Contract Report _____________
December 1999

CADD/GIS Technology Center
for Facilities, Infrastructure and Environment

CADD/GIS Technology Center Guidelines for the Development and Management of Geospatial Data

By Bryan L. Perdue
CADD/GIS Technology Center for Facilities, Infrastructure and Environment

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CADD/GIS Technology Center Guidelines for the Development and Management and of Geospatial Data

By Bryan L. Perdue
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Draft Report

Prepared by CADD/GIS Technology Center for Facilities, Infrastructure and Environment

U.S. Army Corps of Engineers, Waterways Experiment Station, Information Technology Laboratory

Contents

Preface

This report describes the procedures used for the development and maintenance of geospatial data within the Department of Defense (DoD). The report documents the salient findings of literature research on implementing Geographical Information Systems (GIS) within the DoD. It is intended to provide guidance for developing and maintaining geospatial data on military installations, and to identify appropriate processes to determine the feasibility, needs, organization, design, and training necessary to support the development and long-term maintenance of the system. Since each individual installation is unique, this guide does not provide a rigid structure that must be followed, rather it provides recommended guidelines for developing and maintaining a successful program.

This report is divided into five chapters. Chapter 1, Introduction, provides the reader with a brief discussion on why the document was prepared and for whom it was prepared. Chapter 2, Geographical Information Systems, provides a history of the evolution of computer technology, remote sensing, and GIS within the confines of the military structure. It presents a brief discussion on why a GIS should be used and it defines GIS, and finally provides insight into where the technology is going in the next millennia. Chapter 3, GIS Development of Military Installations, provides the reader with a discussion the evolution of GIS and a discussion on the benefits derived from the technology. Chapter 4, Framework for the Development of Geospatial Data and Related Systems, provides the meat of this guide. Here a systematic approach to the implementation process is described. It is framed around the installation's business process and provides the basic guidance necessary to oversee and guide the implementation. The final chapter provides the author's concluding remarks.

This report is a product of the CADD/GIS Technology Center Project Number 99-003, Development of a CADD/GIS Technology Center Guideline for the Implementation of Geospatial Data. The project was funded and conducted by the CADD/GIS Technology Center, Information Technology Laboratory (ITL), U.S. Army Engineer Waterways Experiment Station (WES) Vicksburg, MS, a complex of five laboratories of the U. S. Army Engineer Research and Development Center (ERDC). The CADD/GIS Technology Center was chartered in 1992 to promote the use of CADD and GIS technologies for life-cycle facilities management within the Army, U.S. Army Corps of Engineers, Navy, and Air Force. During the preparation of the report, Mr. Timothy Ables was Acting Director of ITL, and Mr. Harold Smith was Chief of the CADD/GIS Technology Center. Mr. Smith was the WES Management Point of Contact and the Technical Point of contact was Mr. Bryan Perdue, CADD/GIS Technology Center.

The Center functions under the guidance of several oversight committees including the Board of Directors (BOD), and the Corporate Staff (CS). The Military Planning Field Users Group served as the project sponsor and provided technical guidance for the project. Members of these groups are listed below in the following tables:

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Commander of ERDC during preparation of this report was COL Robin R. Cababa, EN. This report was prepared and published at the WES complex of ERDC.

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1. Introduction

No matter how good the armed forces are, they are of no value if they cannot be in the right place at the right time and in the right numbers to get results.

Adm James R. Hogg, USN

"Reinforcing Crisis Areas"

Background

Military communities face the challenge of integrating geospatial information systems (GIS) into the installation's business process. The key to meeting this challenge lies in understanding the organizational business process by understanding the flow of information within the organizational structure, identifying the areas to improve the flow and then identifying the method to improve the flow. Efficiency and efficacy of information flow is the key to integrating geospatial information systems. The absence of defined strategies to synthesize data systems into the organizational process will impact the ability of the organization to meet mission tasking, and result in costly modifications in executing the technology. These strategies must be developed. If managed properly, incorporation of GIS into the organizational workflow will realize the following benefits:

a. Improved operations. One of the basic precepts of efficiency is managing the process, not the function. When this holistic approach is applied, the entire process is analyzed, not individual functionality, which results in improved operational efficiency.

b. Integration of mission functions. Integrating mission functions allows the whole process to be streamlined. For example, construction on an airfield includes the planning department, engineering department, aircraft operations, airfield operations, security, and installation safety. It has the potential to impact the installation's ability to accomplish mission tasking. Integration of mission functions allows cross talk and has the potential to identify and correct deficiencies prior to funds investment.

c. Improved mission effectiveness. An integrated process provides command and management the opportunity to view and analyze multiple data sets and base decisions on the most accurate information available.

d. Improved communication. Organizational communications are improved by allowing stakeholders to synthesize and summarize data in a form easily understood e.g., tables, graphs, charts, maps etc.

e. Consistent information. Redundant information is reduced, resulting in more consistent information for decision-makers.

f. Reduced Operation and Maintenance (O&M) cost. One time data entry, multiple access to the data reduces the cost of data maintenance. Better decisions based on accurate information reduce the costs associated with restructured programs. Data sharing facilitates efficient use of limited resources.

g. Continuity of information. An integrated process preserves the integrity of data even when key personnel rotate.

Purpose and Scope

This guidance is intended to facilitate the analysis and implementation of geospatial data within an organizational business process. It is designed to assist managers in assessing the need, recognizing the impacts, and defining a process-oriented strategy for the development and maintenance of geospatial data within the Department of Defense (DoD) and the four armed services (Army, Air Force, Navy, and Marine Corps). The *"CADD/GIS Technology Center's Guideline for Management and Development of Geospatial Data"* will provide the foundation for this integrated process.

Applicability

This guide is applicable to all DoD project management and technical personnel involved in the development, acquisition, and maintenance of geospatial data and various systems that support the manipulation and presentation of geospatial data. The intent of this report is to provide a starting point and define the requirements for command support and involvement. Contractors that provide geospatial data services will also find this report useful as it identifies the practices and standards utilized by DoD.

Additionally, the report will be a useful guide for the refinement of the Center's spatial data standards. Through the use of standards, it is possible to reduce the duplication of efforts associated with geospatial data collection and maintenance. The use of standards promotes the proper level of details (data content) to meet the multi-discipline analysis applied to these geospatial data.

Related Reports and Research

The ability to use a common set of geospatial data to plan, design, build/construct, and operate and maintain DoD facilities requires that guidelines and standards be rigorously employed in the preparation of these integrated processes. For example, geospatial data are integrated to support an installation's multidiscipline analysis environment, which is driven by such specialized needs such as:

a. Mission Requirements
b. Installation master/comprehensive planning
c. National Environmental Policy Act (NEPA) reporting
d. Installation restoration program management
e. Natural and cultural resource management
f. Site planning and concept design
g. Construction management
h. Mobilization planning
h. Environmental compliance

i. Emergency response
j. Range management
k. Facilities management
l. Work order management
m. Privatization of Installation functions
n. Base closure

Several initiatives are underway to perform research and development of viable methods and products or tools for developing and maintaining spatially referenced data to serve the installation's diverse informational needs. Considerable effort is expended in the identification of enterprise-wide solutions - where data collected once can be used by many. Enterprise-wide approaches are under development within the DoD. Two significant organizations researching and/or developing guidance for geospatial data maintenance within the DoD are the U.S. Air Force (multiple agencies) and the U.S. Army Engineer Research and Development Center.

This guide will provide the foundation upon which managers can develop a viable strategy to design an integrated business oriented process for the development and maintenance of geospatial data and its related systems.

2 Geographical Information Systems (GIS)

"Those who do not know the conditions of mountains and forests, hazardous defiles, marshes, and swamps cannot conduct the march of an army"

Sun Tzu -The Art of War

History

While not denigrating the accomplishments of the civilian sector in the development of computers and the resulting GIS technology, the military appears to have had a strong influence on its development. In an attempt to keep the momentum of wartime research moving forward, the U.S. Government appropriated funds for military research projects. The technical lead was pushed forward in government facilities, at government-funded research centers, or at private contractors working in conjunction with the Department of Defense.

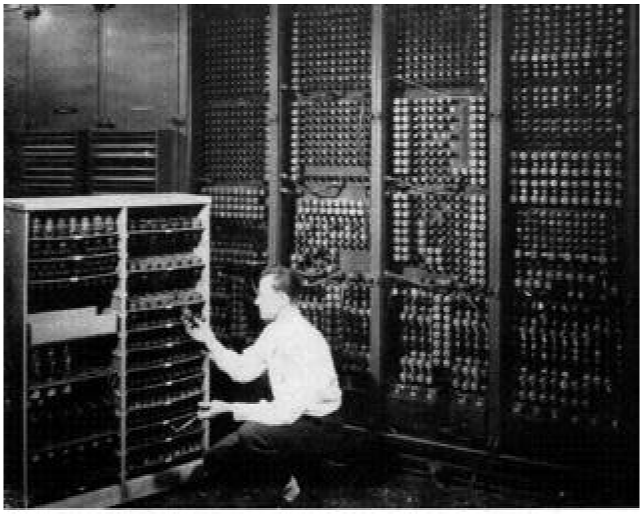

Figure 2-1: ENIAC Computer, (Source: USAF Historical Archives)

In 1942, the Army was falling behind in providing artillery teams the firing tables needed for new artillery weapons. Developing and applying the algorithms to determine the ballistics for these weapons systems was an overwhelming task. The Army recognized the need to develop an electronic devise to "crunch the numbers." Funded by the Army Ballistic Research Laboratory, ENIAC (Electronic Numerical Integrator and Computer) became America's first digital computer. In December 1945, just a few weeks after the atomic bombs ended World War II, the age of digital electronic computers began. In addition to developing firing tables and ballistic algorithms for the Army Ballistic Research Laboratory, ENIAC was used in the design of atomic weapons. (http://www.nasm.edu/NASMDOCS/DSH/LDC/ldc-part4.html).

"Whirlwind," another project with its roots in World War II, led to the development of the first analog computer, developed through the Office of Naval Research (ONR) with the Massachusetts Institute of Technology. Whirlwind was initially designed as a flight simulator.

