**AN INVESTIGATION OF GEOBASE MISSION DATA SET DESIGN, IMPLEMENTATION, AND USAGE WITHIN AIR FORCE CIVIL ENGINEER ELECTRICAL AND UTILTIIES WORK CENTERS**

THESIS

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## Abstract

In 2001, the Office of the Civil Engineer, Installation and Logistics, Headquarters, United States Air Force, (ILE) identified Civil Engineer Squadrons as the central point of contact for all base-level mapping requirements/activities. In order to update mapping methods and procedures, ILE has put into place a program called GeoBase, which uses private sector Geographic Information Systems (GIS) technology as a foundation. In its current state, GeoBase uses the concept of a "Common Installation Picture (CIP)" to describe the goal of a consolidated "visual" that integrates the many layers of mapping information. The CIP visual is formed from a collection of data elements that are termed Mission Data Sets (MDS). There are varieties of MDS each of which contain data specific to a particular geospatial domain. The research uses a case study methodology to investigate how the MDS are designed, implemented, and used within four USAF Civil Engineer Squadron Electrical and Utilities Work Centers. The research findings indicate that MDS design and implementation processes vary across organizations; however, fundamental similarities do exist. At the same time, an evolution and maturation of these processes is evident. As for MDS usage within the Electrical and Utilities Work Centers, it was found that MDS usage is increasing; however, data quality is a limiting factor. Based on the research findings, recommendations are put forward for improving wing/base-level GeoBase program design, implementation, and usage.

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*To my wife and daughters*

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# I. Introduction

*Background*

In 2001, the Office of the Civil Engineer, Installation and Logistics, Headquarters, United States Air Force, (ILE) identified Civil Engineer (CE) Squadrons (CES) as the central point of contact for all base-level mapping requirements/activities. In order to update mapping methods and procedures, ILE has put into place a program called GeoBase, which uses private sector Geographic Information Systems (GIS) technology as a foundation. In its current state, GeoBase uses the concept of a "Common Installation Picture (CIP)" to describe the goal of a consolidated "visual" that integrates the many layers of mapping information. The CIP visual is formed from a collection of data elements that are termed Mission Data Sets (MDS). There are varieties of MDS each of which contain data specific to various work centers. The MDS can include data elements that represent facility location, electrical grid layout, water/sewer/gas piping and lines, emergency response routing, explosive safety clear zones, aircraft parking, etc. With the advent of computers, the Civil Engineer Squadron's (CES) Engineering Flight became the focal point for the creation and storage for electronic base maps. These maps are created with computer aided drawing programs such as AutoCAD®.

Under GeoBase, the Concept of Operations (CONOPS) (HAF/ILE, 2003b) generically directs how bases are to create their particular Common Installation Picture (CIP) (HAF/ILE, 2003b), based upon the main base map. Within the CIP are located the new layers or now called Mission Data Sets (MDS) (HAF/ILE, 2003a). Each MDS layer contains the same information formerly found in the paper-based tab maps and layers used by Engineering Flight, but now each MDS is owned by a data steward, one or more individuals who develop and maintain the information (HAF/ILE, 2003b). As each MDS is specific to the owning organization, (Security Forces, Wing Safety, etc.) that organization must decide what information is pertinent and how best to develop it.

Electrical and Utilities Work Centers, in the past, have had to rely on numerous, cumbersome, and most often outdated maps in order to conduct business. These maps were a compilation of information that had been derived from numerous sources from both within and outside Civil Engineer Squadrons. Some of this information was based on speculation, memory recall, and from other organizations that may have located buried infrastructure components by accidentally severing the service line.

### *Problem and Purpose Statement*

ILE has given guidance only on how bases should establish their GeoBase program and as such, there is much variation and completeness in the individual programs. The research project will identify how four Civil Engineer Electrical and Utilities Work Centers have designed and implemented Mission Data Sets and how MDS are being used in those same work centers. It will also investigate the impact of using the MDS on daily work performance and operations.

*Research Questions*

How have Electrical and Utilities Work Centers designed and implemented GeoBase Mission Data Sets and what is the impact to the work centers?

*Investigative Questions*

1. How were Electrical and Utilities Work Centers' Mission Data Sets created?
2. How did the Electrical and Utilities Work Centers determine what data elements to put within the Mission Data Set?
3. How was hardware/software used to capture these Mission Data Sets?
4. How is the information quality (e.g. accuracy, currency) of these Mission Data Sets maintained once they are developed?
5. How is Mission Data Set (mapping layer) information accessed by users?
6. How are Electrical and Utilities Work Center Mission Data Sets used in meeting mission requirements?
7. How does use of Electrical and Utilities Work Center Mission Data Sets impact the work efficiency within the work centers?

*Methodology*

The research questions will be answered by utilizing a multi-case study design that entails interviews and observations of personnel within four different Electrical and Utilities Work Centers that have designed, implemented, and use Mission Data Sets. At each location, approximately five personnel will be interviewed to obtain answers to the research questions.

Upon completion of the interviews, pattern matching will be used to determine answers to the research questions.  Interview data will be compared with Air Force, MAJCOM, and organization's memos, correspondence, operational instructions, directives, and other documents relating to GeoBase Mission Data Sets implementation and usage.  Additionally, research observations will also be used in order to triangulate research findings.

### *Benefits/Implications of Research*

This research will provide insight as to issues associated with the design, implementation, and usage of Mission Data Sets within the Electrical and Utilities Work Centers.  Additionally, these insights can provide an implementation framework and solid foundation for not only other Civil Engineer Electrical and Utilities Work Centers to use in the design and implementation of their own Mission Data Sets but other Civil Engineer Work Centers and other base organizations that are in the process of Mission Data Set design and implementation.  Finally, the research can provide insight as to potential benefits of using GeoBase/Mission Data Sets in the accomplishment of daily operations.

### *Thesis Overview*

This thesis includes five chapters along with additional supporting information located in the Appendixes.  Within the second chapter, the literature review will examine how the civilian Geographic Information Systems has evolved into the Air Force's GeoBase program.  The third chapter will discuss the case study methodology and its application to this research, along with how the data will be collected and analyzed using a triangulation approach. Using the research questions as a guide, the results of the case study will be presented in the fourth chapter. In chapter five, the results will be discussed in detail along with inferences that can be drawn. Possible limitations and ideas for additional and follow up research will also be presented. Finally, references and appendices will conclude the study.

# II. Literature Review

An investigation of GeoBase Mission Data Set design and implementation issues must be explored by using the civilian Geographical Information Systems (GIS) as a reference. This exploration will begin with a discussion of Information Systems (IS) and IS implementation within an organization as IS is at the very heart of GIS. The discussion will then address the Systems Development Life Cycle (SDLC) and how it applies to IS implementation. Next, the concept of geographic/geospatial information system, upon which GeoBase is founded, will be discussed. Industry standards for GIS programs will also be discussed as they relate to the GeoBase program. GIS implementation will be discussed as it establishes a framework for how the GeoBase program is introduced into the organization. As part of the research is to determine how GeoBase is used, GIS applications and usage will also be discussed. Finally, an examination of the specific Air Force GeoBase program – its components and standards– will be provided.

### *Information Systems Literature as a Foundation*

"An information system (IS) is a system designed to collect, store, manipulate and analyze information and then use the information for the purpose that it was collected" (Pittman, 1990, p. 4). As the IS discipline has been around for 30+ years, there is a large body of literature that discusses the myriad of issues concerning IS. Because this thesis research focuses on GIS – simply another type of IS – the IS literature provides than excellent foundation for this work. We begin with the literature concerning IS implementation. Implementing an IS can be described as an effort to distribute a system throughout an institution (Kwon and Zmud, 1987). As when any new system is introduced into a work center, there are key issues and concerns must be considered so that a successful implementation can take place. Empirical research on information system implementation has shown that certain managerial, organizational, and individual issues should be considered if the implementation is to be successful. The managerial issues relate to the support that senior leadership within the organization places upon the IS. Kwon, et al., (1987) state that the value that management places upon the system directly affects implementation success. Organizational attitude toward and reception of IS implementation must also be considered and is probably one of the most important factors to address (Kwon, et al., 1987). Research suggests that by engaging the organization's informal network – those with unofficial power – to assist with IS implementation, as well as educating the organization regarding the IS benefits can improve implementation success (Hipkin, 2001). The individual perspective must also be addressed as the user is most affected by the IS implementation. To overcome the individual apprehension, those affected by the change should also be involved in the implementation schema, thereby achieving "buy-in" at all levels (Chapman, 2002).

*Systems Development Life Cycle*

The Systems Development Life Cycle (SDLC) is a model for reducing complex processes into a simpler system of smaller segments, phases, or activities (Necco, Gordon, and Tsai, 1987). SDLC is widely used as a methodology to examine the specifics of a system's development, design, and implementation. In realizing that the classic problems of systems development – cost overruns, dissatisfied customers, and schedules that are not met – are manifested to some degree in every project, management has turned to the SDLC model to aid in achieving success in completing projects (Gordon, Necco, and Tsai, 1987). The phases within the model (see Figure 1) provide a logical sequence for planning a new system from inception to maintenance. Each phase sets the foundation for the next and helps guide the new system to reach maturity (Hoffer, George, and Valacich, 2002).

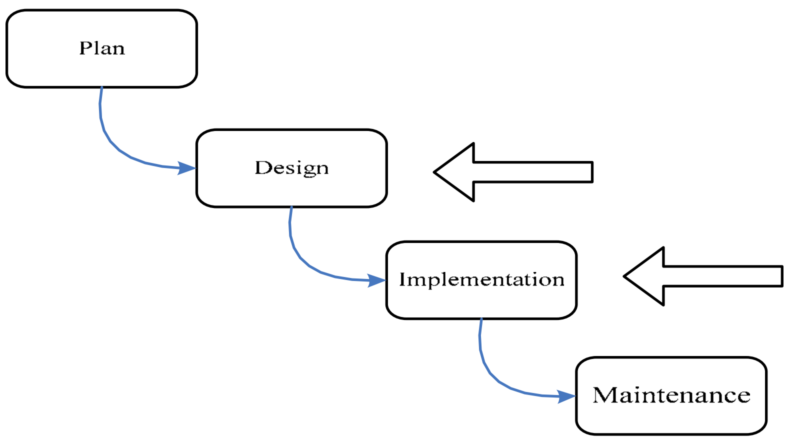



*Figure 1. Systems Development Life Cycle*
*(Adapted from Hoffer, George, and Valacich, 2002)*

Within the first phase, Plan, the organization determines its need regarding the system that is to be developed (Hoffer, et al., 2002). A basic outline and structure of the new system must be decided and it is within this planning phase that the organization must determine how the final product will function. The actual design of the system components, hardware and software, are not decided in this phase, but rather determining if what is currently in use will be sufficient. The focus should be on the end result rather than the actual solution.

It is in the Design Phase in which the system planners determine how the system will operate (Hoffer, et al., 2002). "During the design, you and the other analysts convert the description of the recommended alternative solution into logical and then physical system specifications. …The part of the design process that is independent of any specific hardware or software is referred to as **logical design**" (Hoffer, et al., 2002, pg. 21). Hoffer, et al., continues that **physical design** is when "you design the various parts of the system to perform the physical operations necessary to facilitate data capture, processing, and information output" (Hoffer, et al., 2002, pg. 21).

The purpose of the SDLC Implementation Phase "is to convert the physical system specifications into working and reliable software and hardware, document the work that has been done, and provide help for current and future users and caretakers of the system" (Hoffer, et al., pg. 571). It is within this phase that users can access and begin using the new system. Implementation is not a single instance event but rather an ongoing process as user support must continue throughout the system's complete life cycle.

In the final phase, maintenance, updates and upgrades to the system take place. The focus in not on the data that is used within the system but rather on the backbone and architecture of the system (Hoffer, et al., 2002). The maintenance is necessary as improvements are made that keep the system operating. Inputs from the users must be collected and evaluated for inclusion in updating the system. How well the system was planned, designed, and implemented lead to the level of maintenance that required. While no system is perfect, if the previous phases are well thought through then the maintenance of the system should be minimal.

All phases of the SDLC are important to the GeoBase program as GeoBase is a system that has been put into place across the Air Force. Direction has been given that all installations are to have a GeoBase program (Plan); little guidance has been given regarding how to establish the program (Design and Implement). Maintenance of the GeoBase program logically can only follow after the MDS have been designed and implemented. This research project focuses on the design and implementation phases, as it is within these two phases that the research and investigative questions can be answered.

*Geographic Information Systems*

As stated in Chapter I, the GeoBase program is founded upon the use of private sector geographic information system (GIS) technology. Pittman (1990) defines GIS by stating that the difference between IS and GIS is that the GIS uses an x – y type coordinate and that mapping capabilities are imbedded within the system. Heikkila (1998) adds the Environmental Systems Research Institute's (ESRI) 1990 definition that "GIS is an organized collection of computer hardware, software, geographical data and personnel designed to efficiently capture, store, update, manipulate, analyze and display all forms of geographically referenced materials" (p. 351). Another feature of GIS is that any information that can be stored on a paper-based map can be stored in the system (Korte, 2001). GIS is capable of not only storing the data, but can display the map along with detailed information regarding the numerous features that may be stored within the system (Korte, 2001).

GIS is the marriage of computerized mapping and the storage of the data in a relational database resulting in an interactive computer system (Robison, 1988). Denning (1993) defines GIS as a combination of a computer-aided design (CAD) system with that of a database system resulting in a system that has more analytical capabilities than if each were used separately. GISs were first developed in the 1960s for the Canadian forestry department as a means to analyze spatial data that represented the earth's geography (Korte, 2001). GISs use a database in which to store the information, a computer monitor to see the data, and a plotter (oversized paper printer) to print maps and data. To do so, GIS uses a spatially referenced database that employs latitude and longitude coordinates associated with mapping capabilities (Pittman, 1990).

