layers should be a part of any GIS design. Examples will be used to demonstrate how mistakes with datums and projections are easily done and why it’s important to have a trained GIS or surveyor specialist available to handle spatial data conversions. See Michael Zeiler’s book



called “Modeling Our World” for an overview of geodesy and coordinate based systems commonly used in GIS mapping.

### Project Management

Good project management practices are important for any project to be successful. And implementing a GIS enterprise is no different. From designing the project structure to final deliverables, a good project management design for planning is critical for success in handling and organizing a projects timeline, resources and costs (Badea, 2009). The following will exemplify why project management tools are vital to any project implementation.



**Figure 3: Project Management Allocations**

For a project to be successful, the key is balancing time, quality and costs. Figure 3 displays the three essential resources used throughout a project that need to be managed. This diagram simply displays three factors in a triangle form. From a management perspective, starting with time, the more time spent on a project, the quality may increase, but the costs will also increase. If costs need to be cut, then quality will suffer but less time will be used. If quality needs to increase, then time will increase as will costs. The idea behind this diagram





in Figure 3 is to demonstrate that in any given project, each one of these project resources (time, quality and cost) is inter-related. Making a decision on one side of the triangle will impact the other sides of the triangle. There are other themes along this idea also in which the items in Figure 3 would have alternative values such as schedule, cost and scope.

Pinakin Jaradi, a GIS project manager with many years of experience in the oil and gas industry designs his project management tasks around three central tasks. The first is time management, prioritization, and delivering solutions. To be effective in project management these three things need to be attended to. Time management is important to tackle important things that will have an impact on your project deliverables. There are always many distractions that will side track you from accomplishing things that need to get done.” (Jaradi, 2012). This overlaps with prioritization in that certain things have to be completed within a given timeframe before the second phase of a project can start. If the first task is delayed, this will impact the next task and result in missing deadlines. Delivering solutions, Jaradi says “...management is about finding solutions to finish the tasks the project needs to deliver on. No manager wants to hear the reasons why something couldn’t be completed. Only when and how will the task be completed. Roadblocks will always be a challenge to get past. In order to complete a task within a project certain criteria or objectives need to be met or solved.” This is one skillset a good project manager needs to be successful.

For the implementation of a GIS Enterprise, project management should be an integral part of the process. Depending on the complexity of the GIS enterprise itself, the project as a whole should be broken into individual tasks or activities (Badea, 2009). This will greatly simplify what needs to be accomplished step wise throughout the project.

Another important task that the project management role needs to follow carefully is the scope of the project. Often times, decisions are made to increase the capabilities, or tasks that a project will take on as an item to complete. But the downfall here is often the lack of resources or lack of time available to complete the task. This sets up to be a downfall because as the scope increases, the real risk is missing critical deadlines, and potentially adding significantly to increasing costs. Typically Increasing the scope of any project should



only be done unless additional resources are available and the budget can absorb the extra cost. Controlling these two factors would allow the time component to still be met.



## Workflow

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This section will discuss the overall workflow of a GIS Enterprise system. Examples and key topics will be presented for the design and implementation of a GIS enterprise infrastructure.



### Data Mining

For most companies data will come from multiple sources. And will no doubt exist in multiple places throughout the company. The fundamental task here is to educate employees where data needs to go. Discussion here will cover several common data formats that GIS data is capture in and various tools used to convert this data into ArcGIS standard shape files or geodatabases. Once converted into a useable format it will migrate to the GIS date model (see next section below). This task will likely be the most time consuming because not only are there multiple data sources, the data formats and structures will also be in multiple proprietary formats. An AutoCad file may have a pipeline as-built in the form of a polyline in a referenced coordinate system, but there is no other information associated with the polyline itself. So metadata of the pipeline (size, material, length, name, project, survey date) will have to be manually added to the pipeline feature later in the GIS model.

A lot of organizations may also have legacy data stored as paper reports, databases or maps in hardcopy format. At the same time the data may be stored on a wide variety of mediums such as CDROM's, external hard drives, workstations, flash drives and other electronic databases on local WAN's and network servers. There are many considerations to assembling this information however into the central GIS model. Most importantly is how useful this information is to ongoing operations. If no one in the organization has a business need to access certain datasets then it would be hard to justify spending the resources to process it to get it into the master database you plan to build. This is typical of legacy data that were collected years ago using a wide variety of different methods that are used today. Gathering data that has little value takes time and resources a company may not be willing to spend, especially if there are more recent datasets that have higher value and a higher priority.