Figure 2-2: SAGE, circa 1954
(Source: USAF Historical Archives)

The Soviet explosion of an atomic bomb in 1949, coupled with the outbreak of the Korean War in 1950, heightened the awareness of our nation's vulnerability to attack. This led to the development of a national air defense system. "Whirlwind" technology was transferred to the newly created Air Force, and formed the foundation upon which the Semi-Automated Ground Environment (SAGE) Air Defense project was built (http://cct.georgetown.edu/curriculum/505-98/students/haworth/hist.htm).

The SAGE project pioneered the development of digital technology, introduced the concept of random accessed magnetic core memory, demonstrated the success of computer networking, developed and used on-line terminals, computer graphics, digital real-time system simulation, and light gun output. SAGE became operational in 1958 and was fully deployed by 1963.

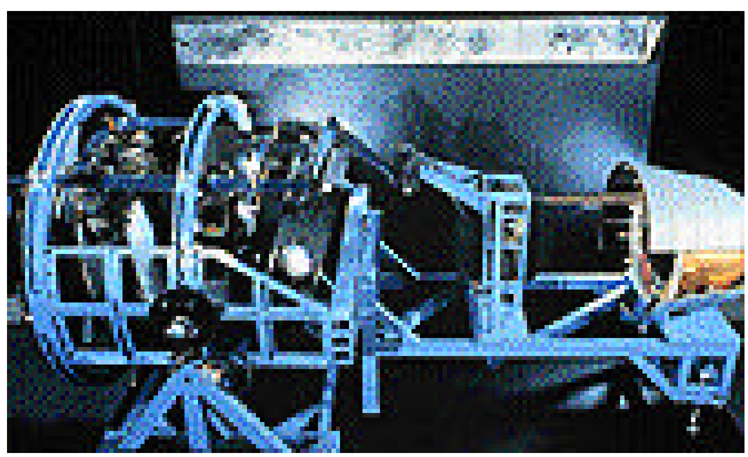

Figure 2-3: CORONA Camera, circa
(Source: USAF Historical Archives)

In 1958, President Eisenhower approved the development of a sophisticated computer that used both intelligence and mapping imagery, code-named project CORONA. Project CORONA utilized imagery from airborne sources and satellites. Project CORONA's first successful satellite launch occurred in August 1960 and was active through May 1972. Project CORONA developed the first photo-reconnaissance satellite, accomplished the first mid-air recovery of a space vehicle, accomplished the first mapping of the earth from space, and used stereo-optical data from space (http://www.nro.odic.gov/corona/facts.htm).

The events of the Cuban Missile Crisis in 1962 demonstrated the maturity of the intelligence gathering community, especially in their ability to gather and analyze information obtained from aerial reconnaissance and satellite imagery. (Johnson and Hatch, 1998). Airborne photography taken by U. S. reconnaissance aircraft revealed the construction of a Cuban air defense system. The defensive system included an offensive capability that enabled Cuba to launch nuclear warheads on the nations' capitol. Information obtained from both sides during the crisis allowed leaders to make a proper decision to emerge unscathed from the crisis.

Operation Igloo White (1967-1972) utilized GIS technology for detecting and targeting enemy troop movements. Housed within the Air Force's Infiltration Surveillance Center (ISC) located at Nakhom Phanom in Thailand, was a computer network connected to thousands of sensors along the Ho Chi Minn Trail. The sensors were designed to detect troop movements along the trail. When the sensors picked up a signal, it was transmitted to and displayed on the ISC's display terminals as a "white worm" overlaid on a grid map. The computer would calculate the rate of motion, direction of travel and relay the coordinates to patrolling aircraft who would initiate action to neutralize the enemy. The "white worm" would then disappear from the screens. (Edwards, 1996).

This vivid display of Command, Control, Communication, and Computer (C^4) laid the foundation for future warfare. During Operation Desert Shield (August 1990) and Operation Desert Storm (January 1991), Commanders exploited data achieved with the advanced geospatial tools placed at their disposal. Using geospatial technology, mapping was provided through remotely sensed platforms, digital imagery was quickly analyzed and updated with current tactical information, and quickly disseminated to the field. The enemy's offensive capabilities were identified, selected, targeted, and neutralized or eliminated. Troop movements were detected and monitored and battle plans were drawn. These two operations demonstrated the capability of geospatial technology to obtain, provide, transmit, and exploit geospatial data in support of the commander. Even rescue operations are impacted by geospatial data. The emergency beacon transmitted by the crew is detected by orbiting search and rescue (SAR). The coordinates are isolated, detailed digital terrain maps are produced, and transmitted to the rescue crew. Rescue aircraft are launched to effect penetration and pickup of downed crewmen – all in a matter of minutes.

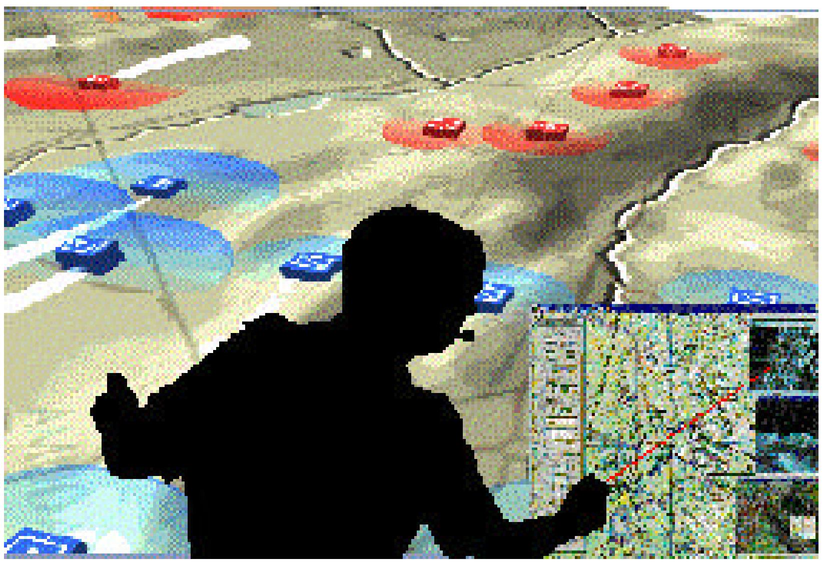

Figure 2-4: Battlefield Operations – Data Exploitation (Source: US Army Battle Lab)

Research continues today in military battle labs, where wartime scenario's are created, engaged, and fought first on the computer screen. It continues in military research and development centers, where innovative ideas are studied, developed and transferred to the civilian sector. It continues through academia funded by government grants. And it reaches the civilian community through contractors hired to accomplish government projects.

Why Use a GIS?

> **Nam et ipsa scientia potestas est. (Knowledge is power.)**
>
> **Sir Francis Bacon**

The discourse on the "History of GIS" provides us with the view that computer technology has been in an evolutionary state since the beginning of World War II. Computers now control vast amounts of military technology. The true impact of GIS within the armed forces lies in tactical applications associated with the electronic battlefield providing the user with Command, Control, Communication, and Computer (C^4) capability. It provides the commander a tool to collect, analyze, produce, archive, disseminate, and exploit geospatial data (Joint Publication 2-03, Joint Tactics, Techniques, and Procedures for Geospatial Information and Services Support to Joint Operations).

Department of Defense (DoD) doctrine recognizes that knowledge is power. The ability to exploit geospatial data is the foundation of that power. Joint Publication 2-03, states "All military operations require geospatial information. It provides the necessary framework upon which all other relevant strategic and tactical information is layered." So, military doctrine provides us with the need to understand and use a GIS.

Beyond doctrine, GIS is prudent because over 85 percent of all data collected are spatially referenced (Antenucci, et.al.,1991). In military applications that percentage is closer to 97 percent, because the focus of geospatial data is on the elevation, foundation features and related textual data, and imagery. GIS provides the user with graphic depiction of the data and visually demonstrates the relationship of features not seen with tabular data. It provides decision-makers with the tools necessary to produce useful information in a cost-effective manner.

In the final analysis the information system is intended to provide the user with the most current and accurate information available upon which users can base a decision. The "Geospatial" component of the system is intended to allow the user to develop insight and understanding of the information by presenting data that show geographical relationships. There are two situations used to justify using GIS – the need for efficiency and the need for efficacy. Efficiency is an issue if it is determined that the current information management structure cannot deliver the required data in a timely manner. Efficacy is an issue if it is determined that redundancy exists, and the data quality and accuracy is questionable. The sole purpose of the GIS is to provide the warrior with the most current and accurate information available in a format that allows rapid assessment and analysis upon which decisions can be based. Technology is not an end in itself, but rather the means to support the warrior in meeting mission objectives.

What is a GIS?

There really isn't an easy, all-inclusive definition for a GIS. Initially, the "G" in GIS stood for "geographic". With the advances in technology and the manner in which data is used and analyzed, current practice uses the more holistic term "geospatial". Hence, the "GI" portion of GIS stands for geospatial information. Geospatial information is concerned with the data about places on the earth's surface. We can further state that geospatial information concerns the knowledge of spatial location or "what is where." If a survey were taken consensus would be reached on these statements. However, when it comes to defining the "S" in GIS, problems arise. The "S" is defined from the viewpoint of its use. If the intended use of the GIS is as an integrated technology then the "S" relates to *System*. If the "S" is applied to theory and concepts of geospatial information, then the "S" represents Science. Finally, if the GIS is applied toward social context, then the "S" represents "Studies". In fact, the "S" can (and does) represent all three concepts (Briggs, 1999)

In the military environment, GIS is represented as a "System". So, building on the concepts above, a GIS is a Geospatial Information System. Further, it's an integrated information system that provides the user (people) with knowledge (data) of locational (geospatial) information about places on the earth's surface at a known point in time. But this definition, in and of itself, is inadequate. It's inadequate because the definition doesn't make a reference to the fact that this system is comprised of a computer (hardware and software). Nor does it state that it has the capability to manipulate the spatial information. For the purpose of this report, GIS is defined as:

"an integrated computer system capable of capturing, storing, retrieving, analyzing, and displaying geospatial information that provides the user with knowledge of locational information."

Notice the wording – "provides the **USER** with knowledge." To make the system complete, the system and the decision-maker must interact – they must do something useful with the data. Without the human interaction there is nothing!

Always remember that GIS is a tool that allows the user to present information in new and innovative ways. It allows the user to gain insight and understanding of the data – it takes all the words and numbers and transforms them into graphic formats e.g., maps, graphs, figures, and charts. The ability of the GIS to analyze spatial data is the prime factor that distinguishes the GIS from other systems whose primary objective is map production.