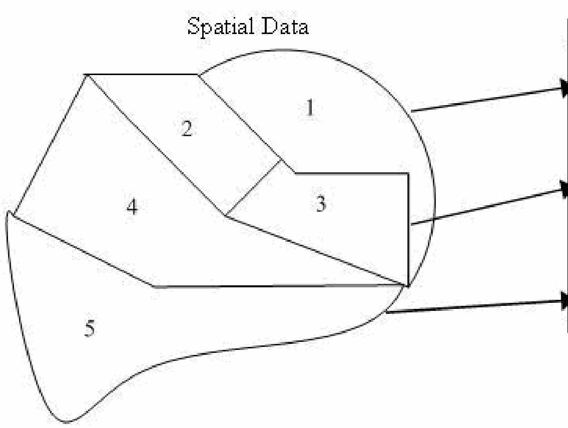
GIS hardware is nothing more than the current computer technology that is used by an organization. Initially, only the large governmental agencies, utility companies, and corporations were able to afford the extreme price of using GIS, as GIS relied upon mainframe, minicomputers, and proprietary software suites in order to effectively store and analyze the data (Korte, 2001). While GIS hardware changes involve speed and storage capabilities, the software, however, is constantly evolving in the capabilities to store and retrieve data.

Computer-aided design (CAD) systems were the first, though very rudimentary, electronic geographic information systems. They were developed from computer cartography (map making) as a tool that engineers and architects could use (Pittman, 1990). The underlying imagery was based on aerial photography and satellite imagery. Additionally, CAD systems were based upon a fixed-line reference and did not contain geo- or spatial data thus preventing them from being true mapping systems (Pittman, 1990). It was for this reason that more robust GIS programs were developed.

The earliest versions of GIS relied solely on key punch cards in order to not only store data, but to execute the programs which limited the computational power to a few hundred thousand instructions per second (Foresman, 1998). The output was also limited in that printed images were forced to be plotted on character-based printers (Foresman, 1998). Those using the early versions of GIS were severely limited in what they could do and how they could do it, but as computer technology – the backbone of GIS – grew, so did the GIS capabilities. As word spread of the capabilities of GIS and with the advent of the personal computer and local networks, GIS became more affordable (Korte, 2001). Additionally, industry developed numerous software packages that not only aided the end-user in analyzing the spatial data, but also in accessing data that had already been compiled (West, 2000).

*GIS Features*

Within GIS, features such as hills, valleys, buildings, roadways, etc., are stored as spatial data along with associated attributes in a point, line, or polygon format (Gilbrook, 1999). By using this data in this format, all manner of spatial analysis can be completed as once was done by hand, but with greater speed and accuracy (Gilbrook, 1999). The spatial database is the most prevalent component of a GIS as the data are stored in relational data tables that contain all of the information relating to the spatial location of each record. Additionally, the data can be displayed on maps and the records can be selected based upon their spatial location (West, 2000). As shown in Figure 2, the spatial data or mapping features, relate directly to the attribute data table that houses the relevant information of the particular spatial point. The spatial data may be a polygon that shows the base boundary, a line showing water supply, or a point that is an electrical transformer. The attribute table holds those identifying features that further define the object. For example, if the spatial data element is a transformer, the attribute data may list the manufacturer, model, serial number, voltage in, voltage out, etc. The attributes are tied to the object through a 1:1 relational database (West, 2000). GIS, with the spatial and attribute data, can reduce a tremendous amount of information for a particular area and divide the information into numerous data files and then relate them together in a large flawless, single map file (Korte, 2001). This single map file is the foundation for GIS usage.




Attribute Data

| Location | Nomenclature | Size | Notes |
|---|---|---|---|
| 1 | Wetland_Natural_in_acres | 18 | River_bottom_rocky |
| 2 | | | |
| 3 | Preserve_game_in_acres | 15 | Hunting_not_permited |
| 4 | | | |
| 5 | Boundary_natural_acres | 25 | Undeveloped_wildland_not_accessible |

Sample Data

*Figure 2. Spatial and Attribute Data*
*(adapted from West, 2000)*

*GIS Usage*

The use of the spatial database and multiple mapping layers have led to numerous commercial and government applications and usage that has included analyzing land features and information, as well as infrastructure management for roadways, utilities, etc. (Korte, 2001). Planners and engineers are able to overlay specific information and layers that are applicable to the area of interest to determine the best usage for that area (Pittman, 1990). The planners and engineers are able to "see" what features are at the location that has been selected for development as well as the infrastructure that may or may not be present (Fung and Remsen, 1997).

In addition to planning, GIS can be used for predictive modeling in which "what-if" scenarios can be examined based upon spatial data and by overlaying the base-level map with various informational mapping layers such as environmental, political, or demographic considerations (Fung, et al., 1997). All these layers enable the planner or engineer to explore "what-if" scenarios and determine the impact that a proposed system (building, roadway, utility, etc.) may have on the location (Fung, et al., 1990). Predictive modeling can also be used for environmental impact analysis, site suitability, and proposed land use development. The National Environmental Policy Act (NEPA) has mandated that environmental impact analyses be conducted prior to any construction in which the federal government may be involved in any capacity (Gilbrook, 1999). Due to the complexity of the environmental impact analysis, many companies must contract out such studies to architectural and engineering (A&E) firms to analyze vast amounts of relevant data and these A&E firms use GIS to analyze the spatial data (Gilbrook, 1999).

*GIS Implementation Issues*

As GeoBase is founded upon GIS, discussion of GIS implementation issues helps identify potential problem areas that Air Force Civil Engineer units must consider. As stated previously, GeoBase is an information system and as such, "… designers should start with a clear sense of and respect of the tasks that end-users will be doing, and then design a system that best supports those tasks (Nardi as cited in West, 2000, p. 14).

As with implementing any information system, the organization must address the same issues when implementing a GIS – managerial, organizational, and individual. A manager cannot merely state that the organization will adopt a GIS program and expect the program to succeed; quite the contrary, the implementation must be phased in over time (Innes, 1993). The manager must be committed, involved, and coordinate the implementation effort (Cooper and Zmud, 1990). For organizations desiring to implement a new GIS program (where one did not exist before) or modifying an existing program, a champion, someone committed to the GIS program, must be its strongest advocate "selling" the benefits not only to the end-users, but senior management as well (Nasirin and Birks, 2002). In addition to selling changes or modifications, this champion who may very well be an end-user or senior manager, must establish a plan geared toward the successful implementation of the program (Nasirin, et al., 2002).

An organizational consideration that must be addressed when implementing a GIS is which GIS software package/suite the organization will use. While most software suites will allow data to be imported from other formats, organizations must still be cognizant of the features, capabilities, and/or limitations of the software of choice. Organizations should consider how the software would impact the organizational culture if a software change is made. If an organization wishes to change from one software suite to another, resistance may be encountered not only from the end-user but from senior management as well. The age-old axiom of "if it isn't broke, don't fix it" mentality can invariably be a hindrance to successful GIS implementation.

Successful implementation must also include the end user of the GIS. It is the individuals that comprise the organizational make up and must be “won over” to accept the new system. The champion can assist individuals in accepting the new GIS system by engaging the individuals in the implementation process. Research has shown that the more committed to the system the managerial levels are, the more readily subordinates will accept the system (Nasirin, et al., 2003). Additionally, as users gain confidence in the system, resistance to change is further diminished.

*GIS Data Standards*

As stated earlier, a GIS is a mapping system that is derived from the joining of CAD and database programs (Denning, 1993). For the database to be effective, a set of data standards must be developed that will not only aid in feature identification, but permit the sharing of data and information among different users (Heikkila, 1998). The standards should be written in a metadata format which describes the characteristics and attributes of the data (Mangan, 1995). The standards are the set definitions and terminology used in the documentation of the geospatial data. While metadata standards are not intended to state how the data are transmitted, the standards do lay a foundation for how the data is to be stored and made available to the end-user (Mangan, 1995). Even with these guidelines, inconsistencies between the commercial software exist in data naming conventions and how the data is linked between the data tables.

Previously, numerous GIS software developers had devised their own data formats that were unique to their own data storage. Early on industry leaders had no desire to share trade secrets regarding the data coding, for fear of loosing market shares, even though the end-users desired a consistent format (Heikkila, 1998). The data was in one format in software A, while software B may have a different format. With the advent of the Internet, more and more governmental agencies, private sector organizations, and companies make their GIS data available to even more users (Gilbrook, 1999). With the various standards used by different organizations, based on the software used, other users had a difficult time in accessing the data and performing the needed spatial analyses unless a middleware solution was purchased (Goldstein, 1997). Many companies and organizations have realized that there needs to be a set standard for all geospatial data and that these standards were applicable to GIS software developers as well as users. Seeing this need, the Federal Government intervened.

In 1990, the Office of Management and Budget formed the Federal Geographic Data Committee (FGDC) to oversee the development, sharing, and use of geospatial data among various federal agencies including the Department of Defense (Mangan, 1995). The FGDC authored the "Content Standard for Spatial Metadata" (CSSM) that became the initial standard for all geospatial data within the federal government (Heikkila, 1998). The purpose of the FGDC standard was to provide a consistent format of naming conventions and relational data tables that all public and private entities could access electronically as well as establishing the layout for their own specific geospatial data (Mangan, 1995).

The FGDC further defined the CSSM standards as the military service components were developing digital mapping and state and local governments were embracing the CSSM standards (Korte, 2001). The DOD, working with the FGDC, stood up the Tri-Services CADD/GIS Technology Center in response to many concerns that were raised regarding CSSM (Foresman, 1998). The GIS Technology Center developed the Tri-Services Spatial Data Standards (TSSDS) that would be applicable to the service branches and contain a data dictionary and a common standard and symbology schema (Foresman, 1998). The TSSDS evolved and grew into the Spatial Data Standards for Facilities, Infrastructure, Environment (SDSFIE) (Korte, 2001). The SDSFIE standards were designed to be used with all the major commercial of the shelf (COTS) GIS software suites such as ESRI ArcInfo and ArcView, as well as AutoDesk's AutoCAD, AutoMap, and AutoWorld (Korte, 2001).

*GIS and the Air Force*

As stated in Chapter I, GeoBase is an Air Force program that uses the same geographic information systems used by the private and public sectors. As the GeoBase Office of Primary Responsibility (OPR), the AF Office of the Civil Engineer has put forth directives outlining the fundamental requirements for the establishment of base-level GeoBase programs. The directives are contained in the *USAF Garrison Mapping Concept of Operations Version 2.0* (CONOPS) dated June 2003 and in the *FY02 USAF GeoBase Strategic Plan* dated January 2002. These documents form the policy and directives foundation for the entire Air Force GeoBase program.

*AF GeoBase Program*

GeoBase was developed from the need to reduce waste and redundant mapping processes that were rampant within the Air Force (HAF/ILE, 2003b). Anecdotal evidence showed that it was not uncommon for one organization to purchase an aerial map of a base, while another organization did likewise with neither knowing that the other had contracted for a photo. To overcome this systemic problem, Major Commands

(MAJCOM) and Field Operating Agencies (FOA) were directed to share processes and procedures among themselves, their subordinate bases, and with the Headquarters Air Force (HAF) GeoIntegration Office (GIO) to help alleviate the redundancy in GeoBase program creation (HAF/ILE, 2002).

The mission of the GeoBase program is to “attain, maintain and sustain one geospatial infostructure supporting all installation requirements” (Cullis, 2003, p. 1). Personnel, processes, and resources comprise the infostructure that are necessary to the collection, analysis, and displaying of the geospatial data that are used to support the installation’s mission (Cullis, 2003). The GeoBase program provides in-garrison bases with mission specific geospatial information (Handy, 2001). GeoBase is USAF’s implementation of GIS in a complete and unified manner that is based upon a vision that is succinct and to the point: “one installation, one map.”

There are three components that comprise the complete USAF GeoBase program (see Figure 3). These components support decisions that need to be made regarding installations, both at home base and at forward operating locations (FOL) (HAF/ILE, 2003b). Strategic GeoBase provides senior-level decision makers within the USAF, Department of Defense (DoD), and other Federal agencies, access to generalized installation information. Expeditionary GeoBase/GeoReach is used by senior planners to effectively preplan FOLs based upon contingency requirements. Garrison GeoBase focuses the mapping and data layers at fixed and established Air Force bases. The USAF Garrison Concept of Operations (CONOPS) defines the Garrison GeoBase “vision, mission, capabilities, requirements, effects, and operations” (HAF/ILE, 2003b, p. 1). The focus of this research project is on Garrison GeoBase.

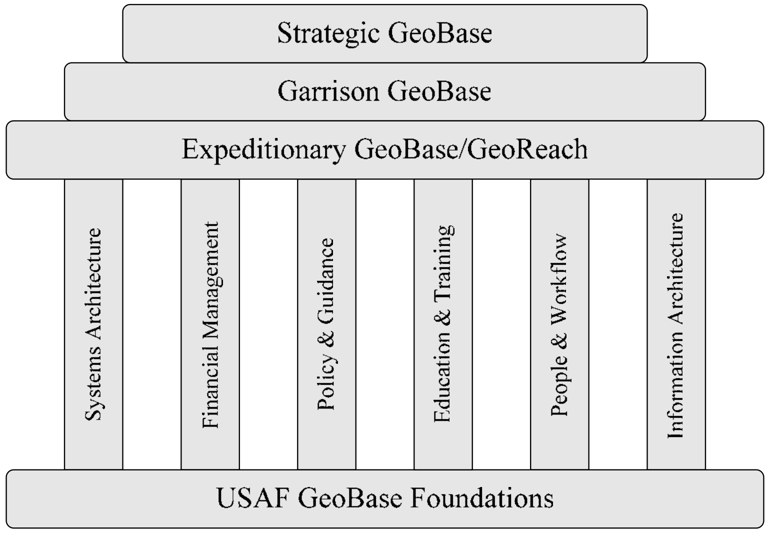



*Figure 3. USAF GeoBase Program*
*(adapted from https://www.il.hq.af.mil/geobase 2004)*

*GeoBase Capabilities*

The GeoBase program focus is geared more toward the managing of geospatial information rather than the developing or acquiring information technology (IT). While it is not possible to have a GeoBase program without the use of IT, a successful GeoBase program is one that can exploit the in place IT infrastructure without redundancy in hardware and/or software (HAF/ILE, 2003b). The GeoBase IT backbone uses a combination of base networks, global positioning system, and computer hardware and software components. GeoBase is not designed to incorporate all base features (facilities, roadways, infrastructure, etc.) into a single database. The GeoBase program software is designed to link all components, features, and attributes together in a virtual database for ease of access necessary to visualize the footprint of the installation and the features and attributes of the various components.