It's important to note that different departments from within a company's organization should retain responsibility of the data sets that they generate or maintain. The only difference would be that the data is pushed to the next level on a central database for storage (Peters, 2008). Other data sources may only be an image with no coordinate information. As an example, a map that shows a pipeline location that was created in 1950 that only shows stationing values but no coordinates. Getting a feature like this into a GIS database may take several hours to several weeks to process. With this situation there are several methods that could be followed to capture this information including

- Digitize the pipeline from the map
- Field Survey (GPS, survey equipment)
- Scan and overlay with Imagery (georeferencing)
- Find additional maps or documents or reports

These are essentially the only methods available to capture features spatially for input to a GIS.

### Network Server

A dedicated projects directory should be established on the company network server to hold the data assets. This serves to be the data depot for all assets an organization owns or maintains. What makes this more important is the folder structure that underlies each theme. As an example, Figure 4 on the right shows a layout of a folder directory structure where data can be placed as it's received from multiple sources. The "ARC" directory would be the sandbox where all GIS layers are created, edited and updated. The "ArcSDE" sub folder would contain all the master GIS layers that are ready to upload to the ArcSDE database on the server. Another master directory called "DATA" would be the holding location for all data received from 3<sup>rd</sup> party data sources or data from other business units.

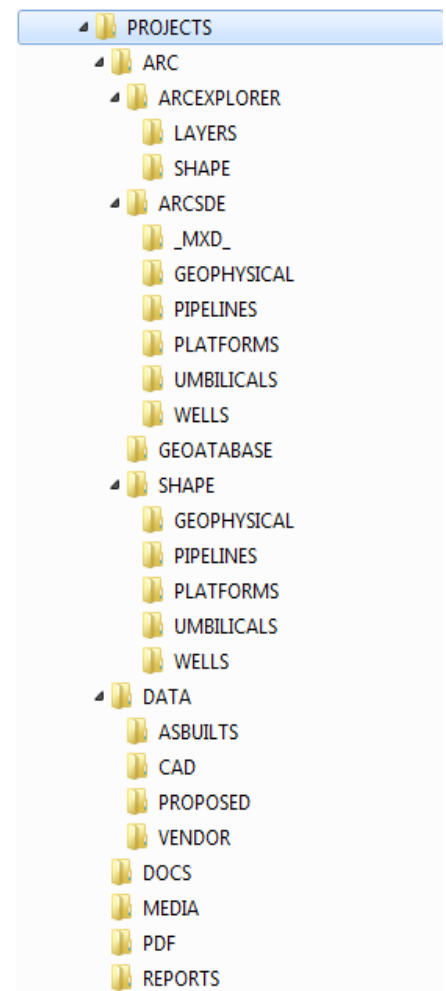


Figure 4 - Network Folder Structure



What is important is that the directory structure that is developed internally is maintained across all projects. This would serve as a common template that others in the work group or GIS division understands and could file and organize data within the directory structure. It becomes the on stop location for all data related to a given project or asset. The solution that this brings to the table is everyone that handles the data knows where to find it and how to store it. The network folder structure will obviously need to be designed on business needs, but it should allow the capture of many data types typically encountered on a project. Files such as word documents, PDF reports, video, photos, auto cad, shape files, satellite imagery, multibeam and sonar data can all be stored in this schema. The list goes on for as many software packages that are in the market place.

### MetaData

If there was anything to be learned from setting up a GIS system, the topic of metadata is probably the most important. And likely the most ignored. Many GIS professionals highlight this topic as important and a necessary requirement, but in practice, it's rarely complete or done at all. Not only is it important to capture basic attribute information on the data, but accuracy standards are also important to document. Without this documentation the utility of the data itself becomes almost useless (Bolstad, 2005). Possible solutions to this will be expanded further on this topic in the final report. A review of current software solutions in the industry will include metadata documentation built within ArcMap or other tools like Microsoft's One Note software.

### GIS Data Model

When data is received the GIS analyst will need to extract pertinent data that is needed for distribution on the ArcSDE network. This would be built as a master as GIS layers in the ARC/ArcSDE folder. Once all the GIS layers are built, ArcCatalog can be used to upload these layers to ArcSDE master database as final. What is critical for a GIS model is that the common layers that are being managed have well defined table fields that need to be populated. This is the information that the