Future of GIS

> **We know from even the most casual study of military history how fallible man is in matters concerning war and how difficult it has been for him, mostly because of the discontinuity of wars, to adjust to new weapons. Yet compared to the changes we consider now, those of the past, when measured from one war to the next, were almost trivial. And almost always in the past there was time even after hostilities began for the significance of technological changes to be learned and appreciated.**
>
> **Bernard Brodie**

The importance of information has always been a prominent tool for the decision-maker and more importantly, the war fighter. The collection, synthesis, and distribution of knowledge are even more critical. The exploitation of knowledge is the key to achieving and maintaining tactical and operational superiority. As the military reexamines its traditional roles, and missions it finds that the emphasis on atmospheric, oceanographic, and terrestrial capabilities, is unfounded. A transition to an "infospheric" military instead is necessary because the "high ground" is not hydrospace, geospace nor even aerospace, but cyberspace.

The future will see information available in greater quantity, quality, and timeliness. But it's important to remember, while knowledge is power, not everyone needs all the information. Frederick the Great, in his instructions to his generals, stated "*Petty geniuses attempt to hold everything; wise men hold fast to the key points. There is an ancient apothegm: he who would preserve everything preserves nothing*." The key to information dissemination is in designing systems that route relevant information to the user who needs it without generating useless data. Timeliness and accuracy measure the value of information. As the speed of data transmission increases information becomes the weapon of choice. Information and knowledge are the keys to successful competition, both violent and nonviolent.

Territorial expansion may not be the purpose of tomorrow's battles, especially among the more advanced post-industrial societies. The purpose of tomorrow's battles may be to capture and exploit information. Consequently, those who have the advantage to control the collection and dissemination of knowledge will be the placed in world leadership roles. It is not information itself that is so important, but rather the systems infrastructure – the criticality lies in how the system collects, processes, and distributes information. It is important that the military retain the advantage achieved through past investments in information systems. To retain this advantage, we must maintain control of the information industry and dissuade competition from outside sources (Lt. Gen. Kelly, 1996).

Space based satellites, both foreign and domestic will increase in quality and quantity (Lt. Gen. Kelley, 1996). Sensors will become more sophisticated and the resulting imagery resolutions will be expressed in sub-meter increments. Sophisticated algorithms will allow accurate conversion of imagery data to useful and accurate graphic data. Space based sensory platforms will become the dominant environment for gathering imagery data, both in the static and real world environments.

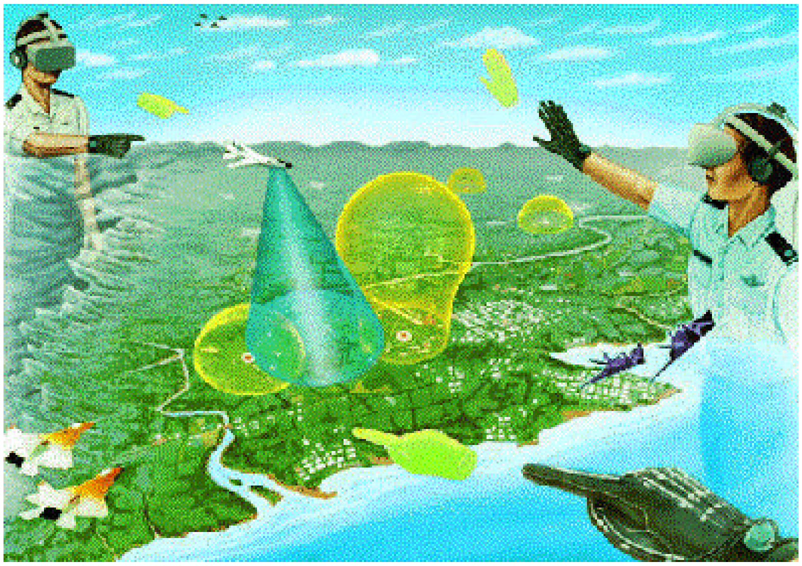

Figure 2-4: Battlefield Planning in the 21st Century
(Source: Air Force Institute of Technology)

Tomorrows battlefield will be fought using advanced applications in virtual reality – unmanned weapon systems deployed to the field – guided by highly trained technicians, will sanitize the area prior to troop insertion. Real time data will be delivered via orbiting satellite systems. Defensive and offensive systems, both space-based and terrestrial-based, will be controlled from space platforms. Each of the systems described use technology spin-offs from today's systems.

3 GIS Development on Military Installations

Information is no longer a staff function but an operational one. It is deadly as well as useful

Lt. Gen. J. W. Kelly-Air Force 2025 Final Report

Overview

Since our nation's beginning in the late 1700's there have been several major transformation periods in American society. Social structure has evolved through several stages with our humble beginnings as an agrarian nation. In the late 1800's we entered the industrial age and, based on the industrial strength, were recognized as a world power. We demonstrated the capability of our industrial and military power in two world wars and in the aftermath of the wars when we rebuilt the war torn nations of Europe and Asia. The next, albeit short-lived, age we entered centered on service. This age quickly transformed to the present information age, where America once again provides the global leadership. John Naisbitt succinctly stated in Megatrends that "*the source of power is not money in the hands of a few people, it's information in the hands of many*."

The military has long recognized the need to develop and exploit information, and has been involved in data gathering and information exploitation since its inception. Not only does military interest lie in data use, more specifically its interest lies in the development, management, and dissemination of geospatial data. As was stated earlier, the new emphasis of military doctrine recognizes that geography provides the foundation upon which all other information is based.

Evolution of GIS Implementation

As in civilian communities, GIS on military installations evolved through a series of recognizable approaches. A strong correlation exists between the approaches used and the maturity of the technology. In all but a few examples, GIS began within a single section to accomplish a specific project. Once the project was complete, the system was retired. Very little, if any, data sharing occurred. As the technology matured and users were cognizant of its capabilities, GIS were implemented at the departmental level. Rather than meeting a single need, the departmental GIS had a well-defined mission need. The GIS became a permanent asset for the department requiring ongoing funding for its salient components – hardware, software, data, procedures, and people. Data sharing within the department began to rise.

The next transition integrated the entire organization or installation within an enterprise-wide system. The GIS was positioned within the organization to meet mission critical elements. It was designed to align with the strategic direction of the organization and to facilitate management decisions. Sharing of common database and structure was designed to eliminate redundant collection and ensure consistency in the data. Long term support was anticipated for the system and the system impacted every department and section.

The final shift in this evolution is occurring now – a societal approach. In this approach not only is the data shared permeated throughout the installation, access outside the installation is available through the internet. In the short term, due mainly to security considerations, data will be served on secure networks to higher echelons geographically separated from the main server. For example, Major Commands (MAJCOM) will have access to necessary data at their subordinate installations. MAJCOM data will be available to their respective departmental service and eventually to the Department of Defense.

Benefits of GIS

Economic realities are an inherent aspect in the overall strategy in developing and managing a GIS, which is inundated with a mixture of tangible and intangible gains. Estimates can be made on the value of intangible gains, but in most cases, a GIS can be justified on the benefits realized through tangible costs and benefits. Most tangible benefits are attributed to gains in efficiency that result from reduced work load and the effectiveness involved in the capability to perform tasks and analysis previously beyond the reach of the organizations (Guptill, 1988).

Benefits derived from efficiency include:

- **Responsiveness to data calls**. GIS allows quick access to data allowing decision-makers to arrive at optimal decisions based on current and accurate data.

- **Efficient use of resources**. GIS allows data sharing, eliminating redundant data efforts.

- **Improves communication**. GIS allows users to view data in multiple formats e.g., charts, graphs, and maps that enhance the decision-making process.

- **Improved operations**. GIS allows managers the ability to manage the process by integrating individual functions into the organizational process.

Benefits derived from effectiveness include:

- **Improved data dissemination**. GIS allows the rapid dissemination of by centralizing data.

- **Improved data availability**. GIS allows data improvement through accessibility to reliable and quality data.

- **Improved decision-making**. GIS data served in a standard format allows access to multiple data sets, enhancing the decision-making process, and encourages data sharing.

Evaluation of an enterprise GIS can present a unique set of problems due to the nature of benefits and organizational structure to which they are applied. Efficiency and effectiveness will vary between individual programs, while other benefits are realized by the organization as a whole. Benefits in productivity are realized in the effectiveness or development of new capabilities due to increased efficiency of existing operations, e.g., linking database information to geographic areas for map production to support management or MAJCOM call for reports i.e., BRAC, Facilities Capability Reports etc.

4 Framework for the Development of Geospatial Data and Related Systems

Framework

Building and implementing a full-scale Geospatial Information Technology is a long and complex process. It impacts every organization on the installation and requires a substantial investment to construct and maintain. The entire process, beginning with the decision to implement the technology through its completion, can be divided into six logical phases. Each phase is discussed below.

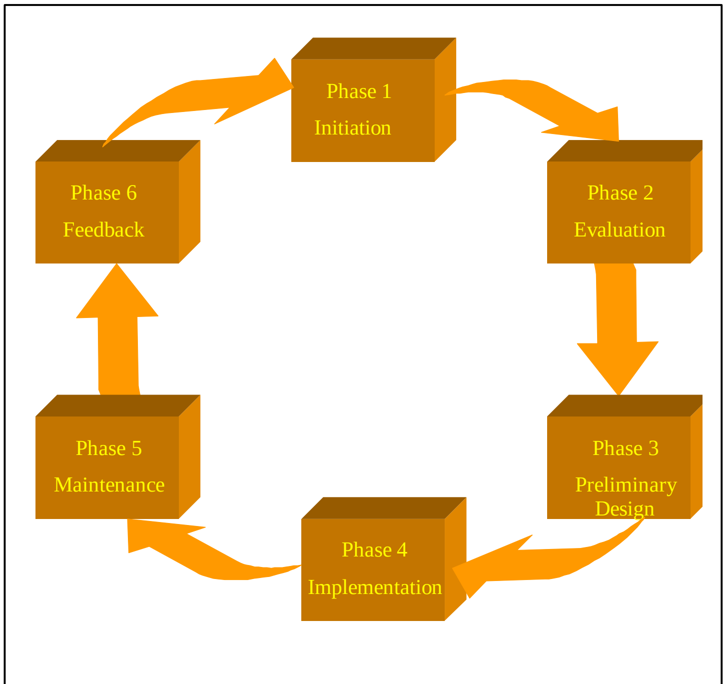

Figure 4-1: Framework for building a Geospatial Information System

Experience has demonstrated that as we approach the challenge of meeting the demand for the development and management of information systems that a strategic approach is necessary to ensure its success. The approach must be logical. It must encompass a documented process that reflects the organizational goals and objectives. It must be achievable. This chapter outlines and discusses the process involved in developing and managing a geospatial information system. Figure 4-1 displays the framework for constructing a GIS. Figure 4-2 displays the process involved in the development and management of this strategy. This guide will present a discussion on each of these components.