*Common Installation Picture*

The Common Installation Picture (CIP) is a high-resolution base map that forms the foundation layer for all GeoBase programs and typically includes all visible assets (facilities, roadways, airfield, etc.) that can be used for reference. The CIP may be generated from aerial photography or from satellite imagery (HAF/ILE, 2003b). While not directly specified, the recommended standard resolution for the CIP is one-meter (HAF/ILE, 2002). The CIP uses geographic features such as points, lines, and areas, as a representation of base's footprint and the area immediately surrounding the base. These points, lines, and areas are then joined together into an integrated map (see Figure 4). While the CIP is not designed to house the data and the different features and their attributes, COTS and GIS database programs should link the CIP MDS and give the user geospatially accurate and relevant data.

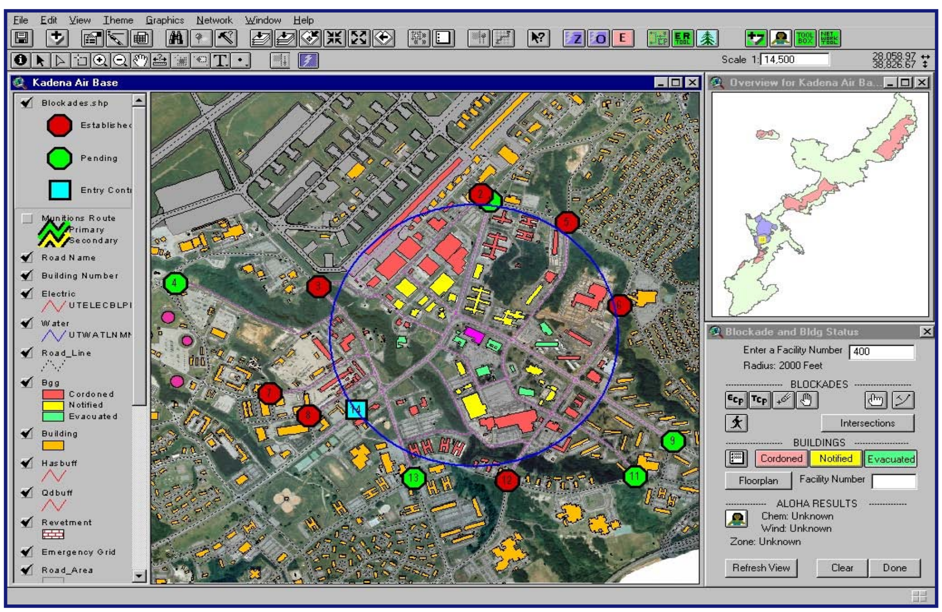



*Figure 4. Integrated Map*
*(https://www.il.hq.af.mil/geobase, 2003)*

*Mission Data Sets*

The Mission Data Sets (MDS) comprise the various geospatial data map layers that represent the elements (water, sewer, electrical, safety zones, etc.) that the functional organizations have determined are necessary to support their specific mission or processes (HAF/ILE 2003b). It is in the MDS that the attributes of the features are maintained. A data steward is appointed to be responsible for the organization's or work center's specific MDS ensuring accuracy and relevance of the MDS data (HAF/ILE, 2003a). The MDS are not components of the CIP but rather the map layers that are used in conjunction with the CIP to present a fused installation picture (see Figure 5).

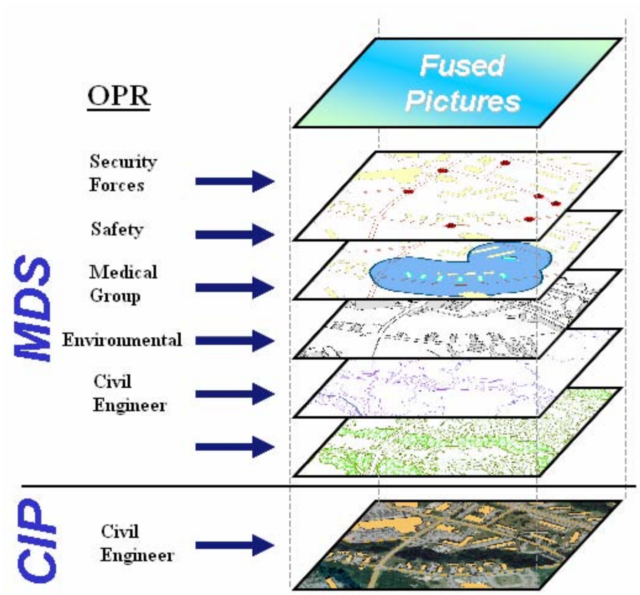



*Figure 5. The Common Installation Picture and Mission Data Sets (HAF/ILE, 2003b, p. 7)*

*GeoBase Implementation*

The *USAF GeoBase Policy Memo* dated 7 Oct 2002 (Zettler, 2002), states that all units, from Major Commands (MAJCOM) to the individual unit level organization, should use the CONOPS to establish a GeoBase program (HAF/ILE, 2003b). The

CONOPS forms the foundation of the GeoBase program and outlines GeoBase implementation for all MAJCOMs, Direct Reporting Units (DRU), and Field Operating Agencies (FOA), which have installation management responsibility (HAF/ILE, 2003b). While the CONOPS are directives, they are general in nature and leave some room for individual interpretation by the individual organizations. Much latitude is given regarding the software and/or hardware used, how data is validated, and where in the organization the GIS office should be located. The only direct guidance stated is that the CIP and MDS shall follow the SDSFIE for naming, features, and attributes. Listed within the CONOPS are DoD Directives, Air Force Instructions, and Air Force Pamphlets that further describe GeoBase operations, policy, and requirements. The actual MDS design and implementation is delegated downward to the MAJCOMs, DRUs, and FOAs which opens the potential for varying interpretations and base-level program development.

### *Summary of Literature Review*

This chapter discussed the USAF GeoBase program as it relates to the civilian Geographical Information Systems (GIS). The discussion began with a discussion of information systems and the IS implementation literature. Next, the Systems Development Life Cycle was discussed as it relates to GeoBase development and this specific research. GIS implementation within an organization was also discussed as the processes established a framework for GeoBase introduction. GIS applications were then discussed as a portion of the research relates to GeoBase usage. Finally, the Air Force' GeoBase program to include its components, and standards, was examined.

# III. Methodology

This chapter describes the research methods used explore the design, implementation, and usage of Mission Data Sets within Civil Engineer Electrical and Utilities Work Centers. The methodology used is one geared toward the research questions in an attempt to understand the particular phenomenon, which is being studied (Leedy and Ormrod, 2001). As such, this research project will employ a multiple case study methodology to answer the research and investigative questions. The following paragraphs will describe the rational for choosing the methodology as well as the specifics about the methodology that will be employed.

### *Rationale for Choosing Qualitative Research*

At the very basic level, quantitative research is used when exploring the relationships between measured variables in an attempt to explain, predict, or control phenomena (Leedy, et al., 2001). Additionally, quantitative research attempts to either prove or disprove hypotheses that are under study. Conversely, qualitative research attempts to answer questions relating to the complexity of a phenomenon using the participant's point of view as the basis for explaining or understanding the events (Leedy, et al., 2001). Finally, qualitative research may end with hypotheses generated or tentative answers relating to the phenomena under study. The qualitative research methodology is used in many disciplines in an attempt to determine and explain what has happened or is happening. This methodology is most advantageous when researching a phenomenon in all its complexity and within its natural setting (Leedy, et al., 2001).

*Leedy and Ormrod's Criteria for Selecting Methodology*

In determining the appropriate methodology to use in this research project, the first question that had to be answered was 'is this research qualitative or quantitative in nature?' Using Leedy and Ormrod's (2001) table, (see Table 1), as a foundation for making this determination, there are five general questions that can be used to determine if the research is quantitative or qualitative in nature.

*Table 1. Selection of Methodological Approach*

| *Question:* | *Quantitative* | *Qualitative:* |
|---|---|---|
| What is the purpose of the research? | • To explain and predict<br>• To confirm and validate<br>• To test theory | • To describe and explain<br>• To explore and interpret<br>• To build theory |
| What is the nature of the research process? | • Focused<br>• Known variables<br>• Established guidelines<br>• Static design<br>• Context-free<br>• Detached View | • Holistic<br>• Unknown variables<br>• Flexible guidelines<br>• Emergent design<br>• Context-bound<br>• Personal view |
| What are the methods of data collection? | • Representative, large sample<br>• Standardized instruments | • Informative, small sample<br>• Observations, interviews |
| What is the form of reasoning used in analysis? | • Deductive analysis | • Inductive analysis |
| How are findings communicated? | • Numbers<br>• Statistics, aggregated data<br>• Formal voice, scientific style | • Words<br>• Narratives, individual quotes<br>• Personal voice, literary style |

The first question relates to the purpose of the research. Quantitative researchers attempt to explain what is happening and to predict future events based upon testing theory. The qualitative researcher, instead, attempts to build theory through the exploration and interpretation of the data. By investigating the design and implementation issues relating to GeoBase Mission Data Set creation and usage, this research is attempting to explain "how" and "why" the particular processes were used at these four case locations. As this research explores the processes, it meets the criteria for qualitative research.

The second question addresses the nature of the research process. The process or series of actions of quantitative research are very rigid and exact in nature while qualitative research is more flexible and adaptable. By being flexible and adaptable, the researcher can modify the data collection techniques to allow for information that was not anticipated and therefore able to provide a holistic view of the topic. Interviews and observations are the most frequently used data collection methods for qualitative process; both will be used in determining the processes that Electrical and Utilities Work Centers have used to develop Mission Data Sets. As the design and implementation processes vary from location to location or even person to person, the researcher must be able to adapt and modify the data collection techniques. As it is not possible to anticipate every possible data collection variable, the researcher must be able to adapt the data collection to achieve the greatest result based upon uncertain and uncontrollable events. Based upon these uncertain and uncontrollable events, the criterion for qualitative research is met.

The third question addresses the methods of data collection. A quantitative study will generally examine a large representative sample of the population and will also use standardized data collection instruments that have been created for the study. Qualitative data collection methods, instead, do not focus on standardized data collection instruments as the researcher is sometimes referred to as the research instrument (Leedy, et al., 2001). The research can be completed using a small sample of interviewees who have a personal knowledge of the phenomenon being studied. As there are only a few individuals at each base who are involved in Mission Data Set design and implementation, the qualitative approach is appropriate.

The fourth question addresses type of analysis, deductive or inductive reasoning, that will be employed in the research. In quantitative research, deductive reasoning is used as the research begins with a hypothesis or theory and then, based upon the data, draws logical conclusions. The qualitative researcher, however, makes observations in collecting the data and then draws inferences regarding the data using inductive reasoning. As inductive reasoning is used, the research is qualitative.

The final question addresses how the research findings will be communicated to the audience. Regardless of the research, all findings are reported in written form, with the composition being the difference. The quantitative report will reference numbers, statistics, and be very formal and scientific in nature while the qualitative report is more narrative or literary in style attempting to capture the entire essence of the phenomenon. As the research focuses on processes, there are no statistical values that can be used to explain how Mission Data Sets are designed and implemented the research is qualitative.

By using these questions to determine the proper research approach, the qualitative methodology is the obvious choice. Leedy, et al., (2001) point out that research studies are enhanced by combining both qualitative and quantitative research approaches. This study, though not designed to be quantitative, may use some quantitative data that may enhance the qualitative data analysis.

*Research Design*

Having determined that a qualitative study is appropriate, the methodology for the study must now be addressed. Leedy, et al., (2001) and Creswell (1994) describe several qualitative research designs that might be applicable to this study; each type was examined for applicability. The designs described are ethnography, grounded theory, phenomenological, case study, and content analysis. As ethnography is based upon a longitudinal study in which the culture is examined, this design is not appropriate for the study at hand. Although individual perspectives – interviews – will be used to gather the data, the phenomenological methodology, which explores personal experiences as they relate to a specific event, will not be used. Finally, content analysis will not be the overarching research design, but rather a portion of the methodological process.

The final qualitative design recommended is case study and has been chosen as most suited for this study. The case study design focuses on the "individual(s), program(s), or event(s) on which the investigation is focused" (Leedy, et al., 2001, p. 149). Additionally, Yin (2003) states that "The essence of a case study…is that it tries to illuminate a decision or set of decisions: why they were taken, how they were implemented, and with what result" (p. 12). As this research is focused on the processes involved in the design and implementation of Mission Data Sets within the Electrical and Utilities Work Centers, the case study methodology is chosen as the most appropriate.

*Rationale for Choosing Case Research*

Voss, Tsikriktsis, and Frohlich, (2002) points out that there are several strengths in using case research:

(1) The phenomenon can be studied in its natural setting and meaningful, relevant theory generated from the understanding gained through observing actual practice.

(2) The case method allows the questions of why, what and how, to be answered with a relatively full understanding of the nature and complexity of the complete phenomenon.