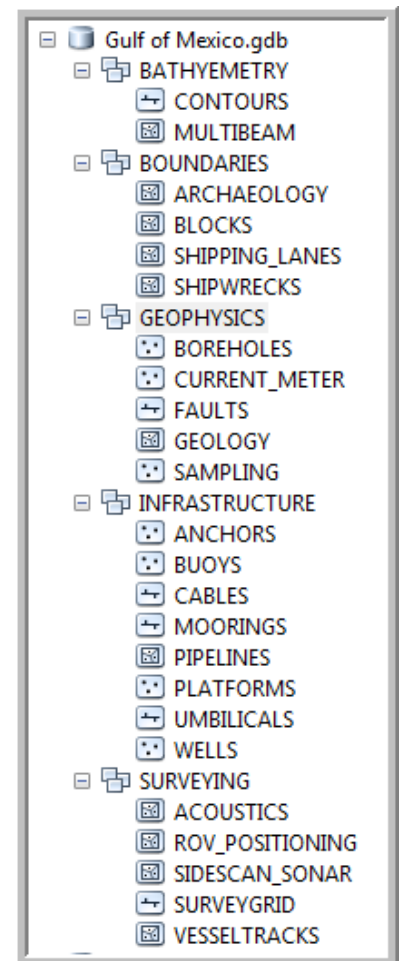


Figure 5: Geodatabase Model



business or company will use for doing calculations, make decisions, and categorize. As an example, the pipeline layer would need to capture not only the spatial location of the pipeline, but other database information on the pipeline like its size, coating type, wall thickness, description, product it contains, number of valves, depth of burial, tariff information, pipe material etc. The list could go on indefinitely. What is difficult is capturing the most important and useful information that the business needs to operate with that would be useful to the end users. The catch is the more complicated the data needed to populate the pipeline table, the more costly it will be to populate. However, if the initial design of the model is missing key fields that the business requires, further re-work will need to be done to fix the data collected to data, thus costing more time and resources. But the opposite argument could be made that the more information that is piled into the pipeline layer, the more useful it becomes to multiple business applications.

Some layers will ultimately be more robust and require more resources to maintain and update than others. A geological fault layer for example may only record the fault type, depth and date of survey. However, as mentioned above, a pipeline layer may contain up to 30 different fields or parameters.

Another important design for the GIS model is designing the architecture of its underlying table structure to be *relational* rather than just a simple list of items or as a flat file. As a relational database more complex questions can be used on the GIS. Such as, *“how many valves with a pressure rating of 100Kpa are located along this stretch of pipeline?”*. Without the underlying relationship between pipelines and valves, this task would have to be done manually. But with a GIS, and the underlying relational database, this task is easily accomplished using a digital map and an interface to enter the requirements.

By building and designing a GIS model, the foundation of what data needs to be collected, how it's collected and how it gets transferred from one location to the next will be established by a required workflow. The GIS model will not only dictate the overall workflow but it will be easier to define the workflow once the database requirements are established.



## **Table Structure and Database Design**

Once the GIS model has been built or at least designed with the GIS layers that the system will capture spatial information on, the next step is defining the actual structure of the fields for each feature layer. For purposes of demonstration, an offshore oil and gas database design will be used to explain the building of specific tables and associated fields. Domain values will also be review to show how they can cut down on data entry and build in standardization to the model itself. This would be the steps required to define the data normalization, table structure, domain values and links to other databases needs to be built into the GIS model.

Figure 5 above shows an example of a geodatabase and its layer structure that contains key feature data sets. The folder structure includes themes such as bathymetry, boundaries and geophysics and so on. Each of these themes then includes the actual GIS layers that contain the spatial information for each feature to be displayed on the map. Each of these features will require individual fields to be defined and what data they hold.

## **Publishing to ArcSDE**

ArcSDE is a database that resides typically on an Oracle based server. It provides the framework to add GIS layers onto a server based data storage system. If this architecture exists, data can be loaded from the network folders (explained above) to the ArcSDE server using ArcCatalog. Ideally this can be done from the GIS model or geodatabase model. Other sources can be directly imported from shape files if needed. Several steps are required to publish a GIS layer from the working directory to the ArcSDE data structure.

1. Start ArcCatalog
2. Create the database connection to the project Schema
3. Right click on the database name and select "Import"
4. Navigate to the GIS layer you want to import
5. Set the privileges, business table and recalculation settings

Once the feature layers have been loaded to ArcSDE, the next task is to build the master map with ArcMap on the desktop. All of the available layers from ArcSDE are added to the



ArcMap table of contents through an ArcCatalog connection. Siri Hall, a DBA and GIS Analyst states that “direct connect to an ArcSDE database should be used within ArcCatalog when possible as this will greatly increase the speed of the connection to the Oracle database that ArcSDE runs on.”(Hall, 2010).

### **Creating the MXD File**

Now that all the required GIS layers exist in ArcSDE, the GIS analyst needs to create a master MXD file that points to all these layers in ArcSDE within ArcMap. Each layer is then customized for colour, shape, labels etc. Another important setup is putting the layers in the table of contents in ArcMap in the correct order and setting the scale dependences for each layer.