An important concept to remember is that building a GIS is a process. All actions must be documented. It's not a solution looking for a problem but a problem looking for a solution. Neither is it built all at once, it's phased in within a pre-determined time line. It begins with a review of the installation's Strategic Plan and ends with a review of the installations' Strategic Plan. It's a continuous, uninterrupted cycle – as the Strategic Plan is updated, so too is the GIS.

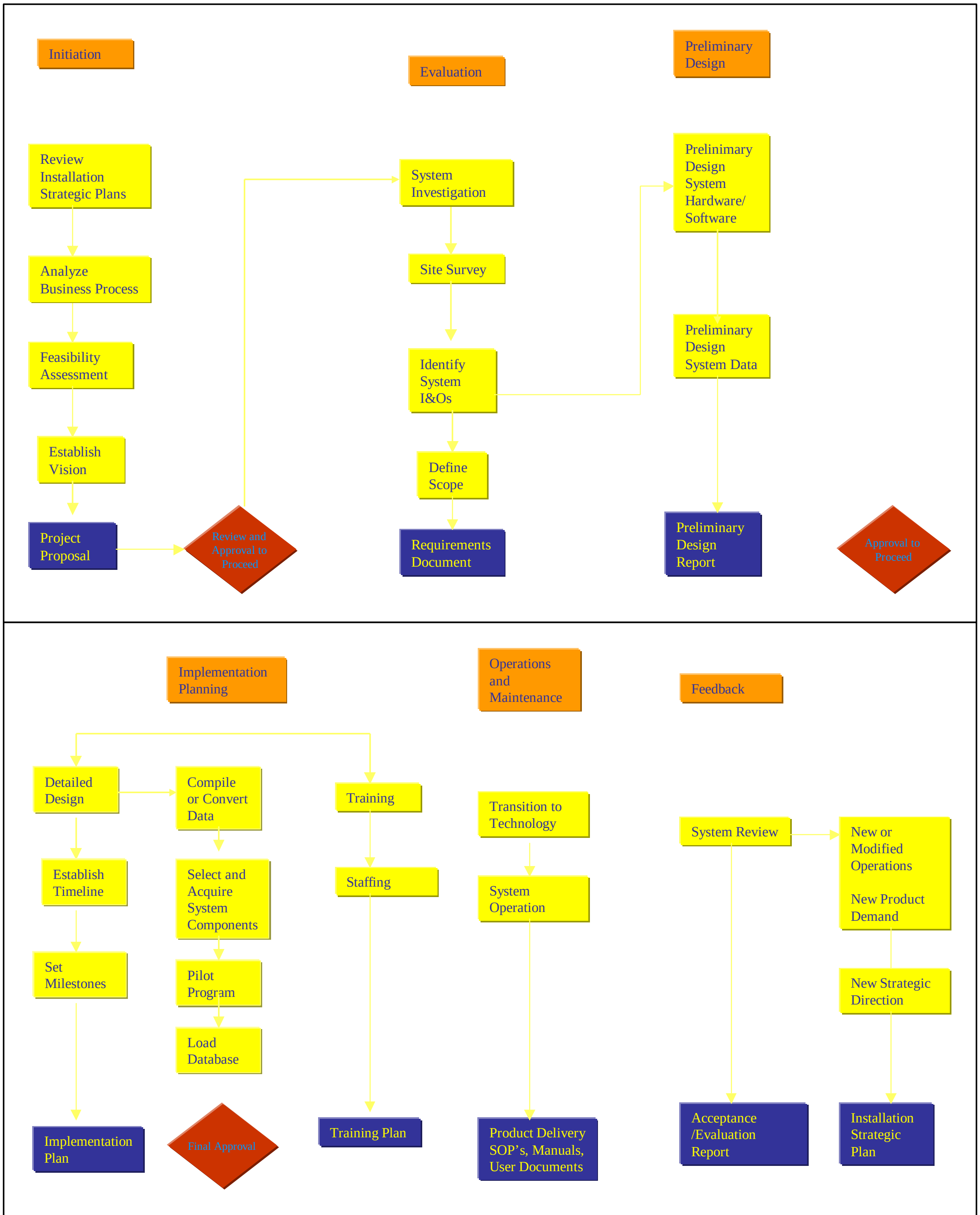

Figure 4-1: Framework for building a Geospatial Information System

Strategy Team

Since geospatial information is the foundation of the future, it is necessary to examine our current business process in terms of geospatial information flows and use. The purpose of this strategy team is to evaluate the business process and establish a management framework within which the GIS Strategy can occur, ensuring that the development is efficient, effective, and useful to the organization. Executive management begins the process by identifying and organizing a GIS Steering Group to examine the impact of transitioning to the technology. Whenever possible, examination of the organizational process should encompass both a “top down” and a “bottom up” approach.

Experience has shown that failure to succeed in the development and management of geospatial information lies not in the technology, but in organizational behavior. Lt. Col. Brian Cullis surmises in his dissertation, “An Exploratory Analysis of Responses to Geographic Information Systems Adoption of Tri-Service Military Installations”, that successful adoption of geospatial technology has to be perceived as more than successfully acquiring the hardware and software, it includes the awareness for the value of planning, establishing objectives, and developing evaluation programs. A team approach then becomes a necessary function of planning. It also allows management to distribute the burden associated with this task while concurrently developing in-house expertise.

What teams need to be appointed? Who should be tasked? Composition or membership of these teams is a critical decision. Experience shows that installations with successful development and implementation of the technology had a common organization. An Executive Management Team was established to provide funding support, a Technical Working Group for technical expertise, a Functional Users Group for functional expertise, and a GIS Manager for overall continuity. This structure ensures a “top down” and “bottom up” approach and encourages “ownership” in the process.

The ***Executive Management Team***, comprised of key directors and policy makers for the installation (commanders and/or their executive officers), has the overall responsibility to:

- Obtain funding
- Identify policy requirements and prepare recommendations for review/action
- Approve resource allocations and timetable for development
- Solve interdepartmental conflicts

The objective of this group is two-fold, the first is to fund and support the implementation process, and the second is to build commitment, hence the high level guidance. Only at this level can funding support be ensured. This level also demonstrates management commitment toward the project, lending credence to the project. While not ensuring the success of the endeavor, experience shows that if staff members perceive that GIS is a management priority, they have vested interest to make it work. So, support from executive management increases the likelihood of success.

Building commitment also includes getting the entire organization involved. The Executive Management Team is in a unique position to provide the necessary support to ensure organizational involvement. Getting everyone to be a part of the solution helps alleviate the fear experienced in transitioning to a new technology. It decreases the amount of resistance and encourages cooperation within the organization. If done properly, morale rises, and unit cohesiveness evidenced by *esprit de corps* is noted.

The ***Technical Working Group*** is a companion group that supports the Executive Management Team. Personnel assigned to this group should have an in-depth understanding of their area of expertise, databases, GIS software/hardware, networking, etc. This team has the overall responsibility to:

- Help develop strategy
- Meet executive management team objectives
- Identify resource requirements
- Provide technical insights and experience
- Identify and evaluate operational processes that can be automated
- Identify GIS priorities
- Manage data structure

The ***Functional Users Group*** is a subordinate group to the Technical Working Group. Personnel assigned to this group are the users – they are the airmen, seamen, and soldiers, who gather, process, analyze, and disseminate geospatial information. The Functional User Group is tasked to:

- Assist in developing strategy
- Identify resource requirements
- Identify data requirements
- Identify those processes that can be automated

This is the group that is intimately familiar with the data that are collected and the output products the data supports. It's the user for whom geospatial information applications are written. It's the user who accesses and shares data. The keypoint to remember is that the system is user driven! When the business process is examined – the user is the client!

The ***GIS Manager*** is the heart and soul of the undertaking. The GIS Manager has responsibility to:

- Prepare development strategy and Implementation Plan
- Manage the Technical Working Group
- Provide technical insights and expertise
- Facilitate end user involvement in appropriate analysis, design, and development efforts
- Assemble the proper people and skills necessary for the Technical and the Functional Users Working Groups

- Create an environment of open communication among groups and teams

This single point of contact serves as a liaison to all teams and groups, internal and external to the process. This position is imperative because a knowledge void typically exists between the user and management. The GIS Manager bridges that void. The GIS Manager possesses a detailed understanding of the political environment and the technology. The GIS Manager acts as a facilitator or negotiator, solving problems as they arise. The GIS Manager has the technical background and can assist management in aligning the technology with the strategic direction of the mission. A common cause for failure in developing a GIS has been the lack or absence of expert guidance.

Initiation

Strategic Plan Review

The process begins with a review of the Strategic Plan (see Figure 4-3). The strategic plan is a document that provides the installation with general guidance. It is usually comprised of several sections including the mission statement, a set of guiding principles, goal statement, and program direction. The strategic plan defines the purpose of the installation (mission statement), in general terms of what it is the installation is tasked to accomplish (goal statement), and it provides specific direction for subordinate units (objectives). Each unit that comprises the enterprise also has a "plan" that provides guidance to the unit. Examine these as well and determine where they fit into the overall direction of the enterprise-wide process. Once these factors are understood then ask the question, does GIS provide the proper tool to meet this tasking? Since a vast majority of the information collected is spatially related it is safe to say that GIS can and does provide the necessary tools to manage mission-related tasking.