(3) The case method lends itself to early, exploratory investigations where the variables are still unknown and the phenomenon not at all understood. (p. 197)

Finally, Leedy, et al. (2001) state that the case study is "…especially suitable for learning more about a little known or poorly understood situation" (p. 149). As GeoBase Mission Data Set design is still not populated at all bases and there is still much confusion as to the processes, the case study approach is the dynamic medium to answer the research questions.

*Case Study Design*

The research design is the plan that is used to explore the research questions and is the structure for all procedures that the research will follow in answering the question (Leedy, et al., 2001). It has been determined that a qualitative methodology consisting of a case study strategy is warranted for this research project. Yin (2003) lists five components of research design that are essential for conducting a case study: the study's questions; its propositions; its unit(s) of analysis; the logic linking the data to the propositions; and criteria for interpreting the findings. Each component will be addressed below.

*Study questions*

In the first chapter, the following research questions were put forth as the central focus of the research:

1. How were Electrical and Utilities Work Centers' Mission Data Sets created?
2. How did the Electrical and Utilities Work Centers determine what data elements to put within the Mission Data Set?
3. How was hardware/software used to capture these Mission Data Sets?
4. How is the information quality (e.g. accuracy, currency) of these Mission Data Sets maintained once they are developed?
5. How is Mission Data Set (mapping layer) information accessed by users?
6. How are Electrical and Utilities Work Center Mission Data Sets used in meeting mission requirements?
7. How does use of Electrical and Utilities Work Center Mission Data Sets impact the work efficiency within the work centers?

The "how" questions explore the processes that are used at the case study sites and are at the very heart of this project. Nevertheless, these "how" questions do not point to what is to be studied, they point to where to look for relevant information as discussed below.

*Study Proposition*

Yin (2003) states that "how" questions are explanatory – focusing on processes – in nature and capture the essence of what is of interest. These "how" questions also force the determination of study propositions that are used to guide the researcher in the right direction and are the fundamental reason for conducting the research. The proposition for this research project is that there is something to learn by investigating the design and implementation of the Electrical and Utilities Mission Data Sets as well as the impact of such across Electrical and Utilities Work Centers at different case locations.

*Case Selection*

As it has been determined that an explanatory case study methodology and design strategy is fitting for this research project, the next determination must be as to whether to conduct a single- or multiple- case study approach. Each approach has its own unique characteristics as it applies to the case study design. A single case study design should be used when there is only a single instance of a phenomenon that is unique, representative of commonplace events, a previously inaccessible event, or can be conducted in a longitudinal study (Yin, 2003). Conversely, the multiple case study design should be use when there is the possibility of replication between cases, or each case may be contradictive in nature (Yin, 2003). Voss, et al., (2002) indicates that that multiple case studies have additional benefits that include external validity and guarding against observational bias.

When using the multiple-case study design, each case serves a specific purpose within the overall scope of inquiry. This purpose is to provide either literal or theoretical replication (Yin, 2003). As for literal replication, similar conclusions can be predicted between the cases and can lead to a more powerful explanation for predictable reasons. Conversely, theoretical replication can predict contrasts between the cases and can lead to a more powerful explanation for predictable reasons (Yin, 2003). As indicated in Chapter I, four Civil Engineer Squadrons' Electrical and Utilities Work Centers will be the focus of this study and as such, this study will be a multiple-case study design.

*Criteria for Selecting Cases*

As there are well over 100 Civil Engineer Squadrons within the active, guard, and reserve components, time constraints made it impossible to contact each unit individually to ascertain the robustness of their GeoBase program. When selecting the research cases, the researcher must "**purposefully** select informants (or documents or visual material) that will best answer the research questions" (Creswell, 1994, p. 148). The selection criteria for determining case locations were based upon the robustness of the GeoBase program. Selection required that the MDS had been designed and implemented and that the Electrical and Utilities Work Centers were using the MDS. Those locations that were still in the design phase or were not using MDS were determined to be inappropriate. As the researcher did not have first-hand knowledge nor anecdotal evidence to determine which bases had robust programs, guidance was solicited from AF GeoBase experts.

The case locations were not selected in a random, haphazard manner but rather with consultations with HAF, AFCESA, and MAJCOM GIOs, along with follow-up inquiries to the recommended bases (Creswell, 1994). HAF and AFCESA GIOs recommended the same MAJCOMs and bases. HAF and AFCESA GIOs had first-hand knowledge of these bases' GeoBase programs and the capabilities that each possessed. The MAJCOM GIOs were then contacted for their recommendations as to which base had a robust program. The MAJCOMs recommended the same individual bases that had been recommended by HAF and AFCESA GIOs. A dialog was established with each individual case location to confirm further the level of the specific GeoBase program. The case locations selected had completed the MDS design phase and were in various stages of implementation and usage of their respective Mission Data Sets.  Data used in this study relates design and implementation that has occurred since January 2003.

*Unit of Analysis*

The next consideration in the case design is whether the study will use either a holistic unit of analysis or embedded unit of analysis (Yin, 2003).  A holistic design is one that is global in nature, examining the entire process, with an analysis based upon this examination (Yin, 2003).  The embedded design focuses on a single group and the individual subunits that are contained within that group (Yin, 2003).  It was determined for this research project that the case be defined as the individual CE squadrons that were involved in MDS design, and the unit of analysis would be the individual Electrical and Utilities work centers.  By investigating the processes used by the individual work centers for Mission Data Set design and implementation, a holistic design would be appropriate.

*Logic Linking Data to Propositions and Criteria for Interpreting the Findings*

Yin (2003) states that linking data to propositions and criteria for interpreting the findings are the fourth and fifth components to case study research design and that “these components foreshadow the data analysis steps in case study research” (pg. 26).  In order to link the data to the propositions, pattern matching and direct observation of the processes used will be compared.  Pattern matching is where “several pieces of information … may be related to some theoretical proposition” (Yin, 2003, p. 26).  Additionally, using pattern matching, data are scrutinized for underlying themes that are characterizations of the broader case than can a single piece of information (Leedy, et al. 2001).  The researcher sought patterns with respect to Mission Data Set design and implementation processes as obtained from interviews and archival data as described later in this chapter.

*Data Collection*

Yin (2003) lists three principles of data collection that when followed can address potential problems with construct validity and reliability. The first principle is that the study uses more than one source of evidence (Yin, 2003). Forms of evidence can include interviews, documentation, and artifacts. Creating a case study database in which to store the data is Yin's next recommendation. Finally, in order to ensure the data remains above reproach, Yin advocates the use of a chain of evidence similar to that used by law enforcement. The application of each principle as it relates to this study is described below.

"A major strength of case study data collection is the opportunity to use many different sources of evidence" (Yin, 2003 p. 83). Additionally, the need for multiple sources of evidence is far greater than with any other research methodology. Creswell (1994) states that there are four distinct sources of evidence: observations, interviews, documents, and visual images. Yin (2003) adds archival records to this list and delineates observations into direct and participant observations. This case study uses direct observations and interviews. The direct observations will focus on how the feature point data is collected at the work site, how the MDS are accessed, and how the MDS are used within the work centers. The interviews used in this study will be with those personnel who have a working knowledge and experience with MDS design, implementation, or usage.

One key advantage of observations is in the flexibility that as new data is introduced the researcher can shift focus (Leedy, et al., 2001). Conversely, a disadvantage to direct observations is that the very presence of the researcher may sway and alter what is said or done. If recording devices are used, respondents might not feel comfortable in discussing the issues and video taping only shows what is happening in a single direction and may miss an important activity that is in a different direction (Leedy, et al., 2001). Additionally, note taking is also problematic in that a full and rich description of the events may not be able to be captured. These limitations should not dissuade direct observations but the list that Leedy, et al., (2001) provide can assist in making observations easier.

For this project, the researcher contacted each base and worked through a central point of contact (POC) who acted as the liaison between the researcher and those in the CE squadrons to be interviewed. Though the POC was the unit's GIO, he was able to provide put the researcher in contact with more interviewees who were able to provide insight into design and implementation issues along with how the MDS were used and the impact to the work centers. The POC arranged for GIS technicians who were not interviewed to take the researcher into the field where first-hand observations of the MDS application were witnessed. The researcher was able to employ the POC as the conduit back with the interviewees for any follow up questions and clarification that was needed.

When conducting the interviews, the researcher chose to use electronic media to record the interview sessions. Prior to the interviews, each respondent was provided a copy of the interview questions (see Appendix B). All interviewees were offered the option to decline having the interview recorded. A copy of the consent form is attached in Appendix C. After the interviews had been transcribed, these were returned to the respective respondent for validation and clarification. The researcher's interview notes were electronically scanned and stored with the electronic recording and electronic transcript of each interview participant. Additionally, any site visit notes were stored with the case location's master electronic file.

*Design Quality*

When determining the quality of the research design, the researcher must keep in mind that readers, reviewers, and practitioners must be able to assess the rigor of the project (Leedy, et al., 2001). As Yin (2003) points out, the research should be tested against four logical tests. These tests though mainly used for social research, are also relevant to case studies (Yin, 2003). Table 2 (Yin, 2003) discusses these four logical tests, the applicable case study tactic, and research phase in which the tactic is applied. Each test and its application to this research project are addressed below.

*Table 2. Case Study Tactics for Four Design Tests*

| Tests | Case Study Tactic | Phase of research in which tactic occurs |
|---|---|---|
| Construct validity | • Use multiple sources of evidence<br>• Establish chain of evidence<br>• Have key informants review draft case study report | data collection<br>data collection |
| Internal validity | • Do pattern-matching<br>• Do explanation-building<br>• Address rival explanations<br>• Use logic models | data analysis<br>data analysis<br>data analysis<br>data analysis |
| External validity | • Use theory in single-case studies<br>• Use replication logic in multiple-case studies | research design<br>research design |
| Reliability | • Use case study protocol<br>• Develop case study database | data collection<br>data collection |

*Construct validity*

Construct validity is gained by employing the correct operational measures for the concepts under study. In order to achieve construct validity the researcher must accurately define the variables of interest, be able to relate them to the study's objectives, and finally illustrate how the measures reflect these variables. Referencing Table 2, Yin (2003) describes three tactics that comprise construct validity for case studies; all were used in this study. The first tactic recommended is the use of multiple sources of evidence, which promulgates convergent lines of inquiry. As stated above, observations, interviews, and documentations were used to satisfy the need for multiple sources of evidence.

Establishing a chain of evidence is the second tactic that is addressed. Once the data had been collected, a method of storing the data had to be devised. A compact disc (CD) was used as a database for the evidential data so that it may be readily available for others who may wish to inspect the data in its raw form (Yin, 2003). Electronic copies of all correspondence, interviews, and other pertinent and related documents including source documentation were recorded on the CDs. The files were also separated into corresponding categories depending on the type of data. The interview transcripts were stored in the database as were scanned copies of the interview notes. The chain of evidence that Yin (2003) describes can be maintained by storing all the evidence in the database as the raw data remains intact as no one other than the researcher has access to the data. As indicated above, the source documents are also stored in the database permitting ready access to all information. By centrally locating all data, reports, and analyses together, all elements could be back traced to the original documentation and point of origin.

To satisfy the Yin's third tactic for establishing construct validity, transcripts of each interview was presented to the respective interviewee for validation and clarification. Any changes or corrections recommended by the interviewees were annotated and recorded on the transcripts.

*Internal validity*

Internal validity within a case study is the degree to which the researcher is able to draw accurate conclusions based upon the data and study design (Leedy, et al., 2001). Creswell (1994) states that internal validity is "the accuracy of the information and whether it matches reality" (p. 158). As internal validity is used for explanatory studies, the pattern matching tactic is applicable and was used in this study (Yin, 2003).

"Pattern matching is the problem of locating a specific pattern inside raw data" (Crochemore and Lecroq, 1996, p. 39) and of all the techniques for case research, the most desirable (Yin, 2003). The data are examined for underlying themes and patterns (Leedy, et al., 2001). The presence of patterns can help the case study and strengthen the internal validity (Yin, 2003).

*External Validity*

Yin (2003) states that in order for case study research to have external validity, a researcher must also employ analytical generalization in which a particular set of results can be generalized to some broader theory. Yin (2003) continues that caution must be taken in that generalization is not automatic and must be tested by using the same replication logic that underlies experiments. As this study uses the multiple-case study design methodology, it relies upon replication to create external validity, specifically literal and theoretical replication. Literal replication (allows the prediction of similar results for predictable reasons) and theoretical replication (allows for contrasting results for predictable reasons) (Yin, 2003). The following paragraphs will demonstrate how this replication was achieved.

As indicated previously, the bases that were selected for this study were suggested by HAF, AFCESA, and MAJCOM GIOs and final selection was based upon the initial dialog aimed at determining the level of MDS design, implementation, and usage, which highlighted similarities and differences as demonstrated in Table 3.

*Table 3. Case Location Selection Criteria Matrix*

| Criteria | Base A | Base B | Base C | Base D |
|---|---|---|---|---|
| **MDS Designed** | In-house & Contract | Contract | In-house | In-house |
| **Work Center Usage** | Yes | Yes | Yes | Yes |
| **Additional Applications** | Yes | Yes | Yes | Yes |
| **Implementation Guide** | In-house | In-house | Mixed | In-house |
| **MAJCOM Mission Orientation** | Support | Support | Operations | Operations |

Referring again to Table 3, the criteria, MDS design, refers to who was involved in designing and creating the MDS. In-house indicates that the design process was completed by the workers assigned to the squadron, while Contract indicates that an outside commercial establishment was hired. The criterion, Work Center Usage, identifies Electrical and Utilities work centers in which the MDS are actually used in some manner. The next criterion, Additional Applications, refers to those locations that have developed other uses for the MDS such as the Air Force Form 103 *Civil Engineer Work Clearance Request* (Digging Permit). The criterion, Implementation Guide, refers to which organization authored the guidelines for MDS design and/or implementation be it in-house, the parent MAJCOM, or Mixed (incorporating the MAJCOM implementation guide to the local level). Finally, the MAJCOM Mission Orientation (MMO) criterion identifies the mission focus of the parent MAJCOM. MAJCOMs (and organizations within them like CE) are identified as support if not directly involved in a wartime mission. For example, a supporting MAJCOM would be Air Education and Training Command or Air Force Material Command. Those MAJCOMs (and organizations within them) identified as Operations have a direct wartime mission such as Air Combat Command or Air Mobility Command.