1. Start ArcMap and ArcCatalog
2. Open the database connection to the project schema
3. Add the GIS layers to ArcMap
4. Save the MXD file

You now have a master MXD file that points to all the feature layers on ArcSDE. This MXD file will be used to create the map service to publish on the server. More detail will be review on how the MXD file is created and what is required to build the next step for creating a map service.

### **Web Browser and Map Services**

With the map service created, any user in the company can now connect to this database with a simple hyperlink to a web browser. All of the feature layers that were added in the MXD file will show up in the map template. More explanation will be presented how map services work and how the web browser connects to these maps. Other map features such as GeoRSS feeds from other data sources on the internet will be reviewed.

GIS enterprise implementations will no doubt require some customization of the user interface to provide the functionality the end users will require. However, some industry users have expressed that highly customized solutions on the web map interface may require a lot





of IT support. When upgrades and software platforms migrate to newer operating systems additional IT support will be required. One company stated that their IT support group was spending almost 90% of their time maintaining developed custom programs (Petrecca, 2010). So overdoing customization will have impacts on a company's ability to support change and upgrades over time.

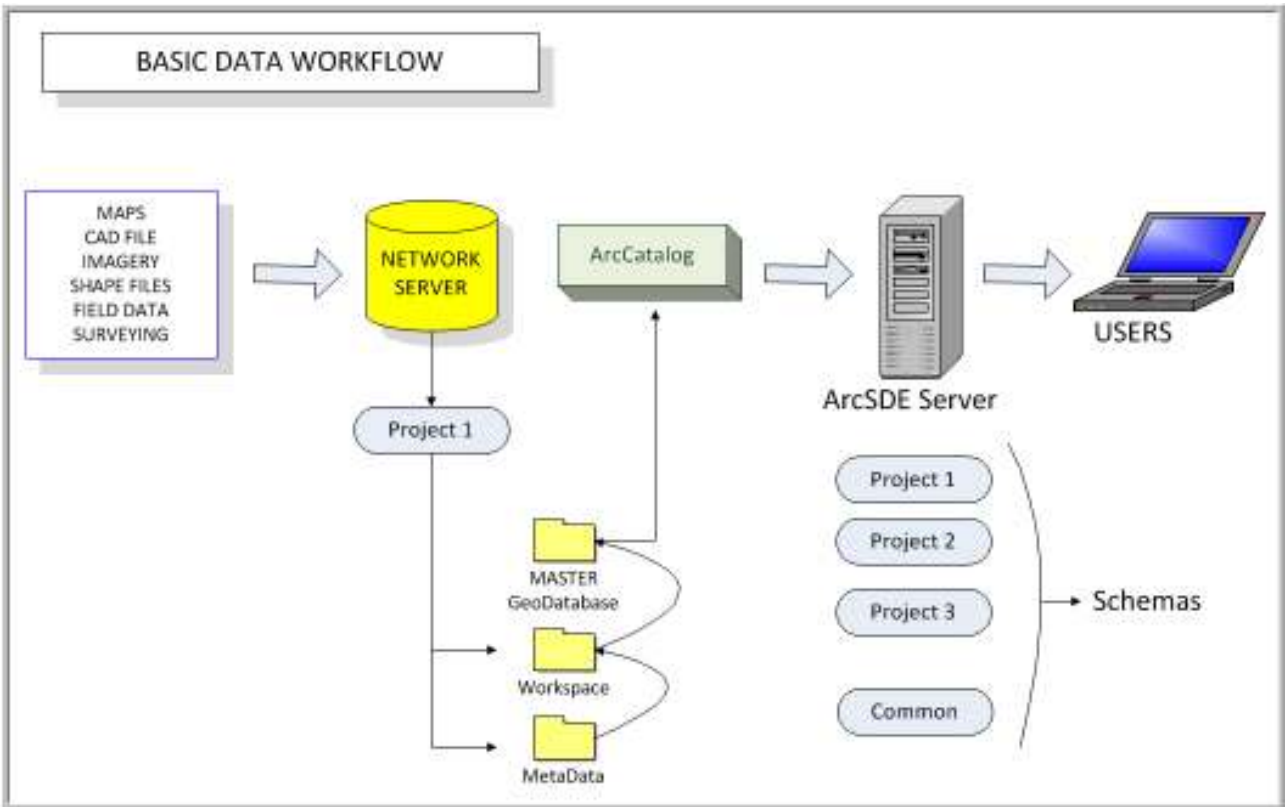
Page 54 of this document lists several examples of web based mapping projects that other various government institutions and organizations have made public over the internet. It's easily demonstrated that viewing these examples that each design is fit for purpose as needed. The quality of these web based map system examples also vary quite a bit along with bandwidth issues and ease of use.

Other technology is currently taking hold such as cloud computing. But this technology also has a lot of downfalls such as working with very large data volumes, data security and expensive maintenance and service fees (Kang, 2011).