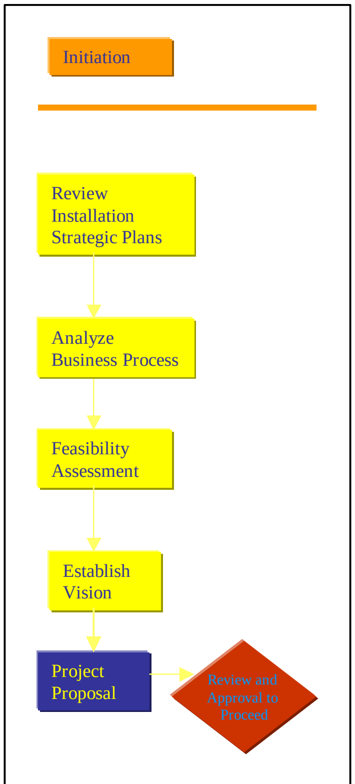

Figure 4-3: Initiation

Analyze the Business Process

Implementing a GIS can (and will) impact the structure of an organization. Implementation of geospatial systems usually results in modifications to typical roles and responsibilities that apply to information processing. Typically the shift will require a modification of responsibilities within the organization, resulting in a new organizational philosophy, new lines of communication, and a realignment of the business process. The purpose of this analysis is to understand the existing organizational framework, how it operates, how the new technology will change the structure, and to create a framework under which the impacts of change can be managed. This analysis is an opportunity for management to tune-up virtually every job and function that is performed on the installation.

Remember that this analysis is a subjective assessment of the organizational process – not a major tasking. Determine what the driving forces are that motivate the organization? What is the management philosophy and style? Who is pushing the GIS – senior management, middle management, or staff?

Management must determine if information flow can be streamlined using a GIS. What information is gathered within the organization? In broad terms, examine the information and determine whether this information can best be displayed as locational information or as tabular data. Do spatial relationships exist with other data? Can these relationships be portrayed more efficiently with GIS?

Is redundant information being gathered and maintained within the organization? Do multiple agencies collect the same data? Does information within the organization conflict? Are these duplicate data files necessary? Do they hinder dissemination of accurate information or hamper communications within the organization?

If efficiency and efficacy are issues, is GIS the appropriate mechanism to solve the problem? Providing answers to these questions allows management to determine organizational needs and allows management the opportunity to identify and examine alternative solutions.

Feasibility Assessment

Experience has demonstrated that as we approach the challenge of implementing a GIS, it is imperative that management focuses on the salient considerations of budget, manpower, and time. So, management must determine the feasibility to implement a project of this magnitude. Feasibility falls into three basic categories - technical, financial, and organizational. To determine whether or not a project is feasible, management must examine and answer the following questions:

- **Technical.** Is the necessary technology available? Can it be procured at a reasonable cost? Is the required staffing available? Can it be obtained with a reasonable amount of funding? With a reasonable amount of training, can it be used by the staff?

- **Financial.** Is cost within the realm of resources that can be obtained? Does the return on investment (ROI) justify the investment? Can funding be allocated and sustained over the entire planning horizon?

- **Organizational.** Are organizational impacts (structural and processes) within acceptable parameters? Can performance measures be determined that satisfy management and policy requirements? Can funding be sustained throughout the planning horizon?

Answers to the above questions determine whether or not the installation should proceed with the implementation. If the answers to all three parameters indicate feasibility can be supported, then the current business process should be examined for efficiency and effectiveness. This examination is time consuming. Management must determine whether or not information flows efficiently throughout the organization. Identify where the bottlenecks to information flow occur. Identify processes that are uniquely geospatial in nature, e.g., data that pertain to locational features and their related attributes – buildings, roads, land parcels, real estate.

Establish GIS Vision

Once management has a clear understanding of the total mission tasking, organizational structure, and the information management process, determination can be made on how to proceed with high-level planning for the GIS development. Establish the vision. The GIS Vision, like the strategic plan discussed earlier, defines the general direction for the GIS development. There basically two reasons for developing a GIS vision:

- Build commitment

- Align the direction of the GIS with the strategic direction of the mission and incorporate it into the decision-making process.

The content of the vision statement will vary depending on the degree and level that computer technology that permeates the organization. If information management is advanced less guidance will be needed. The vision should define, in general terms, the desired outcome and, when possible, user participation. For example Kadena Air Base stated their vision as:

> ***"Provide precise geospatial information, at the proper place and time, regularly maintained from reliable sources, in a form that users can understand, easily access, and reliably use to accomplish their mission and tasks more efficiently and effectively"***

The vision statement is the compass that provides the direction of the GIS rather than a set of goals and objectives. It needs to be flexible enough that it can be modified as the technology and mission change. It needs to be broad enough in scope to capture future applications without being so vague it doesn't provide direction. It needs to be founded in reality – but challenging to the point that it draws both management and participants together as cooperative partners. It builds commitment.

The second purpose was to align the direction of the GIS with the mission, organizational strategy, policy, and management. Management has now reviewed the strategic plan and has determined the goals and objectives for the entire organization. They have also determined that the feasibility exists to support both short-term and long-term commitments to the technology. Finally, management has determined and portrayed the vision for GIS. Now that these factors are known and accepted, the next step is to draft a project proposal.

Project Proposal

The project proposal is a formal written request to management from the GIS Manager requesting funding to begin a formal investigation to change the current business process to one centered on geospatial information. This proposal should state the current process and present the advantages and disadvantages of developing this technology. It should provide a clear discussion on how the GIS will facilitate mission accomplishment and how the system will align or modify with the current business process.

Include a discussion on the data that are collected, (the types of data used (tabular, locational)), what products are produced and a comparison of this data to the mission tasking should be presented. An assessment of current capability should be included. The intent is to provide Executive Management a document that justifies the expense of undertaking the development of a geospatial information system. If possible, a rough calculation of the expenditures and time frame to develop should be included.

Strategic planning is a process. However, while strategic planning is a process it is still necessary to have a document available where records of management approvals and other supporting information can be maintained. It should be developed in a manner that facilitates updates and changes. These records along with subsequent documents form the Strategy Plan for the entire development and management process.

Evaluation

The primary concern during this phase is to obtain an accurate and detailed assessment of the present method of operation (PMO) coupled with a complete inventory of equipment and resources. This will provide a baseline against which all actions will be measured.

System Investigation

Building on the steps initiated with the analysis of the business process, examine and inventory information management equipment. During this process inventory the computers (both hardware and software) and the peripherals (digitizers, plotters, scanners, digital cameras etc.) Also look at the established communication links – determine how computers and peripherals communicate with one another. Determine the networking capabilities of the organization?

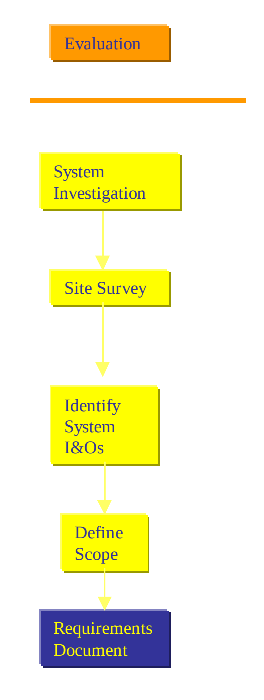

Figure 4-4: Analyze Needs

Site Survey

The first step in this procedure is to conduct a site survey. The site survey employs a variety of techniques that can include (but are not limited to) interviews, workshops, questionnaires, and modeling. The goal of the site survey is to obtain an accurate depiction of the organization's requirements – both present and future. The survey instrument should inventory not only computer needs, it should also include personnel requirements e.g., skills available, skills needed, training requirements, and past investments that support geospatial technology.

During the site survey the strategy support team assesses what data the organization collects, activities that collect the data, and mapping and graphic needs of the organization. This survey should include all collected data, e.g., tabular data, graphic data, charts, and maps. Compare data collection with present mission requirements and identify extraneous data and data voids (data that should be but is not collected). Examine future needs of the organization. Is a mission change scheduled? Is the organization tasked to support the bed-down or deployment of troops during contingency operations? What data are needed to support this tasking?

Identify Input and Output

Identify and list the products (inputs and outputs) generated by the organization. What is produced? Why is it produced? How is it produced? Who produces the product? How often is this product produced? What data is needed to support the product? How does this product support mission accomplishment? To answer these simple questions it is imperative that the support team thoroughly understands the installation mission and have an in-depth understanding of the requirements the organization will place on the new system.

After compiling "current products inventory" meet with the customer and develop a detailed listing of the products the system should produce. Combine the two lists and prioritize the inventory based upon some functional criterion e.g., mandatory product, product aids mission accomplishment, internal use only etc. Using the product list as a guide, determine the specific data requirements for the system – are data spatially related? Are they maps, reports, images?

Are tolerances or accuracy specified? What mapping scales are required to adequately present the data?

If the product is a map, attach a sketch and itemize the visual aspects (features) on the map. If it's a report, define the information that is needed, including the headings and other common data fields – if possible, obtain a copy of the product. Identify the relationships between the data elements and the database. Finally, examine the tolerances and accuracy that are needed for the data. Error tolerance impacts the cost of the system. Determine how much error can be allowed and still retain the integrity of the final products. The less tolerance acceptable the higher the cost – cost of data precision is exponential.

Define Scope

Analysis of the site survey and inventory of available resources allows the support team to define the scope of the proposed project. Knowing the mission requirements, available resources, data needs, and product requirements, allows the support team to prepare a requirements document. The requirements document should include all of the information discussed above, i.e., results of survey, results of inventory, current practices, current resources, needed resources, current training status, and a history of past investments toward the technology. It should also include a listing of output products – including examples of maps and map scales, reports and graphs etc., data requirements, types of data collected, logical linkages and error tolerances, and cost projections for the technology. Finally, a projected timetable should be developed and provided to the Executive Management Team. This document, including recommended priorities, is presented to the Executive Management Team for approval – remember the Executive Management Team has the responsibility to set priorities and align the project with the overall organizational goals and objectives.

Preliminary System Design

During this phase, the support teams will develop a preliminary system design based on the information compiled during the mission review, visioning, and the needs analysis. This is not the final system – it is merely the first attempt at its design. Apply the information gathered for the "Project Proposal" and the "Requirements Document" to identify system requirements e.g., hardware, software, and people. This step allows the support team and the users to optimize the system based on input received from the users and to examine the system design to ensure it is developed along a logical path.

While the basic components of the system – data, hardware, software, and maintenance are discussed as disaggregated elements, they are not mutually exclusive – each has an impact on the other and is typically accomplished at the same time. They are separated below only to facilitate discussion.