A look at Table 3 helps demonstrate how this research design accomplishes both literal and theoretical replication. Literal replication should be evident between Base A and Base B as these bases have four of the five criteria in common as well as share aspects of the fifth criteria. As Bases C and D share four of the five criteria the same it would also be expected that a high level of literal replication would be present.

Theoretical replication should exist between the Base A and B pairing, the Base C and D pairing as there is a difference in the MAJCOM Mission Orientation, and the focus of the GeoBase program may be different. Additionally, there may be variations in the exactness of the processes used that are identified by the other criteria, as each base is a separate entity within totally different MAJCOMs. In selecting the case locations the intent was that both literal and theoretical replication would be present so that common and different processes would be evident, as well as having unique issues identified.

One final issue that must be addressed regarding the research design is that the research sponsor directed that one of the four case locations be added at the request of the sponsor. The addition of the case impacted the ability to achieve precise literal and theoretical replication, but the general intent identified by Yin (2003) was served.

*Reliability*

Leedy, et al., (2001) state that reliability is one of consistency, which is using the same processes and procedures, the same way, every time. Yin (2003) continues by saying that even if the results of the testing are different the study is still reliable if, and only if, the procedures are applied similarly and consistently. The key to ensuring that consistency is applied is that the researcher documents the procedures followed and the protocols used. This chapter on the research methodology, Appendix B Interview Questions, and the database serve as the documentation that can be used to replicate this study.

### *Summary of Methodology*

This chapter described the research methods used to explore the design, implementation, and usage of Mission Data Sets within Civil Engineer Electrical and Utilities Work Centers. The research project employed a multi-case study methodology to answer the Research and Investigative questions. The rationale for choosing this methodology was outlined by discussing the rationale for choosing a qualitative research methodology, the rationale for choosing the case study research procedures, as well as the case study design.

# IV. Results and Analysis

The review of the literature, case-study interviews, and implementation guides provided an extremely large pool of data. The focus of this chapter is to present the results of the data collection in a logical analysis based upon the research questions. Each case location will be discussed separately in relation to the investigative questions. A summary matrix is provided in Appendix D.

### *Case Location A*

For this research project, Case Location A (CLA) served as the pilot study location based upon discussions with HAF and AFCESA GIOs. CLA is located within a supporting MAJCOM as identified previously in Chapter III. The mission orientation of the parent MAJCOM is to provide the necessary tools to support a wartime mission. The population of the parent MAJCOM distinguishes it as a one of the largest commands in the Air Force.

The basic organization chart for CLA is shown in Figure 6. It should be noted that the organizational layout as discussed and depicted has been modified for simplicity. For the discussion of CLA, the discussion will focus on answers given by interviewees in the Resources and Operations Divisions.

At CLA the Chief, Information Systems Flight, oversees the GeoIntegration Office and is also the GeoBase Program Manager (GBPM). His office is located within the Resources Division and his area of responsibility includes the GeoBase program, as well as support of the CE local area network (LAN) and computer operations and support. The GIS office is comprised of military personnel, Department of the Air Force

(DAF) civilians, and contractor employees. Even though the GBPM oversees the entire GeoBase program, the GIS office does not directly report to the GBPM but falls under the direction of the Operations Division. While the GIO and GIS offices are in different divisions, the lines of responsibility for the GeoBase program are blurred. The GBPM provides support the GIS office as needed, but other than ensuring compliance with MAJCOM and Air Force directives, he has no direct supervisory control over the GIS office.

The GIS office along with the Electrical and Utilities Work Centers are located within the Operations Division. The Operations Division oversees all in-house Civil Engineer work that is completed on the installation as well as the management aspects for the base's infrastructure. The Engineering Division is responsible for all military construction (MilCon) and Simplified Acquisitions of Base Engineer Requirements (SABER) construction projects. MilCon projects are the large, congressionally-funded construction projects while SABER projects are generally funded at the local level.

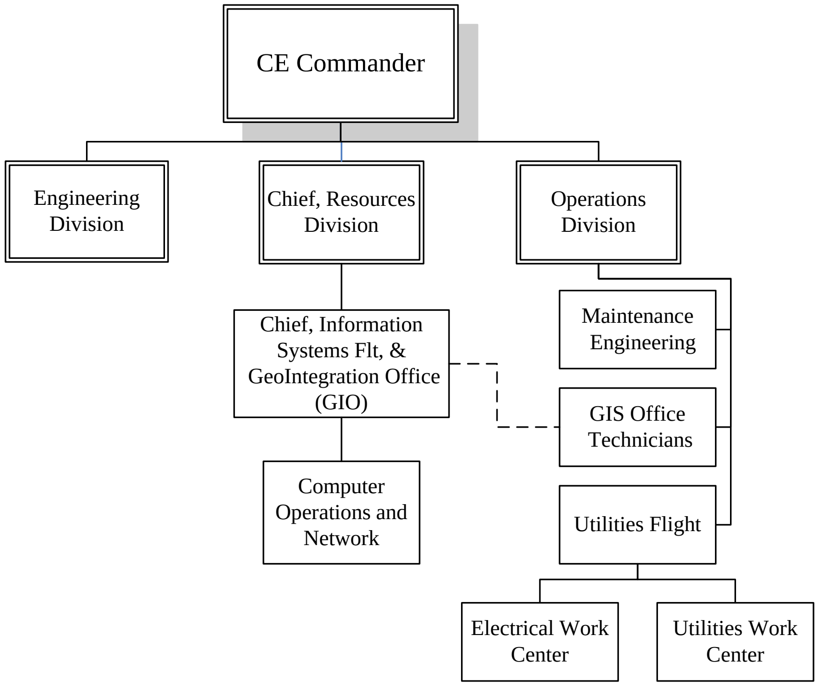



*Figure 6. Case Location A Organization Chart*

*MDS Design Issues*

Recalling from the previous chapters, Investigative Questions 1 – 3 address MDS design issues and focus on how the Electrical and Utilities Mission Data Sets at a particular location came into existence. The focus of these questions was to determine what steps and processes were employed in the Electrical and Utilities MDS design.

*MDS Design and Creation Processes and Issues*

As discussed previously, investigative question one asks, "How were Electrical and Utilities Work Centers' Mission Data Sets created?" The investigation at CLA revealed that varied steps and processes were employed in the MDS design. Recalling Table 3 from Chapter III, the MDSs were designed in a partnership with a local contractor who assisted with the scanning and digitizing of all paper- and Mylar-based electrical and utilities infrastructure drawings the organization had into AutoCAD® .dwg or .dwf files for ease of access. The new AutoCAD® files became the foundation for the creation of the MDS. After completing the map digitization, the next step was to create a separate data set database for the electrical and utilities components that was based upon and compliant with the Tri-Services Spatial Data Standards for Facilities, Infrastructure, and Environment (SDSFIE). Once the databases were created, the data sets were imported into the GIS software that was being used. At CLA, the GIO office used the Environmental Systems Research Institute (ESRI) software suites and the GIS technicians checked the data ensuring compliance with the SDSFIE standards. As a note, any reference to data is assumed to mean the electrical and utilities data sets unless otherwise indicated.

Within the AutoCAD® software, a single line on the map approximates a general location for an individual component. As such, the GIS office personnel suspected that the data might not be completely accurate as anecdotal evidence suggested that work centers had spent countless hours searching in AutoCAD® specified locations for features that were not present or in an entirely different area. They had determined that the locations, depths, and attributes of both above ground and buried components needed validation before the data could be used. The validation was necessary to identify the components and the component's locations. At CLA, it was determined that in order to ensure the accuracy, validity, and completeness of the data, an additional physical survey of the infrastructure components was necessary. It should be noted here that any reference to infrastructure, components, or infrastructure components is assumed to include any electrical and/or utility components (cables, lines, pipes, transformers, wire, etc.) unless specified otherwise. Though the above ground components could be readily identified and attributed, it was decided to let a contractor collect the underground data. The determination to use a contractor was based upon a contractor having the knowledge and dedicated work staff to locate the components. Several techniques were employed by the contractors to validate the underground infrastructure, which included the use of ground-penetrating radar (GPR), smoke, cameras, and toning. The smoke and cameras were used to follow the sewer line flow directions as well as determining where pipe junctions were located. Toning involved the use of sensing equipment for locating special metallic marking tape or the presence of a metal pipe or electrical field.

Even with using these techniques, there still were numerous questions raised regarding the actual location and component and "best guesses" made in locating the underground components as the techniques used were not able to locate completely the components. It was stated that this could be due to no tracing tape being present, the buried feature (pipe, conduit, wire, etc.) was too small to be identified by GPR, or that the piping used was made of plastic versus metal. It should be noted here that any reference to feature can be interchanged with component unless otherwise indicated. Certain assumptions relating to some components' locations had to be made, as the actual location could not be determined for the above stated reasons. As was explained for example, "We looked at the [runway and taxiway] lights and made the best approximation for underground [conduit and wiring]." His comment was in reference to the airfield lighting, but was applicable to many other situations. By using visible or known features, such as poles, manholes, or valves, the GIS technicians drew in "point-to-point" lines that estimated the path the underground feature probably would follow.

As the MDSs are based upon the AutoCAD® drawings and physical surveys, both the electrical and utilities MDS were loaded at the same time. As stated above, contractors located and identified the above and underground infrastructure components. The data was then returned to CE in SDSFIE standards as was specified in the contracts. This data was also loaded into the relational data tables so that all feature and attributes would reference the appropriate component.

Capturing the same type of infrastructure data after Military Construction (MilCon), Simplified Acquisition of Base Engineer Requirements (SABER) projects or in-house work orders continues to be a concern for this location. Historically, at the completion of MilCon and SABER projects, "As-Built" drawings were submitted to CE in an AutoCAD® format. The requirement now is to have these drawings submitted in a SDSFIE compliant format complete with the attributes loaded into a source file for importing into the GIS data tables. In-house work orders, those completed by the Electrical or Utilities Work Centers, do not generate new AutoCAD® drawings once the work has been completed. Rather the GIS office produces any drawings that relate to the work location and provides those drawings to the work centers for use at the work site. Once the work is completed, the work center personnel annotate changes to the infrastructure components and then return the drawings to the GIS office. The GIS office personnel then update the MDS based upon the information received from the work centers. As indicated by all interviewees, communication between the GeoIntegration Office, GIS office, work centers, etc., is the key to ensuring that the infrastructure data is available, and loaded into the database. Each office that might have inputs to the MDS communicates with the GIS office in order to ensure that the "As-Built" or redline drawings are provided as updates occur.

*Data Elements*

Investigative question two, "How did the Electrical and Utilities Work Centers determine what data elements to put within the Mission Data Set?" seeks an explanation as to how different infrastructure components were identified, labeled, and named. The foundation for identifying, labeling, and naming the components was the SDSFIE. The foundation for this identification was based upon the feature classes (poles, transformers, etc.) identified in the SDSFIE and every attempt was made to ensure all infrastructure data, both old and new, was compliant with these standards. As the SDSFIE and AutoCAD® naming features were nearly identical, incorporation of the data elements into the data set databases was relatively seamless. As indicated by the GIO, the SDSFIE identifies components by common names (pole, fire hydrant, transformer, etc.) and these common names are identical to industry naming schema (National Electric Code, Uniform Plumbing Code).

*Hardware/Software Usage*

As stated previously, investigative question three asks, "How was hardware/software used to capture these Mission Data Sets?" Initially, AutoCAD® software was used to display and print the electrical and utilities drawings. The software that CLA used is ESRI ArcGIS software suite, loaded on desktop computers, that has the capability to edit, manipulate, display, and analyze the data. CLA also used the handheld Trimble GeoXT® (a handheld Global Positioning System (GPS) and data collection unit) and the Trimble Pathfinder Pro XRS® (a backpack mounted GPS and data collection unit) and its bundled software to collect component information, specifications, and GPS coordinates. The GeoXT® and Pathfinder Pro XRS®, the primary data collection hardware, are fully compatible with the ArcGIS software suite in that the data tables are able to be synchronized and as such, facilitate the collection and update of the database without the need for a middleware solution. Both Trimble products have the capability to collect not only component's GPS coordinate points with an accuracy level of 30 cm (about one foot) or less, but also can be used to collect the component's feature and attribute data. When using the Trimble components, operators are able to enter the data using an integrated alphanumeric key pad, much like a typewriter.

*Design Summary*

MDS design and creation processes at CLA followed a logical progression that began with the digitization of existing paper-based drawings and maps. Electronic drawings that were obtained from MilCon and SABER projects were also added to the MDS. Using the ESRI ArcGIS software suite, the infrastructure data was loaded into a database that was based upon SDSFIE to ensure that the data was collected and could be presented in a format that was both standard and consistent. New and updated data were being collected using Trimble GeoXT® data collection hardware that interfaces with the ESRI ArcGIS software.

Recalling from Chapter II, the research into GeoBase follows the SDLC model. As the design phase at CLA has been discussed, the implementation phase discussion will follow. Within the implementation phase, the MDS were made available to the end-user. The implementation phase addresses maintaining the MDS data quality and how the users are able to access the MDS.

*Implementation Issues*

Investigative Questions four and five focus on how the MDS data quality is maintained and how the MDSs are made available to the end users. As the SDLC model demonstrates, after a system has been designed, it must be implemented. The implementation guide for MDS design and implementation was developed by CLA itself and was still in development during the site visit. The implementation guide was being authored for application to not only CE, but also for other organizations who would be using GeoBase on the installation. The implementation issues at CLA focused around the maintenance of the MDSs as well as how users were able to access the MDS.