## Workflow Summary

Figure 6 shows a simplified overall schematic of how should migrate from data collection to the end user. Data is collected from several sources and organized on the network server.



**Figure 6: Basic Data Workflow**

From the network server, master GIS layers are loaded onto ArcSDE using ArcCatalog. Within the ArcSDE database GIS layers or features can be organized into separate schemas. A schema in the world of ArcSDE is simply a database folder where GIS layers are stored and organized. Once the GIS layers are in ArcSDE, the layers are pulled into the desktop version of ArcMap. Within ArcMap each feature's display, colour, and other visual cartographic representations are set including the display order in the table of contents. Next the MXD file is saved. This MXD file preserves the display settings for all of the feature layers. At this point the MXD file is used to create the map service that the map service will use to display the feature layers in a web based map viewer through a client like ArcServer or Navigator. This summary will be expanded to explain specific data connectivity and organization using an example project model of an offshore oil and gas field.



## Building Connectivity

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Since the foundation of a GIS is ultimately built on a database system, the possibility of linking a GIS to other company database assets can be easily be designed and built. The only requirement would be software, and a programmer to customize a user interface or build the linkages between the GIS database and another database. The features in the map all have database feature tables that contain records specific to the features being displayed on the map. From this, database connectivity can be created including one to many or many to many relationships. Lamount states that “The technology enables the fusion of business-specific layers into a single reporting and analytics tier using just the underlying geospatial data to integrate the systems.”



### Connecting to Documents

One example would be building connectivity from a map interface to other file storage database systems such as Filenet or Documentum to access and view PDF documents, maps, photos and videos that are relevant to the features in the map. Other methods include simple hyperlinking from a HTML interface. Existing methods that are being used today will be explored with example applications and how a business could leverage this technology with minimal effort on programming and design.

### Field Data Collection

Features from the map interface could also be linked for example to field reports and other data collected from field data collection programs. (Inspection campaigns, ongoing maintenance, work requests, service repairs etc.). The map then becomes the spatial search engine for finding these types of company documents. Many companies previously used a paper and filing cabinet system to document this type of work However; more companies today are turning to electronic based filing system to manage this information. With the field data captured in an electronic format, it can be quickly filtered for a specific report, or summary reports can easily be generated for management meetings. And more importantly, spatial trends can be visualized with the data displayed on a map. This proposal will review several applications where a GIS Enterprise can be used to support and leverage an electronic records management system for field data collection and maintenance.



## **Map Production**

For a lot of cases it would be a benefit to have a system that was capable of generating maps for a user. In a simple implementation a basic map template could be built, and the display on the computer monitor would be extracted into a pdf file for hardcopy printing or sharing. The hardcopy map could then easily be taken to a meeting or out to the field as a reference.

## **Mobile Access**

Many organizations collect data in the field or maintain company assets from different locations from the main office. In these situations, mobile access to company information is often beneficial to the field crews that work on these assets. Data could be collected on the remote interface like a laptop and then returned to the office. An upload procedure could then be programmed to add new information back to the master GIS. Mobile maps could also be brought offshore for oil and gas exploration operations and construction activities.

## **GPS Surveying**

GPS technology has progressed to a point now that it can easily be incorporated to collect data from field operations at minimal cost. Although GPS equipment costs will vary a lot depending on the accuracy the coordinates need to be captured at. However, leveraging GPS data collection should be considered to support data collection and populating company GIS databases with spatial information.

## **Base Maps**

There are several ways to leverage other forms of GIS data by combining a company's data sets with other sources over an internet connection. GeoRSS feeds are a great way to imbed background information for a user. Government organizations like NASA, USGS and National Weather Services all provide data links to real time GIS layers. ESRI now provides a wide variety of base maps that improve the cartographic appeal of maps. And reduces the amount of time in-house resources are utilized to build map backgrounds.



## **Map Customization**

There are many software tools available on the market that can be utilized to customize the map interface to deliver functionality to a user's needs. Most out of the box web based mapping tools like PetroWeb's Navigator or ESRI's ArcSever software can be upgraded using programming tools like Visual Basic, VB.net or Silverlight.

## **Map Analysis and Statistics**

GIS algorithms and statistical analysis are somewhat limited within Web based mapping applications, as their functionality mostly relies on internet database connectivity. Rendering maps in 3D at the time is also very limited compared to desktop applications that handle GIS data. Statistical analysis on GIS data also has issues in that conventional statistic calculations assume or requires that samples are random (O'Sullivan & Unwin, 2003). The problem here is that almost all spatial data violates this fundamental requirement that in order to perform statistical analysis on spatial data its sampling should be random. Spatial autocorrelation as defined by O'Sullivan and Unwin is "data from locations near one another in space are more likely to be similar than data from locations remote from one another." So statistical calculations performed on spatial data should be done with this consideration. Further discussion on this topic will be reviewed in the full paper.