- Database issues are concerned with data storage - where and how the data is stored, data access, data security, data accuracy, data standards, and data conversion.

- Software issues relate to what software should be used, and the modules necessary to support the GIS.

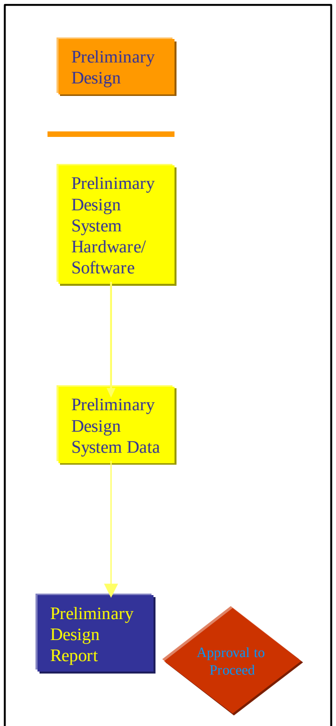

Figure 4-5: System Design

- Hardware concerns configuration requirements, communications (networking), type of equipment, location of equipment, and system performance.

- Maintenance is concerned with support issues e.g., responsibilities for maintenance and updates, procedures, and access.

Database

Database issues are a major concern because they are the most cost intensive factor of the system. Seventy percent of the total cost of a GIS is attributed to data collection, standardization, and conversion. Some of this cost can be mitigated using approved standards. Each of the military services has adopted the standards created through the CADD/GIS Technology Center located at Vicksburg, Mississippi. These standards are free and available for download at http:/tsc.wes.army.mil/. The Spatial Data Standards provides a relational database schema and a naming convention that is compatible with most software used within the military services. Having data files in a SDS format eliminates the cost of data conversion. Using the standards also facilitates data sharing across services – this means that applications can be readily shared between the services with little or no modification reducing the cost of application development.

Database issues need to address how data will be stored. Is it centralized or decentralized. Where will the data be stored? Who has access to the data? What level of access – read only, read and write? Not everyone has a need! Access should be granted only to those who have a legitimate need for the data.

Finally, the level of accuracy or error tolerance must be specified for the GIS. It is impossible to develop a GIS without error. Error is built into the system! It comes from a variety of sources. Algorithms are used to convert images from raster to vector – error occurs. Vector images, complete with their errors, form the foundation for many CADD drawings. These drawings are "stretched and warped" to force-fit drawing to the digital geometry - increasing error. Error cannot be avoided – it can be minimized and an acceptable level of error can be prescribed. See the Center Guidelines for Mapping and Geospatial Data. It is important to understand the needs of the end product and not over specify accuracy requirements. The more accuracy required the higher the cost of the GIS. The cost increases geometrically. Be cautious of vendors who prescribe centimeter accuracy!

Metadata

Metadata is nothing more than data about the data. Metadata describes the content, quality, condition, and other characteristics of a data. Metadata serves three important functions. First, it provides end-users if data sets with adequate information for proper use of the data (documentation). Second, it provides a listing of work that can be shared with others (inventory). Third, it supports search capability of a data set based on its extended properties for others to find (catalog).

The concept of metadata is familiar to most people who deal with spatial issues. A map legend is an example of a metadata. The legend contains information about the publisher of the map, the publication date, the type of map, a description of the map, spatial references, the map's scale and its accuracy, among many other things. Metadata are nothing more than that type of descriptive information applied to a digital geospatial file.

Software

Software, too, is a critical element. The software chosen to support the GIS must consider the interoperability between the software packages e.g., CADD, GIS, spreadsheet, word processor, database etc. The applications developed for the system will also have a bearing. Identify programming needs. Automate routine functions.

Hardware

Again, consider operability between software and the computer hardware (memory, ram, speed of processor, video card, compact disk, etc) and peripherals (scanner, digitizer, plotter, printer, camera, etc.).

Maintenance

Determine where equipment will be located, and identify who is responsible for the maintenance of the equipment. Develop operating procedures for maintenance, (schedules, instructions, etc.). Determine access requirements. It is imperative that *line item* funding for system upgrades be part of the budget. Schedule system upgrades annually. For example, computer technology changes render computers obsolete every five years – the budget should allow for a fifteen-percent turnover of computers annually. Software upgrades will be needed annually in some cases and semi-annually in others. Ensure these items are included in the budget.

Preliminary Design Report

As a minimum, this report should address two functions - data and system. Based on the inventory, compile a list of data layers needed to support the GIS. Annotate data availability e.g., available, partially available, not available. How much of the available data is usable with the planned system? How much data conversion will be required? Prioritize this list. The systems section should include a description of the existing system and a description of the planned system and a map explaining how the organization will transition from one to the other. A description of the hardware and software components should be provided to include communications and interface requirements. This report will serve as the guideline for the development of the GIS. As with all reports that support this undertaking, send to the Executive Management Team for their concurrence and approval.

Implementation Management

The purpose of the implementation plan is to ensure the implementation process is efficient, effective, and useful to the organization. The process involves transforming the implementation process into specific tasks that can be accomplished within the constraints identified during the initiation and evaluation phases. It allows management the opportunity to schedule time and resources against a logical sequence of events.

Up to this point this guide has emphasized strategic planning concepts. The focus now shifts to the realm of application development – transitioning from the conceptual model to the practical application – translating the previously gathered information into a working GIS.

During the previous investigation and evaluation phases an assessment of the organization's capability to support a geospatial information system was evaluated. The organization's constraints and opportunities were identified. A prioritized listing was developed stating the sequence applications were to be developed and implemented and the requirements necessary to support the applications (data inputs and outputs etc.). The hardware and software requirements were examined and an overall design and methodology was developed. Finally, with the approval of the preliminary design report, management has committed support for the development and implementation of the technology. With this approval consensus and agreement has been reached.

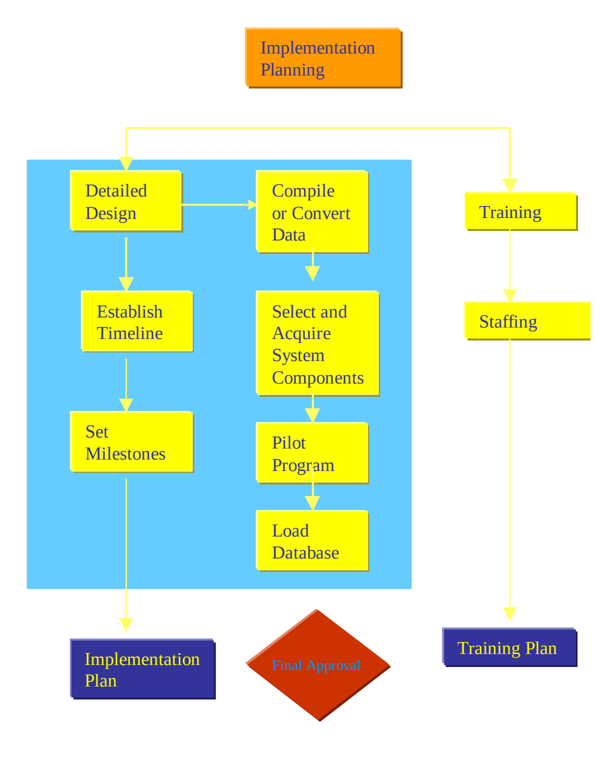

Figure 4-6: Develop Implementation Plan

Detailed Design

The detailed design is a continuance of the preliminary design. During this phase the preliminary design is translated into a specific functional system aligned with the organization's business process. The database architecture is finalized and data compiled and converted to work within the architecture. Acquisition and assemble hardware and software components. Train personnel are trained and position to receive the final product. The organization work process is restructured and production is transferred to the new process.

Compile and or convert data.

Earlier a discussion on database architecture was presented. One of the key points presented was the need to develop a database schema. The spatial data standards developed by the CADD/GIS Technology Center forms the foundation of the approved schema for use on military installations. Additionally, it provides a data dictionary. Whenever possible adopt these standards. It reduces the cost associated with the development of a schema and it facilitates data sharing within the unit, the installation, and between major commands, and services. Data sharing is a key concept of the system.

Data compilation began with the survey and inventory discussed in the evaluation. A list of all the data the organization uses was compiled. Now that data is reviewed for its quality and appropriateness. If it is compliant with the database structure then the data is uploaded. If not, the data must be converted. Conversion includes taking manual maps, engineering drawings, plans, as-builts and digitizing them in a standard format. Existing digital files are converted to a single format, flat files are converted to relational files, raster files to vector, tabular sets are geo-coded, and images sets are georeferenced to their relative position on the earth's surface.

As the data is gathered it will become readily apparent that it is not standardized. This results in increased cost in data conversion. Data conversion is typically the most expensive portion of the GIS development. The following extract is provided to demonstrate the common disparities encountered and to provide the user an example of what can happen when data standards are not established and followed, hence the reason why data conversion is needed.

"…Team had to consider the following data disparities: 1) The (site name) orthophoto was not georeferenced, 2) The CAD files were in NAD 27, 3) The DTED was geographic decimal seconds, 4) The CIB was geographic decimal degrees, and 5) The environmental coverage's were UTM."

Select and acquire system components

Procurement of the system components is dependent upon the individual service policies and procedures. It's beyond the scope of this guide to evaluate or make recommendations related to their individual practices. However, a source that should be explored prior to committing to system acquisition is the Facility CAD2 contract. It's a full service, Department of Defense, contract vehicle open to all federal agencies. One advantage of using this contract is that it has already been competed. Consequently, the normal solicitation process can be by-passed. Information on this source can be obtained at http://cad2.wes.army.mil/

Pilot

During this phase, hardware and software are delivered, assembled, and tested according to some formal acceptance testing procedures – preferably stated in the functional specifications of the project. These procedures are designed to ensure the operability of the system, validate the database, its structure and format, create a benchmark, and provide hands-on training. This not a complete system but rather a sampling or a cross-section of the entire system. It should allow the user to validate digitization routines, data entry, data retrieval, map production, functionality of specific applications, and its analysis capability. As the system undergoes the testing procedures technical problems will arise – don't be alarmed! This is one of the major functions of the pilot project, it ensures the operability of the system, that the system accomplishes what it was designed to do. Most of the problems that arise during the validation process are simple problems that can be -corrected on the spot, e.g., missing link to the data, broken computer board, improper data request, etc.