*Information Quality*

Investigative question four addressed the MDS quality by asking, "How is the information quality (e.g. accuracy, currency) of these Mission Data Sets maintained once they are developed?" The GIS office at CLA used three different, yet similar, processes for maintaining the accuracy of the data. The first process was based upon the work centers using 8 ½ x 11" printed maps and making redline changes – corrections, additions, deletions – to the maps and submitting the maps to the GIS office for updates. In the second process, the GIS office personnel used a GPS unit such as the Trimble Pathfinder Pro XRS® backpack mounted data collection unit, which like the GeoXT®, has the capability to have the operator input the component's features and attributes at the work location. The component's features and/or attributes are then imported directly into the GIS software. The final process used electronic "As-Built" drawings from MilCon and SABER projects. The information is given to the GIS office in an electronic format via a compact disc (CD).

Working together, the work centers and GIS office performs quality assurance (QA) checks relating to the accuracy of the "As-Built" drawings and electronic files. The QA is performed by visiting the work location and comparing the drawings and electronic files to what is actually at the site. These checks validate the naming schema, attributes, and location of the components. If there are questions relating to a component, the GIS office will seek clarification from the contractor.

The frequency of the MDS updates follows two general rules. The first rule is that as data is returned to the GIS office, updates are made immediately in an attempt to have the most current and accurate data available. The second rule is based on the individual MDS and the need to keep the data current. Features and attributes that are constantly changing (i.e. lines) are updated as they are changed, while static features and attributes (i.e. transformers) may have updates on a monthly or longer time cycle. This latter process generally occurred in conjunction with the annual updating of the comprehensive base map collection.

Regardless of how the GIS office receives the information, or the when the updates are made, the data stewards first must validate the data. By definition, the data stewards are those who are ultimately responsible for the data and its accuracy. At CLA, the data stewards are chosen at a shop level and are identified based on their knowledge of the utility system whether it was electrical or water/sewer/gas. CLA also determined that the data steward should be at the four-letter (superintendent) level within the organization or within a certain function such as the Engineering Flight or Maintenance Engineering Office. The organization's leadership decided that by keeping the data collection outside the actual work centers, the data collection and manipulating would not become an additional duty for work center personnel. Several respondents stated that communication is crucial to the success as the data steward must be in constant contact with the work centers and the GIS office ensuring that the data is current, accurate, and relevant.

*MDS Access*

As stated previously, investigative question five asks, “How is Mission Data Set (mapping layer) information accessed by users?” Access to the data is accomplished through a web-based viewer that queries the LAN-based GeoBase server located within the CE organization. CLA uses two web viewers, which were ArcGIS viewer and Intergraph GeoMedia. Using these viewers, all base personnel who can access GeoBase via the LAN are able to “see” the basic CIP data layer. With these viewers, the user is able to zoom, pan, and ultimately print a map of the area that is needed. Both viewers have the capable of displaying the MDS as “read-only” as well as providing editing tools for those who have permissions to update the data.

The ability to selectively view is beneficial in that maps can be printed of specific locations as well as showing only those features that are needed. For example, if an Electrician needs data relating to pad-mounted transformers that are on the secondary network, he would select only those features for display.

Individual work centers or the GIS office prints maps on an almost daily basis. The printed maps are included with work orders and job orders so that the work center personnel can identify the work location as well as having a printed map of site-specific data showing all infrastructure components at that location. The printed maps are also used for validating the underground components in which the work centers make their redline annotations. Additionally, maps are printed for historical purposes. All CIP and MDSs are printed annually and stored within the CE drawing vault. This process serves as a reference to what the data was at a particular point in time. The electronic map versions, as well as the paper-based copies, serve as the foundation for the daily use of GeoBase MDS.

Currently, the shops are not able to access electronic versions of the MDS from the work site. This is because a wireless (Wi-Fi) network has not been installed on the installation, nor do the shops have portable computer hardware such as tablet or laptop computers. It was stated that if portable computers were available, the MDSs and viewing software could be installed and the work center personnel could take the computer to the field for use.

*Implementation Summary*

The MDS implementation phase involves several elements. Data is collected by using annotated maps, GPS data collection units, and electronic “As-Built” drawings. Data stewards, working in conjunction with the work centers, validate the data ensuring accuracy. Access to the MDS is accomplished by logging into the LAN and using a web-based viewer. The user is able to view the different data layers based upon individual needs and permissions set in the MDS databases. Once the layers and data have been selected, the end-user can print hard copy maps for use at a work location. The GIS Office prints other maps on an as needed basis or annually, based upon requirements and usage needs of the end-users. Currently users are not able to access the MDS from the actual work sites, as the necessary hardware components are not available.

*MDS Usage Issues*

Though not a direct aspect of the SDLC the usage of the MDS is crucial to the research. It is not enough to have the MDS available to the work centers; they must be willing to make use of the MDS. Investigative Questions six and seven address the issues surround the MDS usage from a work center's prospective.

*MDS Usage in Mission Requirements*

Investigative question six seeks to determine "How are Electrical and Utilities Mission Data Sets used in meeting mission requirements?" The work centers at CLA were in the process of incorporating the MDS into the daily operations as well as determining how the MDS could be used and if there were any additional applications, processes, or programs that could make use of the MDSs. All personnel interviewed to answers these specific questions were not assigned to either the Electrical or Utilities Work Centers and as such had a different perspective and view on how the MDS were used. As indicated above, the web-based viewer has been recently introduced and the work centers were just beginning to access the MDS using the web-based viewer. In response to questions of the level of and for what reasons the MDS access, the responses varied, among the respondents.

Of the two work centers identified for the research, the Utilities Work Center makes the most use of the MDS. Utilities, as the work center is more commonly referred to, use the MDS primarily to locate components in the event of a disruption in service to due to a line breaking. The Utilities MDS is used to locate valves that can be closed to isolate the break, as well as opening valves so that service can be rerouted around the break.

According to the personnel in the Electrical Work Center, or Electricians as they are commonly called, the main use for their MDS is in validating data that are represented on an electrical print of the electrical MDS. As stated previously, contractors validated the electrical components for the distribution grid, and as such, it was stated, the sub-stations have the most accurate information associated with the electrical MDS. The Electricians indicated that they do not use that particular MDS dataset, as the vast majority of their daily work does not involve the sub-stations; the center's workload focuses on the secondary components of the electrical distribution grid. Shop personnel indicated the MDS are not complete enough, so far, for job and work order planning as feature and attribute data is lacking. They continued while some data is present, the level of detail was not sufficient to plan the work without having to visit physically the work location to verify what components were present. The example that was related was that the MDS might indicate that a fuse is present, but it may not indicate the size or amperage of the fuse, key attributes to know if the fuse needed to be replaced.

While the Electrical and Utilities Work Centers may not use the MDS on a daily basis, these MDSs are used by other offices for various programs and processes throughout the organization. One of the primary uses for all the MDS is for the Air Force Form (AFF) 103 *Civil Engineer Work Clearance Request* (103) process. The form is used when it is necessary for an agency to excavate to any depth regardless of the location on the installation. Concerned agencies, such as CE and the Communications Squadron (CS), must validate the presence or absence for any underground infrastructure component for which their particular agency is responsible. By using the MDS, the Utilities Work Center is able to validate the presence or absence of components at the dig location; however, the Electric shop is not able to clear a location due to missing data in the MDS databases. The Electricians rely more heavily on the shop personnel with the most corporate knowledge to clear areas to be excavated. Should there be a knowledge deficit, shop personnel would physically inspect the location to validate the AFF 103.

The AFF 103 program is not the only use for the MDS. The MDS are also used in the approval process for siting new or additions to facility footprints. As one data steward indicated, the MDS helps pinpoint where potential problematic components such as valves, transformers, etc. might be located and helps the work centers develop a preventive maintenance program for these components.

CLA has found other uses for the MDS that also have a positive impact on other base organizations. As CLA is in a severe weather location, the MDS are used to pre-plan for emergency response should a hurricane be forecasted to affect the installation. As the overhead electrical distribution layers of the MDS have been updated, the Electric Work Center has access to accurate data to help determine which circuits might be impacted as well as the locations of sub-stations and transformers that might be in need of repair. Additionally, by using the various MDS, the Crisis Action Team (senior base officers and commanders) is able to predetermine the severe weather impact to the base and to evaluate the need for evacuations and the stand up of shelters.

*MDS and Work Center Impact*

Investigative question seven asks, "How does use of Electrical and Utilities Work Center Mission Data Sets impact the work efficiency within the work centers?" The impact in using the MDS on work center efficiency was stated to be minimal at the time of the site visit. As stated above, the web-based interface had just been fielded and the work centers had not started using the interface with great frequency. The continued reliance on the GIS office to produce the paper-based maps used by the work centers was evident. As one interviewee indicated, there was some resistance by the work centers in using the MDS, as the workers were more comfortable using paper-based maps, but that resistance has begun to fade.

It was stated that the use of the MDS had increased the efficiency within the work centers as time was not spent validating outdated data as well as creating a central point or repository where the latest information could be accessed. Less time was spent on unproductive tasks such as locating buried component and more time was spent being productive by effecting repairs. It was also indicated that the work efficiency had been increased as the web-based viewer provided the data faster and with greater accuracy than the G-Tab maps.

All respondents indicated that they believed the work centers would continue to use the MDS even if their usage was not mandated. While the impact and benefit of using the MDS on a daily basis was still being internally evaluated, all respondents stated that having the data in a single location that could be easily accessed would aid immeasurably to increasing work center production. A caveat to the continued usage was identified; all stated that the data needed to be accurate, relevant, and updated before the entire benefits of usage could be realized.

*Usage Summary*

The primary use for the MDS at all levels is for locating underground infrastructure components for various processes including the AFF 103, Work Clearance Request – Dig Permit. Other processes and programs make use of the MDS such as emergency pre-planning and reoccurring work scheduling. The impact of using the MDS in daily operations has not been directly observed at any level, but the organization's anticipation is that as the data's accuracy and ease of access is increased, the usage will also increase.

*Summation*

The MDS were developed from digitized AutoCAD® files as well as inputs from an utilities survey. Data elements that were included in the MDS were based up the SDSFIE. CLA used the ESRI software suite for data editing and manipulation and Trimble products for field data collection and validation. Users were able to access the MDS by using a web-based viewer and could selectively determine what was displayed. The primary use for the MDSs was for the AFF 103 program. Finally, work center efficiency was improving, as workers were able to access more accurate data than was indicated by the G-Tab maps.

*Case Location B*

As identified in Chapter III, the mission orientation of Case Location B's (CLB) parent MAJCOM is support. The MAJCOM's focus is on the education and training of future Air Force leaders versus a direct war-fighting mission.

Case Location B (CLB) has an organization chart that differs from the other three case locations in that CE is not only a base level squadron, but also functions as a MAJCOM Civil Engineer Directorate (see Figure 7). The dashed lines indicate an indirect reporting track based on responsibility. The CE organization answers to both the parent MAJCOM as well as the Installation Commander. XYZ Contracting Company (not the real name) who is responsible for the daily operations performs the vast majority of the base level CE work requirements. Within this CE organization, several DAF employees are "dual hatted" in that they work both base level as well as headquarters functions. One such employee is the GBPM. The GBPM is located within the Programs office (left side of the organizational chart) and serves as both the Headquarters and CES GBPM with separate job requirements but same overall mission – overseeing CLB's GeoBase program.

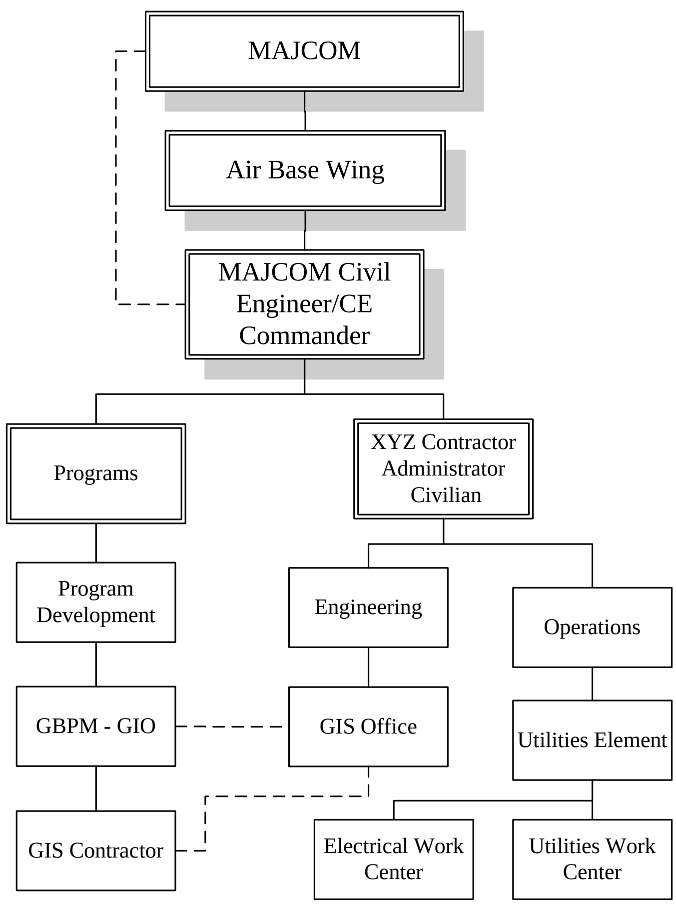



*Figure 7. Case Location B Organization Chart*

The GBPM enjoys a simplified chain of command to the CE commander. Though the GBPM does not have any direct subordinates, he oversees the GIS office (dotted line) that is staffed by XYZ Contracting Company's personnel as well as a government contractor who is the assistant GBPM and is responsible for much of the day-to-day GeoBase operations.