## **Video and Multimedia**

As technology advancements march forward there are industry trends embracing new data collection methods. Offshore surveying for example that use remotely operated vehicles (ROV) in the past used to monitor pipeline as-builts as a ship laid the pipeline on the seabed. The only recording done was the acoustic positioning of the ROV to capture coordinates, and a video feed captured to VCR or DVD mediums. Today video feeds are now captured with real time events along with georeferenced video logs all in digital format to hard drives. Valerie Ralph, a Surveyor Analyst in the oil and gas industry for offshore operations indicates that "... just in the last couple of years the amount of data captured in offshore field oil and gas operations has been 10 fold. The investment in infrastructure to store large amounts of video footage has been considerable." (Ralph, 2012).



## Roles and Responsibilities

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As with most business processes, it would be wise to dedicate planning on what the key roles and responsibilities would be. Understanding these roles would facilitate better communications and improve productivity. Common roles for supporting a GIS Enterprise include:



Surveyor/Data collection

GIS Analyst

GIS Programmer

DBA and IT responsibilities and support

Systems Data Architect

Project Manager

Upper Management Support

Customers and Stakeholders

## Equipment and Software

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For implementation of an enterprise GIS, minimal requirements for hardware equipment and software are required. This section of the report will include topics on:



- Equipment Requirements
- ArcSDE and server Requirements
- Software Requirements
- Software licenses
- Industry Standards
- Data Storage Requirements



Also a detailed comparison will be presented of several software map packages including ArcExplorer, ArcServer, GIS Portal and Petroweb Navigator.

### **Technology Advancement**

Consideration of future technology developments should be reviewed before a company invests a lot of capital in a given GIS system. For the most part, software development improvements will have positive outcomes for an existing system. And hardware advancements such as increased storage capacities will benefit the system as a whole. However one should avoid vendor specific solutions and utilize open standards where possible (Carlson, 2008). Customized data solutions and data sets may disappear with the advent of newer technology. It would be less painful that the system in place is flexible enough to migrate to future platforms without huge IT costs or impacting business processes. More importantly the GIS architecture should be built in a way that future technology developments do not adversely impact it's operation to support critical business functions (Challen, 2007).

## **Literature Review**

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Several important literature resources for GIS design and implementation are available. Roger Tomlinson is a pioneer in the field of building GIS systems and is highly regarded in the industry. His book "Thinking About GIS" is used extensively in academia programs, consulting organizations and government institutions.



Another more technical book just recently released is "Building a GIS. System Architecture Design Strategies for Managers" by Dave Peters. This is a through technical reference for detailed system design discussing network communications, security, performance and implementation.



An excellent literature resource for general GIS concepts is the book “GIS Fundamentals” by Paul Bolstad. Data models and database design are explained well in several chapters including topics of coordinate systems, data entry and sources and GPS usage.

## Cost Benefits

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For a company to approve an Enterprise GIS system deployment, there are several key factors that need to be met first. Most important is a return on investment (ROI). Many companies are adopting this technology as a way to leverage existing databases and improve data access, storage, and retrieval. But, to succeed, management will need to be convinced that implementing an enterprise GIS system would bring benefits and cost returns to the business. Unless there is a good reason to spend resources on such infrastructure, management will not be willing to approve it (Tomlinson, 2007)..



In some cases cost can also be a roadblock to implementing a robust integrated system (Raths, 2010). But the implementation scale can sometime be controlled to limit costs and remain within allotted budgets and still deliver an effective system. Indeed some organizations maintain their systems with only one GIS analyst on staff.

There are several key business process areas that a ROI could prove to be invaluable to a company by building an enterprise GIS.

1. Opportunity Cost
2. Saving money by reducing time wasted looking for data
3. Company wide access to more accurate information
4. Business decisions are done faster and more reliable
5. Standardization
6. Legal requirements and regulation requirements
7. Emergency response
8. Building corporate Memory





9. Support for auditing processes
10. Reduction of data duplication and redundancy
11. Extend data access to non GIS users
12. Mobile access in the field
13. Reduce error and mistakes
14. Increase safety and reliability

## Cost Estimates

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Cost estimates for the implementation of an enterprise GIS system are provided below in Figure 7. This cost estimates are loosely based for the operation of a GIS based on a one year operating period and include costs estimates for software, labor, and equipment. These numbers would obviously vary greatly depending on the size of the organization and scale of the implementation itself.