Training is also provided during this phase. Training is provided by the contractor (if one was used), the vendor, or the team responsible for the system development. Ideally, this training is conducted on base, using the installations system, data, and applications. Training should consist of application familiarity, commands, product generation, system operation and system maintenance. It is important that training include long-term data maintenance and procedures on how to update the database.

Load Database

After the pilot project is thoroughly tested and all identified errors or technological problems corrected, the remaining applications and complete data files should be loaded. It is imperative that the data files undergo a quality control measure prior to loading into the system. The quality control measure should allow the database administrator the opportunity to evaluate the data contents, accuracy, continuity, and data consistency. The administrator should also examine the structure for integrity of the layering scheme and ensure the definitions for each of the elements are present and accurate.

Training

An integral aspect of designing a Geospatial Technology is the development of an effective training plan. The training plan outlines a basic curriculum that allows the student to achieve a stated level of competency in GIS. The training process involves all staff and support personnel throughout the organization. It must recognize that there are (at least) three distinct levels of proficiency that must be addressed in the GIS Profession. Each of these is unique and requires a specific set of skills. The three levels are:

Doer. The doer is the most highly trained GIS technician within the organization. These are the experts who create the data and write the applications.

User. The user's focus is on manipulating and analyzing the data. This person creates derivative data sets from the parent database.

Viewer. The viewer views, extracts, analyzes, and displays data for communication purposes.

The training plan must also address the source of training, e.g., vendor, university, on-the-job training, consultant, or government based courses. GIS technology is not limited to a single discipline but rather encompasses a variety of skills across a multitude of practices. In reality, GIS is an inter-disciplinary tool, drawing its knowledge from several fields of study consequently, the GIS technician must have an understanding of several disciplines. The Center has developed a recommended curriculum for the GIS professional and has provided a list of training sources. This curriculum can be viewed at: http://tsc.wes.army.mil/headlines. Particular attention should be paid to the distance learning mode. When this venue is appropriate, it provides an excellent avenue for training, minimizing training cost. It provides a formal means for the evaluation and preparation of professionals who use GIS skills in performing their job responsibilities. Course work is served on the computer while the student studies in the comfort of the home or office.

The training plan must also target the student based on the level of interaction. Training demanded of senior management (viewer) differs from that required for middle management (user) and again for the training necessary for the operator (doer). Each has a specific need that must be met. Senior management is concerned with issues that relate to how the technology will impact the budget, personnel, policies, and procedures. They will be concerned with how the system will be implemented and what their specific role is to ensure the success of the endeavor. Middle management is also interested in these items. They also need more specific knowledge on how it works, what makes it successful, what tasks need to be performed, and what impact this technology will have on the business process. Operators need to know how to use the specific programs, enter data, generate reports, and maintain the system.

The vendor usually provides GIS training for vendor specific programs. However, due to the complexity of the technology, education should go well beyond vendor supplied training. They should also receive training in computer-aided design and drafting, cartography, coordinate geometry, spatial relations, information technology - programming, database management, systems administration, and presentation skills. Providing the user with in-depth the knowledge base will help alleviate problems during the implementation of the technology. It will provide the user with the skills necessary to recognize and avoid product bias.

Staffing

As stated in the previous discussion, GIS is an inter-disciplinary field. Consequently, there are various full-time skills that are necessary to ensure the success of this endeavor. Some of these skills have been identified and can be stated as positions, e.g., GIS Manager, GIS Analyst, Computer Programmer, Systems Administrator, Database Manager, and a CADD Operator or Draftsman. These positions can be filled with existing personnel who have the stated skills or existing personnel can be trained to accomplish these tasks. The option also exists to go outside the organization and hire personnel with the requisite skills or the function can be outsourced to a contractor. The requisite skills are not necessarily available since this is still a relatively new field. Consequently, a combination of contracting and existing personnel, working together is prudent.

Initially only the GIS Manager (working in concert with the Strategy Team) should be sufficient. However, as the system evolves other skills are brought into play. For example, application development should involve the programmer, database design should involve the database manager. A definitive schedule should be developed to allow this transition. If contractors are initially used, then a scheduled transition from contractor to in-house personnel should be explicitly built into the process. The training plan should ensure that personnel are identified and provided the necessary training to ensure they are capable of assuming the assigned tasks and responsibilities.

A description of needed skills and responsibilities is provided as an appendix to this guide.

Operations and Maintenance

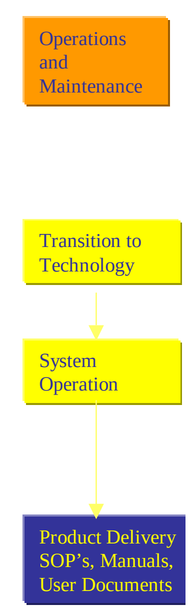

Figure 4-7: Operations and Maintenance

A discussion on building an initial database to support the GIS was presented earlier in this paper. However, building a database consists of two distinct steps. The first step is inputting the initial data and the second step is maintaining the data. Inputting the data consisted of acquiring from multiple sources the data necessary to support the selected geospatial applications. Maintenance consists of keeping the data current.

Data is the heart and soul of any information system. It provides the foundation upon which decision-makers plan their activities. Sound data and maintenance procedures are essential to ensure that data and the information derived from the data are above reproach. Once the quality of the data is questioned then the value of the geospatial system is negated. Data are of little value if the cannot be trusted.

It has been stated that the most significant costs attributed to the development of a Geospatial Information system lies in the data and data-related activities. Conversely, the greatest savings are gained from data and data related activities. A significant saving is realized by reducing the number of times a piece of data must be entered and manipulated. For example, savings are realized when data are shared from a single data file rather than from multiple inconsistent entries. This also leads to increased efficiency in data processing, increased data reliability, and better decisions based on accurate and current data. An underlying goal of information technology is to increase the efficiency of data entry and serve consistent, accurate, and current information to the decision-maker.

Data maintenance is probably a larger problem than data collection mostly because data maintenance is an on-going process. Not only is it on-going, maintenance cost over the long haul are just as (or more) expensive than the initial data gathering. But, it also provides a platform from which the user may realize significant savings through gains in efficiency. Huxhold provides this adage**: "***No data should be captured and converted without an associated plan for maintaining those data***."**

Transition to Technology

Everything known to mankind has a beginning and an end. Just as every project has a beginning and an end, somewhere along the line the GIS Implementation reaches fruition - the project ends and the system becomes operational. Exactly when this change occurs varies from base to base depending on a multitude of factors. Whenever the transition occurs there is a corresponding change in the business process. The focus shifts from planning and education to operation and maintenance of the system.

System Operation

There are two important factors remaining impacting the organization that must be addressed. The first issue is the placement of the GIS within the organizational structure. The second is budgeting for the new technology.

Experience demonstrates that there are multiple solutions to the placement of a GIS based on the organizational structure and the level of command interface involved in its management. There are three levels of operation where this exchange occurs: (1) organizational level, (2) tactical level, and (3) strategic level. Each of these levels of operation reflects the organization's character. From our "lessons learned" we know that the successful placement is dependent upon where the "hands-on" manager reside, hence our three levels of operation.

- **Operational level** is consistent when the operation and control of the GIS is at an organizational level. For example, Civil Engineering or Public Works Departments is logical when the Installation Commander relies on subordinate command structure to deliver the required services and provides the responsibility and authority to that unit commander to ensure its successful operation. This also means the Installation Commander isn't likely to become involved in short-term management decisions. This mode of operation usually results in a decentralized approach to GIS.

- **Tactical level** places the GIS under a broader function representing the installation usually through a steering committee. This level can assure equitable use of limited resources throughout the installation. Examples of tactical level placement would include information management, database administration, or other enterprise-wide organizations like master or comprehensive planning. This level of placement is usually the most cost intensive due to high level of complexity, competing interests, high skill levels, high personnel costs, and high budgets.

- **Strategic level** places the GIS under the direct control of the Installation Commander. This is probably the most logical placement of the technology because policy originates at the strategic level and consequently, the GIS manager is in the position of responding to the strategic needs of the installation. This removes the GIS manager from the dubious position of determining the value of competing interests and focuses the GIS on public services and areas of management concerns.

Budgeting for a GIS is related to the level of operation in that the determination is made for a centralized or decentralized budget. Arguments can be made concerning the merits of each but whichever method is selected there are a few consistent areas where a direct fiscal component exists. These areas include (1) labor, (2) hardware, (3) software, (4) maintenance of existing system, and (5) miscellaneous expenditures.

- **Labor** cost includes the annual salary of the personnel assigned to the GIS functions. While the salary is set, the manager may prefer to track internal costs in separate categories such as direct and indirect labor costs. Direct costs are associated with time spent on project management or project completion. Indirect costs are costs not directly attributable to the GIS such as time spent in training and administrative functions.

- **Hardware** cost should include all existing maintenance and or service contracts for all hardware necessary to support the GIS function to include the CPU's, modems, digitizers, scanners, etc., It should also include indirect costs of replacement and modernization of equipment. Computer hardware life cycles run about eighteen months and become truly obsolete every five to seven years.

- **Software** cost should include funds associated with the purchase and or lease of software packages including periodic upgrades of software. In general, GIS software tends to be upgraded on an annual basis. For planning purposes, a GIS life cycle for management applications is about five to seven year life cycle, after which much of the technology and many of the procedures should be replaced. Engineering quality GIS databases though can have a life cycle measured in decades if properly maintained and updated through the years.

- **Maintenance** cost should include time spent maintaining the system. Maintenance includes preventative maintenance, backup of system files, system repairs, and changing parts (if assigned to this function). A general rule of thumb estimate for an annual budget is to fund fifteen percent of the systems total purchase price.

- **Miscellaneous** cost includes all other costs. As a minimum, these should include administrative support, office supplies, and travel and per diem costs.

At this point, an operational GIS is available. This implies that more than just hardware and software are functional. It also means that the system is making a difference in how the organization is meeting its mission tasking. Being operational means the customer is receiving the products they have been promised in the implementation plan.

Feedback

Even the best laid plans change. The implementation process must remain flexible to accommodate evolving missions, technological advances, and personnel changes. Short-term focus may redirect the course of the implementation plan. Consequently, a systematic review can ensure the implementation remains on track or reflects its direction as mission needs change.