*MDS Design Issues*

Again, recalling from the previous chapters, Investigative Questions 1 – 3 address MDS design issues and focus on how the Electrical and Utilities Mission Data Sets at a particular location came into existence. The focus of these questions was to determine what steps and processes were employed in the Electrical and Utilities MDS design.

*MDS Design and Creation Processes and Issues*

As discussed previously, investigative question one asks, "How were Electrical and Utilities Work Centers' Mission Data Sets created?" The Electrical and Utilities Mission Data Set design appeared to follow a logical progression. All interviewees indicated that the original "As-Built" drawings were scanned and digitized using those drawings as the foundation for the electrical and utilities MDS. Knowing that the data was not accurate because numerous changes had been made to the infrastructure that had not been previously captured, a contract was let to have all the utilities (electric, water, gas, sewer, storm water, wastewater, and potable and non-potable reservoirs) surveyed and re-validated. Requirements were established for the contractor to provide the validated data in a format compatible with ESRI ArcGIS® and in accordance with the SDSFIE. The contractor was also required to obtain (more commonly called "shoot") GPS points for each key feature (transformers, poles post indicator valve, water valves, etc.) and to include that information in an Oracle® relational database. Additionally, the contractor was to revise and update the government furnished maps, as well as locating and identifying the key infrastructure components such as valves, hydrants, transformers, etc.

The MDS data validation techniques varied greatly depending on the infrastructure component, with ground penetrating radar (GPR) being one of the two primary data collection techniques. GPR uses a process similar to echolocation in which ultrahigh frequency radio waves are transmitted into the ground. The returning waves are received, and variations in the underground features indicate the presence of buried objects. The second technique employed by the contractor was using the workers' corporate knowledge of the infrastructure to determine components' locations. This individual knowledge, along with the information in the G-Tab maps was used to complete the validation process where gaps existed in the underground imaging. Where corporate knowledge and maps were lacking, the contractor assumed that the components followed a straight line and completed the data by making point-to-point annotations. This process was based upon the visualization of above ground components. For example, if the contractor were unable to determine the exact location of a buried secondary electrical line, he would find the location of the servicing transformer and the facility's electrical panel, and then assume the line followed a straight path from origin to termination.

Validation, as all the respondents indicated, was an ongoing process that the GIS office and work centers continue even after the locating contract was finished. When a buried component was uncovered, someone, either from the GIS office or from the work center, would capture the data in some manner whether it was with a GPS data collection unit, making red lines annotations on the work drawings, or by making notes on a piece of paper. If the latter two methods were used, the drawings or notes were given to the GIS office for MDS updating. The same held true for capturing data during and after construction projects.

Capturing MDS data after MilCon or SABER construction project completion was a multi-step process. When a contract was let, the GIS office provided the contractor with the most current electrical and utilities MDS data that was in the GeoBase system to use as a reference point. While it was widely known within the CE organization that the GeoBase data was not very accurate nor complete, it was a starting point for the contractor. The contracts state that the contractor must furnish, at the completion of the contract, a digitized copy of the "As-Builts" in an AutoCAD® format, which was capable of being imported into the ESRI ArcGIS software. This format was a necessary feature to ensure that the MDS data was in compliance with the SDSFIE data standards.

*Data Elements*

Investigative question two, "How did the Electrical and Utilities Work Centers determine what data elements to put within the Mission Data Set?" seeks an understanding of how the different infrastructure components were identified, labeled, and named. While there was some uncertainty in how the data elements (transformers, valves, hydrants, etc.) were determined, all respondents knew that there was a legend printed on the maps that could be used to identify these different elements. One respondent further clarified that the mapping legend was based upon the SDSFIE, and that all feature nomenclature was defined by those standards. To capture the specific MDS data elements, various hardware and software components were used.

*Hardware/Software Usage*

Examining "How was hardware/software used to capture these Mission Data Sets?" is the focus of investigative question three. To capture the MDS data elements associated with infrastructure components and features, the GIS office personnel would, if possible, visit the work sites and shoot GPS coordinates prior to any underground component or feature being buried. This was accomplished by GIS office personnel shooting GPS coordinates and capturing the data using Trimble GeoXT® and Pathfinder Pro XRS®. If the GIS office personnel were not able to visit the location, the work center personnel working at the work site would red line the paper-based drawings and submit them to the GIS office for updating.

*Design Summary*

The MDS design was based primarily upon the use of digitized drawings and maps as well as contractors conducting infrastructure re-validation surveys. Various techniques were used to locate and identify all underground infrastructure components. Primary lines were generally determined to be point-to-point from visible components. Other than Trimble GPS units, portable computer components were not used to capture the data. The MDS data collection and validation was an on-going process.

*Implementation Issues*

Investigative questions four and five, focus on MDS data quality, maintenance, and availability to the end-user. As the SDLC model demonstrates, the implementation phase begins after a system has been designed. At this location, several issues were expressed as they related to the implementation of the MDS. Most notable was the issue of information quality.

*Information Quality*

Recall that investigative question four seeks to determine "How is the information quality (e.g. accuracy, currency) of these Mission Data Sets maintained once they are developed?" Several issues were identified during the interviews relating to the implementation of the MDS across the CE domain. All respondents stated that the MDS data that was currently in use was not accurate which subsequently affected MDS usage by personnel. Work center personnel stated that the data (locations, features, attributes, etc.) that has been loaded into the database was erroneous and inaccurate based upon personal knowledge of the infrastructure components. Currently, work center personnel stated, the utilities MDS (the one received from the contractor) was not even SDSFIE compliant. For example, the SDSFIE and Uniform Plumbing Code (utilities oversight rules) identifies the fire department's hose connection point that is not attached to a building as a "fire hydrant." The contractor erroneously labeled all fire hydrants as "Fire Point Connections" which are fire department's hose connections located *on* a facility. Upon seeing this error, shop personnel immediately questioned the accuracy of the remaining data.

Most of the respondents indicated that the "point-to-point" drawings provided some reference to the location of components that were buried, but the accuracy was no better than the outdated paper-based G-Tabs maps. The indications were that the MDS that were available were a good starting point for referencing particular infrastructure components, but much work needed to be completed before they were considered completely accurate and usable.

Providing updates to the MDS was an ongoing and continual process. The GIS office used the portable GPS data collection units to collect data when buried components were revealed. One GIS technician indicated that GPS coordinates and attributes of only small segments of the exposed lines were obtained, but with that, the remainder of the service line could be approximated. The majority of updates, however, were accomplished by the work centers completing red line annotations on existing paper-based maps and returning those maps to the GIS office for updating into the specific MDS database.

As CLB has a contractor performing the majority of the CE daily operations, specifications for MDS data stewards (i.e. those directly responsible for maintaining the MDS data) was not formally identified nor applied to any particular job position description. It was identified in the contract that when the contractor (XYZ) took over organizational duties, the role of data maintenance was transferred from the previous office of primary responsibility to the new GIS office. However, the data maintenance role was as an additional duty and was handled as time and workload permitted. The work centers under XYZ contractors, in an effort to have the current and accurate data, have begun to take the initiative in updating and storing the data internally in addition to providing the updates to the GIS office. At the time of the site visit, there was no individual or individuals identified as data stewards.

*MDS Access*

In focusing on the access issues, investigative question five asks, "How is Mission Data Set (mapping layer) information accessed by users?" The MDS data layers were stored within an Oracle® relational database on the GeoBase server located within the CE organization and connected to the base's LAN. Electronic access to the MDS was achieved by logging onto the installation's LAN and navigating to the CE GeoBase server. At the time of the site visit, final preparations were being made to bring the ESRI ArcView® web-based viewer on-line for users not located in the main CE facility. The CIP had been loaded along with the Electrical and Utilities MDS and users were able to access, though in a limited fashion, the CIP and MDS elements located in the Oracle® database, which forms the basis of the GeoBase server. Access to the CIP and MDS would be allowed using permissions set in the GeoBase Oracle® database. The primary users of the web-based viewers were those located in the main CE facility, as the work centers did not have access to the web-based viewing software. One remote work center individual was given training on the use of ESRI software suite as well as how to update the MDS. He has become the focal point with in his particular work center for MDS access and printing of the needed maps. The other work centers must rely on the GIS office for printing maps that are used at the remote work sites and in the work centers.

The ESRI ArcIMS web-based viewer has tools in which the end user can selectively determine what is seen by using the component's feature classes that are loaded in the CIP and MDS. The entire process begins by selecting a particular area of the base that needs to be viewed and then zoomed inward or outward to the appropriate scale. Feature selection can be done at this point, and then the map can be printed.

While the web-based viewer has the capability for end users to visualize digital maps, the hard-copy map is the most common method of accessing the MDS for the work centers. Once these features are displayed, prints can be made which are then used for archival purposes, by the Electrical or Utilities Work Centers, or at their remote work locations.

*Implementation Summary*

Virtually all comments relating to MDS implementation focused on the lack of the accuracy of the data; accuracy related to location of the infrastructure components. The data that was originally provided by the infrastructure survey contactor that was used in the MDS design was faulty and as such, has led to some implementation issues and concerns centering on acceptance of the data. In an ongoing effort to increase the data accuracy, the GIS office was visiting remote work locations and re-capturing the data using Trimble handheld and backpack units. If the GIS office was unable to visit the remote work location, the work center personnel have been redlining their hard copy prints and providing them to the GIS office for MDS updates.

*Usage Issues*

Though not a direct aspect of the SDLC the usage of the MDS is crucial to the research. It is not enough to have the MDS available to the work centers; they must be willing to make use of the MDS. Investigative Questions six and seven address the issues surround the MDS usage from a work center's prospective.

*MDS Usage in Mission Requirements*

Investigative question six seeks to determine "How are Electrical and Utilities Mission Data Sets used in meeting mission requirements?" While the indication was that the MDSs' data were not accurate or complete, the MDSs were still used in various ways by the work centers.  Primary among the uses was in the Reoccurring Work Program (RWP).  According to the contract Performance Work Statement (PWS) for XYZ contractor, the work centers must perform certain tasks and conduct inspections of various infrastructure components on an annual basis.  For example, the Utilities Work Center must locate and exercise all water valves on the installation every year, while the Electricians are required to inspect all electrical transformers.  The MDSs, in their current state, are able to provide a generalized placement of the valve and transformer locations.

The AFF 103 *Civil Engineer Work Clearance Request* (Digging Permit) program also makes use of the MDS.  The AFF 103 program requires the requestor to visit the GIS office to obtain the necessary paper-based maps of the area to be excavated.  It was stated that although the MDS data may be inaccurate or incomplete, the information contained on the maps still provides sufficient details to indicate whether there are buried infrastructure components in the area.

Another use for the MDS that was expressed was their use during exercises and real-world responses such as water or electrical outages, major accident response exercises, etc.  The Crisis Action Team (CAT) can view the CIP in its assembly area and, at the request of the CAT commander, the necessary MDS can be displayed as well.  As the CAT and specific work centers are "seeing" the same data at the same time, the specific work center's response times to the "emergency" can be reduced.

*MDS and Work Center Impact*

Investigative question seven asks, "How does use of Electrical and Utilities Work Center Mission Data Sets impact the work efficiency within the work centers?"  Work center personnel relayed that, initially, using the MDS data was more time consuming than using the old G-Tab maps. As the MDS were being updated with more accurate and complete data, the time needed to accomplish tasks was diminishing as time spent searching for components was reduced. For instance, knowing where a water valve was located, the Utilities Work Center could more rapidly isolate a broken water line thereby expediting repairs. In addition, Electricians could identify a de-energized circuit based upon which facilities were without power and effect repairs to the damaged component quicker than if they had to trace wires to locate the affected transformer.

All respondents stated that they believed that there was some positive benefit to the work centers using the MDS as response times were being reduced. Additionally, all respondents stated that the MDS presented a starting point for locating buried components. They continued by stating that even if the commander indicated that the GeoBase program did not need to be followed, the organization would continue to do so. The work center personnel stated that regardless of how the data was presented, they would continue to use the MDS, even if it was only in a paper-based format.

*Usage Summary*

The primary work center use for the MDS was in locating underground infrastructure components. The MDS are also used in the AFF 103 process for determining the need to visit the projected work location or to certify the absence of underground infrastructure components. The indications were such that MDS usage did have a positive impact on the work centers in that the time to locate components had been reduced thereby increasing work efficiency.

*Summation*

Case Location B was unique to the research project, as the CE organization is comprised mostly of contract personnel with a limited number of DAF or military personnel. The MDS design process was accomplished by first digitizing paper-based CAD drawings that CE had in its possession. Once done, a contract was let to have the location of the underground infrastructure components located and validated or re-validated. The data provided by the contractor was added to the digitized drawings files and included in the MDS design.

The accuracy of the MDS data was a concern in that it was stated that the data was neither accurate nor complete. The GIS office and work centers were working diligently to correct this discrepancy; the respondents indicated that updating was a slow process. More often than not, the work centers relied upon old paper-based maps (not generated from the MDSs) that were located in the work center. Work center personnel would continually update the work centers' paper-based maps and would forward changes to the GIS office so that updates to the database and MDS could be made.

The GeoBase server was located within CE, and the MDS were accessed mainly by CE and XYZ contracting personnel located in the main CE facility by using the ESRI ArcIMS web-based viewer. After accessing the MDS, personnel were able to select the data features and elements that needed to be visualized. During the time of the site visit, there were no capabilities for accessing the MDS from remote work locations. Work center personnel relied upon paper-based maps that were physically taken to these work sites. Changes were annotated on the maps and returned to the GIS office for updating into the MDS database.

Regardless of the accuracy of the current data, all respondents stated that they firmly believed that the organization would continue to use the MDS. As the GIS office and work centers have begun the task of updating the MDSs, all respondents expressed that there was a desire to continue MDS usage. Even without being able to access the MDS in an electronic format, the updated maps were allowing the reduction of work times and improving work efficiency as the work centers were able to locate more rapidly. The need for MDS data accuracy in the databases was the prevailing theme through all the interviews.