Software	Labor	Equipment
ArcInfo – \$10,000	GIS Project Manager - \$100,000	Desktop workstation - \$2400
AutoCad - \$6000	GIS Analyst - \$80,000	Server - \$5000
ArcServer - \$10,000	IT DBA - \$90,000	Server Maintenance - \$15,000
ArcSDE \$12,000	IT Programmer - \$90,000	Data Purchases and licensing - \$5000
Oracle - \$10,000		Data Storage \$1000
Sub Total: <b>\$48,000</b>	Sub Total: <b>\$360,000</b>	Sub Total: <b>\$21,000</b>

**Total = \$429,000**

**Figure 7 - Cost Estimate**

Keep in mind the full cost here includes four staff members on a full time bases over a one year time period. Depending on the amount of data that needs to be processed and organized, initial costs would be even higher. But, once the GIS enterprise is in place and the system becomes a part of the organizations infrastructure that it supports as an ongoing process.



### Turnaround time for updates

If the workflow is defined and followed a reasonable timeframe could be established to keep updates relatively recent. As the GIS system becomes more of a company resource, more people will depend on it as a source for information, and making decisions. After implementing a GIS enterprise data updates will likely improve greatly. One municipal government used to take over 110 days to add new land parcel data to its main database. With GIS implemented they only require 5 days (Lo, 2008)



### Mistakes and omissions

As with any data input process, any human interaction will be subject to errors. A good process to have in place is a second person to verify data entry and analysis calculations. Data reviews and quality control should be performed before information is released or published to end users. This serves to minimize mistakes and builds trust for the end consumers of the information.



### Data silos

Data generated on projects will always have a place to reside. Whether on someone's hard drive, a random network directory, USB flash drives, CD ROMs etc. Today there are multitudes of data storage formats available. The challenge is convincing everyone in the company that data needs to be copied or forwarded to a central location. Employees will end up spending hours looking for data and other resources will be spent trying to locate critical business information. With a central data resource the cost savings in time management would potentially be quite large in larger corporations.



### Information void

In other situations, some companies may not have the resources to process or manage data. In many cases upper management is not aware of the poor data practices within the company. Field offices that run maintenance on



company assets may collect the data, but in turn is never reported back to the main office. Data is lost. Managers are too busy to spend time on such issues because of other pressing business needs. Many of the senior managers in companies today have little to no knowledge of servers and storage, because when they were starting out, everything was done on paper forms and stored in file cabinets.

### **Performance**

Consideration should be given to geographic locations of your users. If the server where all the GIS layers are located in one city and users in another country need to view the maps, there will be bandwidth issues. The data volume that needs to be pushed throughout the system may also have a negative impact on performance of the GIS system (DiMarco, 2012).



### **International Data Exchange**

It's important to note that some countries have laws on data sharing and file transfers. It's important to verify data transfers of information, including maps, is checked with management before deployment is commenced. Software licenses may also be an issue.



### **Data Security and Data Access**

Data security will be only needed if the GIS data being assembled is sensitive and should not be available to everyone in the company. There are network settings that can be used to only allow people with approved access using AD security groups on a server. This allows only approved users access to the map application. Where security is not required, network access can be granted to anyone in the company.



### **Geodesy: Datums, Projections and Units**

It is critical that as the GIS feature layers being built on the network server and master database have datum and projections defined and documented for every single GIS feature layer. This overlaps with metadata data standards and accuracy standards.



## Technology Platform

Technology is always moving forward, especially in the computer world. The best design is building a file architecture is that it can be migrated to newer platforms structures. Although this can be a challenge because no one knows what the next advancements will look like. Data is often lost when computer operating systems are upgraded to newer editions and or the medium that data is stored on changes. The first time this really was acknowledged was the move from 3.5” disks to CDROM. Companies had thousands of 3.5” disks sitting around offices everywhere and no resources to migrate the information to the newer standard of CD’s. How about all the Lotus 123 spreadsheets that were made throughout the 1990’s? Where is that data now? Williams mentions that “Because more than 90% of all records are born electronically now, the problem is increasing in frequency and magnitude of potential consequences.”(Williams, 2004).



## Archiving and Recovery

Most businesses will have a data archiving policy that needs to be followed. This is critical for most businesses for a number of reasons, but most commonly is done for legal or regulatory requirements, system of record, audits, and general knowledge building. A generic setup will have an active system where data is added, or updated throughout daily business operations. But on a periodic bases, there should be backup procedures in place to maintain company records. This will often include a storage location that is offsite from the main business. This would facilitate if a natural disaster (hurricanes, fires, earthquakes) destroyed the business premises. Any business that has information or data that is critical to operations will have a robust archiving and data recovery plan in place.