The initial review of the system should entail some sort of formal appraisal. It should be channeled toward specific, pre-defined aspects of the system comparing the original design to the delivered or manufactured product. Is this system accomplishing the tasks as designed? Does it function as expected? Is it more efficient than the "old way"? Does it follow the parameters established in the Delivery Order? Is it producing the designed products.

Remember that the GIS is a tool that provides the decision-maker with the tools necessary upon which they can base decisions. Decisions are based on their confidence in the data provided. In order for the GIS to remain a viable tool, it must continue to meet these expectations.

Plans do change. The GIS must remain flexible to meet these changes. As mission change and evolve, so too should the GIS.

Periodic reviews of the system are in also in order. The frequency of these reviews remains at the discretion of the GIS Manager. However, every change in installation plans should be reflected in the GIS. The GIS Manager must constantly re-evaluate the GIS to ensure its integrity.

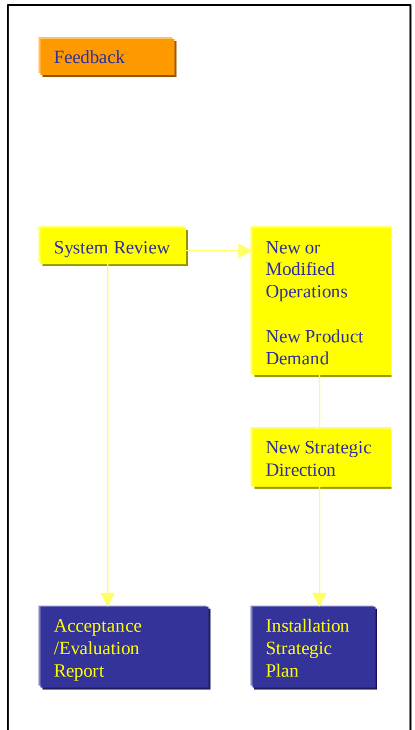

Figure 4-8: Feedback

5 Conclusions

There are commonalties present in successful GIS technologies. In each case, there existed a "Top-Down-Leadership-Approach" to the implementation and planning of the GIS technology. Management examined the top-level requirements and designed the system to meet those needs. They provided the vision the plan would follow ensuring that the GIS aligned with the strategic direction of organization's mission. Successful systems incorporated the geospatial technology early in the decision-making process.

Successful implementation occurred when management involved all levels of users, seeking their input and expertise. The vision of the geospatial technology was established and shared with the entire organization. Management provided the overall guidance for the technology, defining the organizational requirements and postulating the direction and intent of the project. The vision was shared and each echelon was cognizant of their individual impact on the system.

Management created a comprehensive structured approach to the implementation process. They defined the management structure, responsibilities, and established organizational goals. In partnership with key players, management established the necessary management framework to provide the expert guidance necessary to ensure its success. The framework is cyclic beginning and ending with a review of strategic mission planning documents. Even when operational, periodic reviews are necessary to ensure the data integrity remains above reproach.

Management recognized early, and planned to meet all five critical elements of the geospatial system. These elements hardware, software, data, people, and organizational process, were the cornerstones upon which management based all decisions concerning development, implementation and operation. The hardest element to understand and lie at the heart of the implementation process, are those concerned with organizational processes.

To date, all instances of GIS implementation have been made without official geospatial policy. Consequently, military organizations have been designing geospatial data systems in a void – force-fitting geospatial technology to existing military policy. Policy should precede implementation. Military policy must recognize, embrace, and design with geospatial technology as the foundation for the future. Today's battlefield is the electronic battlefield and it is dependent upon the ability of the user to capture, exploit, analyze, and rapidly disseminate information concerning the battlefield. To accomplish this geospatial policy must be placed at the forefront of the technology.

Failure to establish geospatial policy will lead to the continued development of stovepipe solutions. Policy should recognize geospatial systems as the foundation of future systems. The alternative results in separate geospatial systems for each organization. Geospatial systems will be a critical foundation for the electronic battlefield. Therefore, military policy concerning geospatial systems must precede the technology to ensure its viability.

Bibliography

Antenucci, John et.al., 1991. Geographic Information Systems: A Guide to the Technology. Van Nostrand Reinhold, New York

Blevins, Roger, 1997. "General plan guide and template." US Air Force comprehensive planning. HQ AFCEE, Brooks AFB, TX.

Briggs, Ron, 1999. “Geographical Information Systems (GIS): An Introduction”, Class notes from the University of Texas. http://utdallas.edu/~briggs/poec5319/intro.ppt

Hughes, Thomas et. al., 1999. “*Funding a revolution: Government support for computing research*”, Committee on Innovations in Computing and Communications: Lessons from History, National Research Council. National Academy Press.

Day Dwayne A., Logsdon, John M., Latell, Brian, 1998. “Eye in the sky: The story of CORONA spy satellite,”Washington D. C., Smithsonian Press

Department of the Army, 1996. *Engineering and Design Standards for Maps, Drawings, Engineering Surveys, Construction Site Plans, and Related Geospatial Data Products, EC 1110-87.*

____________, 1996. *Engineering and Design: Geospatial Data and Systems*.

____________, 1997. *Guidelines for the Use of Remotely Sensed Data*, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Department of Defense, 1999. Joint tactics, techniques, and procedures for geospatial information and services support to joint operations, Joint Pub 2-03.

Edwards, Paul, 1996. “The Closed World: Computers and the Politics of Discourse in Cold War America”. MIT Press, Cambridge, MA.

ESRI White Paper, 1997. "Military installation management GIS,” Environmental Systems Research Inc., Redlands, CA.

____________, 1996. “Managing a GIS”, Environmental Systems Research Inc., Redlands, CA.

____________, 1989. “Implementing a GIS: Necessary functions, successful strategies”, Arc News, Vol 11, No. 2 (Summer 1989), Environmental Systems Research Inc., Redlands, CA.

Federal Geographic Data Committee, 1998. *Geospatial Positioning Accuracy Standards. Part 4: Standards for Architecture, Engineering, Construction (A/E/C) and Facility Management*. Public Review Draft.

Foote, Kenneth E and Huebner, Donald J., 1996. The Geographers Craft Project, Department of Geography, University of Texas at Austin. *Managing Error*.

Guptill, S., 1988. A process for evaluating geographic information systems. Technology Exchange Working Group, Technical Report 1, USGS Open file report 88-105, Federal Interagency Committee on Digital Cartography

Huxhold, William E., Levinsohn, Alan G., 1995. “Managing Geographic Information System Projects”, Oxford Universty Press, New York.

Mugnier, C.J., 1998. Grids and datums.

Nale, David K., 1996. GIS development strategy and photogrammetric solutions for GIS landbases, 5th ed., ADR, INC.

NASA, 1998. The Remote Sensing Tutorial. Goddard Space Flight Center, Applied Information Sciences Branch.

National Center for Geographic Information analysis (NCGIA), 1998. Maps and Maps Analysis.

__________, 1998. The Raster GIS

__________, 1998. Raster GIS Capabilities

__________, 1998. Vector GIS Capabilities

__________, 1998. Digital Elevation Models

__________, 1998. Urban Planning and Management Applications

Peeples, Curtis L., 1997. “The CORONA Project: America’s First Spy Satellites.” U. S. Naval Institute, MD

Perdue, Bryan L., 1998. Utilization of Satellite Imagery in Lieu of Aerial Photography for Engineering and Installation Comprehensive Planning Applications. U.S. Army Research and Development Laboratory, Vicksburg, MS

Smith, D., 1998. "Installation life-cycle management," http://www.instars.com/ilm/

Appendix A - Position Responsibilities

GIS Organization

A typical GIS organization consists of a GIS Manager, GIS Coordinator, Database Administrator, Programmer, and System Administrator.. The duties of the GIS organization key personnel are:

GIS Director

The GIS Director's primary responsibility is to provide guidance, direction and to be a receptor for new ideas for the organization's GIS. The Director is responsible for approving and/or obtaining approval for equipment, training, and any major focus or direction changes, which may be incorporated into the GIS.

GIS Coordinator

The GIS Coordinator's chief responsibility is to insure all GIS providers and users perform their daily functions aided by the use of a GIS and to assist in the planning of GIS related product development. By managing daily GIS functions and directing the System Administrator, the GIS Coordinator can incorporate required provider and user changes within the GIS.

System Administrator

The System Administrator's principal responsibility is to insure system management and configuration standards are adhered to and sustained during the design, implementation, and modifications of a GIS. The System Administrator is responsible for the management of the GIS network interface; file transfer protocol and movement; system access; disk and peripheral configuration; system performance; and backups and archives. The System Administrator is also responsible for system performance; development of a system operator's instructional manual; system security classification, and future system expansion. System Administrators typically have extensive background, experience and education in computer hardware and software configuration and system management.

Database Administrator

The Database Administrator's primary responsibility is to enforce the established SDS/FMS graphic and non-graphic database standards during all phases of the GIS installation. The Database Administrator is responsible for the administration of relational and graphic data format and structure; graphic and non-graphic data privileges; and data quality control and assurance. The Database Administrator is also responsible for database performance tuning; database operator's instructional manual development; custom data requirements; and future database integration and design. Database Administrators typically have extensive background, education, and experience in relational and file-based database administration.

GIS Analyst

The GIS Analyst is considered an "expert" GIS user. The Analyst is skilled in core GIS topics and high-level GIS analytical applications. The GIS Analyst should be fluent in any applicable GIS data entry, analysis, and output procedures. The Analyst is a "customer consultant." He or she is responsible for custom GIS software interface and macro development; training support and course development; development of an operator's workflow instructional manual; and data translation support. A GIS Analyst could be any user (engineer, planner, etc.) with *at least* eighteen months of full-time GIS experience.

GIS Operator

The GIS Operator is considered a "proficient" GIS user, well trained in all GIS core topics. The GIS Operator should be capable in all appropriate GIS data entry, and data output procedures and capable of system demonstration support. A GIS Operator could be any user (CAD operator, surveyor, engineer, etc.) with at least six month of full-time GIS or CAD experience.

GIS User

The GIS user, also referred to as the "GIS customer", generates studies, requirements, products, and other outputs by using data that are usually completed by other GIS support personnel. The GIS user should understand the principles of GIS and be familiar with select products. Typical users might be managers, maintenance staff, engineers, and clerk-typists.