Another important issue is the time required to recover from downtime. Some business information assets may need to be brought back online in a matter of hours. Other dataset may only need to be recovered after a few days or weeks. Either way a business process needs to be planned out to design how data could be recovered as needed by the business. This requirement needs to be in place obviously before an event was to happen.



In some cases there may be a business requirement for changes over time to be logged and recorded. One example would be a company that maintains and operates pipelines. When a pipeline is originally built or installed, an as-built map would typically be completed by a surveyor documenting where the pipeline was located with coordinates and stationing values. However, over the course of time, a pipeline may be rerouted, and a portion of its location would now be different. It would be important of course to update the GIS system with the new coordinate positions of the moved pipeline. But the original document of reference (the pipeline as-built) would typically not change. Thus, it would be critical to reflect this change in the company records. A GIS system is ideal for capturing changes like this as new records would document this change and at the same time easily preserve a formal record in the database where the pipeline was originally. This is often captured in log files or a document of change electronically. The GIS software and database records can be designed to capture events like this.

### **Culture Change**

Culture change with implementing a GIS enterprise will prove to be a battle in some organizations because of politics, control over certain processes and organizational entropy where people just don't like change (Raths, 2010).



Some processes may have been done a certain way for decades, and convincing team members that a better way to do things will be met with a lot of distrust and resistance. Others that may have been with the organization for several decades simply do not understand what all the fuss is about because this is the way things were always done. Others again may find the technology overwhelming and refuse to use it. But with a good training program in place a lot of these issues can be overcome.

### **Simplicity**

One large trap that companies get bogged down with is the technology itself.

What is more important is to focus on the solution that bringing a GIS enterprise to the table will solve. Many companies go overboard with the IT infrastructure to a point that it becomes impossible to add new data to their database without the help of several DBA specialists, and expensive customized software packages to



interface with the master database. Out of the box software solutions are easier to install and implement. Unless money is not an issue, customized software solutions are very expensive to maintain. Out of the box software from reputable vendors can make an implementation program much easier. Implementing a solution like this should not bring more problems to solve.



## GIS Software and Tools

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This is a collection of software tools that would prove to be helpful in managing GIS data.

### **ArcGIS**

A suit of software developed by ESRI including ArcMap, ArcCatalog and ArcScene.

### **ArcSDE**

The database software installed on a server used to manage GIS layers created in ArcMap.

### **QGIS**

An open source GIS software package with no license requirements. Handles many open standard GIS data formats including ESRI shape files. QGIS is available on both Mac and PC platforms.

### **Geographic Calculator**

This is a software package used to define and convert datums and projections and perform coordinate calculations. Since GIS data can be generated from a number of sources, it will often require to be edited to fit into the GIS system. Often times shape files or CAD files don't have the geodesy documented.

### **Google Sketchup**

This is a useful tool for building 3D shapes if ESRI's ArcScene were to be used.

### **ArcPad**

A straight forward software package that is installed on a pocket PC-based computers for collecting data in the field utilizing a GPS system.

### **Global Mapper**

This is mostly an imagery processing software tool, but can convert between many different GIS data formats including grids and DTM surfaces.



## Recommendations

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- Map Interface needs to be easy to access and easy to use by non GIS specialists
- Minimum number of people updating the master database
- Chosen architecture can be expanded or be easily migrated to future technology platforms.
- Spatial Engine of software can handle multiple datums and projections since multiple projects will be built in different geographic regions globally and internationally.
- Management has buy-in on GIS implementation and agrees it brings value to the corporation. Business and financial decisions are made to commit resources to building, maintaining and deploying the GIS Enterprise system to the company and stakeholders.
- Pilot program is developed and used to test where improvements can be made. Choose and evaluate alternative software and hardware solution platforms.
- Scope needs to be defined from the beginning of the project. What will be built, what is included and what is not included. The general framework of tasks needs to be outlined early in the project execution. Otherwise, the goal line will continuously be pushed forward trying to take on more and more tasks and solutions. This is detrimental to adhering to previously agreed on deliverables.
- Selected technology platform should be designed with the foresight that it could be migrated to future or newer database designs.
- There should be a business plan or procedure in place for archiving and recovery of key business data assets.





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EMC<sup>2</sup> – Documentum

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## Appendix A - Abbreviations

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Abbreviations

[www.Abbreviations.com](http://www.Abbreviations.com)



AUV – Autonomous Underwater Vehicle

CM – Corporate Memory

DEM – Digital Elevation Model

DMS – Document Management System

DTM – Digital Terrain Model

EDM – Electronic Distance Measurement Instrument

GIS – Geographic Information Systems

IT – Information Technology

ROI – Return on Investment

ROV – Remotely Operated Vehicle

SME – Subject Matter Expert





Nevin Gaudet – June 2012