### *Case Location C*

Based upon the Case Selection Matrix, (see Chapter III, Table 3), Case Location C (CLC) was recommended by AFCESA GIO as having an advanced program that was worthy of review. Discussion with the AFCESA GIO indicated that CLC had completed the virtually the entire MDS design in-house and would make a good case study location. Additionally, this location is under a different parent MAJCOM than either CLA or CLB, and appeared to have a greater interaction with and oversight from its parent MAJCOM that CLA and CLD. As indicated in Chapter III, the addition of CLC also allowed for theoretical replication in light of the other study cases.

Recalling from Chapter III, the mission orientation for CLC's parent MAJCOM is operations meaning that the MAJCOM's focus is on a direct wartime mission. The bases under its control are considered on the "front lines" and the missions of the individual bases complement each other so that a complete air superiority package is available to the MAJCOM commander as well as Air Staff and Joint Staff. As the primary mission for

CLC's installation is one of air superiority and air interdiction, the CE organization focuses on providing the tools necessary to accomplish the mission.

The GIS office is comprised of military, DAF employees, and contractor support personnel. Figure 8 displays a simplified CLC organization chart. The GIS office is located within the Operations Flight, under the direction of the Chief, Maintenance Engineering, and headed by the Non-Commissioned Officer in Charge (NCOIC) who is an Engineering Assistant. The NCOIC directs the daily operations of the GIS office and is responsible for the CIP and all CE MDS. Although he has no direct responsibility for the GeoBase server, he is responsible for the GeoBase software and the all GeoBase data. Also within the Operations Flight are the Electrical and Utilities Work Centers under the supervision of the Utilities Superintendent.

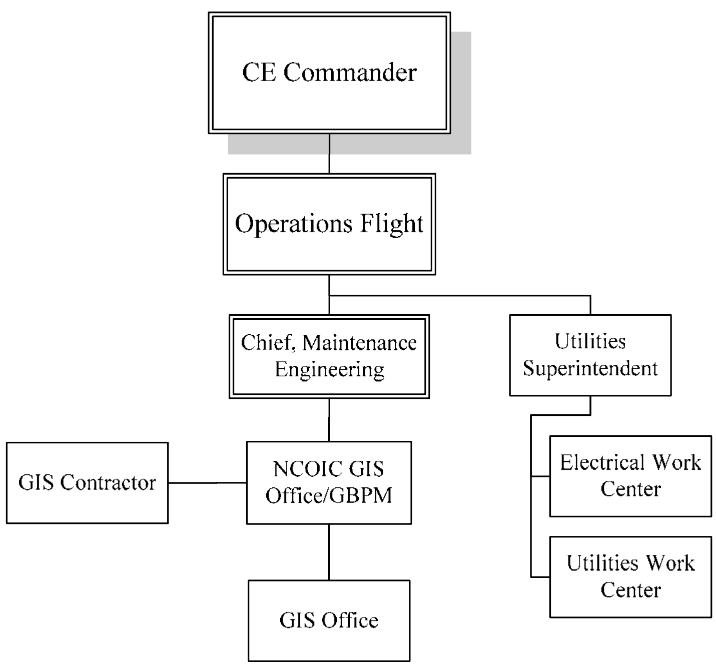



*Figure 8. Case Location C Organization Chart*

*MDS Design Issues*

As stated previously, Investigative Questions 1 – 3 address MDS design issues and focus on how the Electrical and Utilities Mission Data Sets at a particular location came into existence. The focus of these questions was to determine what steps and processes were employed in the Electrical and Utilities MDS design.

*MDS Design Processes and Issues*

As outlined previously, investigative question one inquires as to "How were Electrical and Utilities Work Centers' Mission Data Sets created?" The design of the GeoBase program at CLC was founded on a MAJCOM directive that outlined the minimum requirements for the MDS layers and attribute data. Using the directives from the MAJCOM, CLC converted the electronic infrastructure CAD drawings (G-Tab maps) to ESRI ArcGIS by using drawing conversion features embedded within the software suite. Knowing that the original CAD drawings were not accurate due to the fact that the infrastructure indication lines were placed where they could readily been seen rather than a true representation, MAJCOM directed CLC to continue MDS development by re-validating component locations. Using GPS equipment, the EAs collected data points as they related to the different infrastructure components and overlaid those points with the new GIS data.

Initially, the plan for re-validating the MDS data at CLC was to focus on a sector approach, meaning that the installation would be divided into sections. The work centers; however, preferred to approach the MDS design from the standpoint of collecting the data by concentrating on specific components (as opposed to sectors) such as primary or secondary electrical, primary water distribution, etc. The work centers argued that by collecting the data for an entire infrastructure system (primary or secondary electrical, primary water distribution, etc.) the emphasis could be placed upon data collection. For example, the Electrical work center preferred to capture the data for transformers, poles, etc., as they related to an individual electrical circuit. The reasoning was that both work centers "thought" of their respective systems as a continuous run from a point of origin to a point of termination. It was through this logic that the final decision was made to capture the data as it related to a system as a whole, rather than by sectors. Re-validating the underground components involved a "point-to-point" estimation that was based upon the corporate knowledge from the work center's personnel as well as the infrastructure maps. Additional component and feature data was collected when the work centers, or contractors, excavated and revealed a portion of a buried system. The GIS technicians as part of their re-validation processes collected component and feature data for above ground components. Coordinates were gathered and the components and attribute data were collected and delivered to the GIS office for MDS updating. The work centers would coordinate with the GIS office when excavating existing or installing new components and work together to capture or re-capture the necessary data.

The Electrical and Utilities work centers were able to support the GIS office by providing technicians who assisted in the data collection. These work center experts provided valuable insight as to what the components' nomenclature and specifications were. Their expertise aided in ensuring that the features were identified and labeled correctly. Although the data collection for both MDSs was conducted at the same time, at the time of the site visit, the electrical MDS was complete, while data was still being collected for the Utilities' MDS.

Capturing the MDS data from MilCon and SABER projects was accomplished by coordinating with the GIS office. The aim was to have a GIS technician visit the contractor work location and capture the component, feature, and attribute data while underground components were exposed as well as capture data points throughout the entire construction project. If that was not possible, the GIS offices relied upon the contractor's "As-Built" drawings for the component's data and incorporate that data into the GIS software. As one GIS technician stated, "It is very important to get all that information (use of tracing wire or tape, periodic GPS coordinates, etc.) written into the contracts before the contract is even put out to bid. There needs to be a GPS/GIS component section in the contract that says component's features and attribute data be provided and/or have spatially accurate locations of all infrastructure components provided because the "As-Built" isn't really enough information."

MDS data capture for in-house work followed a slightly different process. Some work center personnel were trained in how to capture the component's features and attributes using a portable hand-held device – Trimble GeoXT®. After capturing the data, the device was returned to the GIS office for downloading and incorporation into the specific MDS. The goal was to have the latest information loaded and available for viewing in the MDS layers as soon as possible.

*Data Elements*

Investigative question two, "How did the Electrical and Utilities Work Centers determine what data elements to put within the Mission Data Sets?" seeks an explanation as to how the different infrastructure components were identified, labeled, and named. As stated previously, the parent MAJCOM established guidance regarding MDS design and the data standards that would be used across the command. In developing these data standards, the MAJCOM polled all the subordinate bases to determine what data elements were needed and used at the different bases. Once completed, the guidance included the data feature classes and attributes that were to be included (which also aligned with the SDSFIE). In ensuring that the MDSs at CLC were complete, the GIS office queried the work centers to determine if other feature classes and attributes were needed. If so, these additional feature classes and attributes were added to the system and followed the SDSFIE format. While all data elements identified at CLC were listed in the SDSFIE, guidance from the parent MAJCOM did not provide a comprehensive listing that mirrored the SDSFIE exactly, so CLC ended up having to make additions.

Creating the legend for the data elements followed a process that was similar to the process used to determine the data elements used. The legend was also created by the MAJCOM and was based upon the SDSFIE. Additionally, CLC had the approval to modify and add to the legend as necessary to ensure all elements were captured and represented.

*Hardware/Software Usage*

Investigative question three asks, “How was hardware/software used to capture these Mission Data Sets.” At CLC, the original MDS data were from digitized AutoCAD® paper-based drawings as well as AutoCAD® electronic files. These files were converted into the ESRI ArcGIS and ArcInfo software suites and compared to the original AutoCAD® drawings and files. This process presented a challenge, as one respondent stated, in that the AutoCAD® drawings could have as much as 30’ or 40’ margin of error in showing the component placement. To overcome this margin of error portable data collection devices were used at the work sites and re-validate component's positions.

Once the MDS design guidance from the MAJCOM was obtained, the organization began collecting data points, feature classes, and attributes using the Trimble GeoXT® and Trimble Pro XRS® backpack unit. These data collection devices were used to gather the surface and subsurface features and allowed incorporation (by the GIS office) of that data back into the respective MDS. The work center personnel collected only the GPS and nomenclature data and then had the GIS office upload and update the attribute data within the GeoBase data system. It was determined that this was the best course of action as work center personnel rotated frequently and the amount of training needed to learn detailed data collection and updating processes precluded in-depth training for work center personnel. While a laptop computer was used initially in the off-site data collection process, it was determined that using the Trimble was more efficient in that updates could be made directly to the MDS via a direct downloading into the GIS software.

All software components of the GeoBase system are stored within a network server that is located within the CE organization. The data itself is stored in an Oracle® database. All MDS data, according to a GIS technician, is stored in the same layer within the GeoBase database, but based upon the symbology the user can select what is seen and displayed. The user can selectively determine what is seen such as primary lines, secondary lines, lateral lines, etc. When the MDS is initially viewed, all data is shown, but by clicking on the respective symbols, only those components will be displayed.

*Design Summary*

The design for the MDS at CLC were based upon directives from the parent MAJCOM that outlined the required data elements, features, attributes, and legends. Some autonomy was given to CLC in that it could add to the listing provided the additions adhered to the established standards. The MAJCOM also directed that all components of the MDS follow the SDSFIE. Once populated, the MDS were stored within an Oracle® database located on the GeoBase server within the CE organization.

*Implementation Issues*

Investigative Questions four and five focus on how the MDS data quality is maintained and how the MDSs are made available to the end users. Recalling the SDLC model from Chapter II, after the MDSs have been designed, the next step is the implementation of the MDS. This section addresses MDS implementation issues.

*Information Quality*

Investigative question four addresses MDS quality by asking, "How is the information quality (e.g. accuracy, currency) of these Mission Data Sets maintained once they are developed?" A GIS technician explained that the key to maintaining the accuracy and currency of the data was to keep in constant contact with those who provide the data be it "As-Builts" drawings or red line maps. This was important as the individual (one providing the drawings or maps) has the knowledge of the system or systems that were identified on the maps and could answer questions that might be raised regarding the data. He continued, that at any given time, there are numerous construction projects, both contract and in-house, happening on the installation and the GIS personnel have to stay on top of what is going on.

Updating the MDS is a constant and ongoing process that begins with receiving the data from the originating source, be it the work centers, Contract Management, SABER or the GIS office collecting the data.  It was stated, data is collected, and the MDSs are updated continually.  Respondents at CLC stated that the maps were substantially different from the original AutoCAD® drawings and files that were used as the MDS foundations.  Indications are that the data is still not completely accurate (e.g. buried lines are not where they are indicated on the maps), but as new or corrected data is given to the GIS office, updates are entered into the system and the MDS is becoming more reliable overall.

MDS Data re-validation was reported to be a continual process.  While it was indicated that there was no one single person who was the data steward for the individual MDSs, all agreed that the responsibility for the data was a joint effort between the work centers and the GIS office.  If possible, the GIS office preferred to physically visit the work location and collect the data with the Trimble data collection units.  Additionally, the GIS technicians were able to upload data files to the data collection units and were then able to field validate the data.

*MDS Access*

As discussed previously, investigative question five inquires, "How is Mission Data Set (mapping layer) information accessed by users?"  At the time of the site visit, end-users were able to access the MDS via the installation's LAN by using the ESRI ArcIMS web-based viewer accessible from the installation's intranet homepage.  A feature of the web-based viewer, ArcIMS, is the ability to determine what is viewed and printed.  Users can click on a feature, such as a primary water line, and see only those components that relate to the selected feature. Additionally, the user will see all relevant data that defines the selected feature. It was expressed that, at the time of the site visit, that the most current maps were not available to the users via the intranet. As explained, this was due to concerns having been raised regarding who should have access to both the CIP and MDS, and therefore access was limited to work center leaders and above in the chain of command. However, the GIS office could print out the current and accurate maps and provide the maps to those requesting and having a need for the maps. The GIS office printed maps that ranged in size from the large-scale wall mounted maps to individual 8 ½" x 11" base maps.

MDS access at the work location was possible through the use of the map books or other prints generated from the ArcIMS web-based viewer or from other maps printed by the GIS office. While it was possible to download the MDS into a portable computer device for use at the work site, at the time of the site visit, no portable computers were available for use.

*Implementation Summary*

The implementation of the MDS was based upon a constant communication between the GIS office, work centers, and Engineering Flight so that the most current data was available. The GIS office would visit work locations to gather the MDS data and verify the data with the work centers further ensuring the data was correct. The preferred method of receiving data that was to be entered into the GIS software was in an electronic format, however, if the GIS office was notified of a project, technicians would respond to the work site in order to gather the MDS data using Trimble data collection devices.

*MDS Usage Issues*

Designing the MDSs and making them available to the work centers is only part of the GeoBase program; the shops must use the MDS. Usage is considered to be a subset of the SDLC Implementation Phase. Investigative questions, six and seven explore how the work centers are making use of the MDS and any impact or benefits that are realized by MDS usage.

*MDS Usage in Mission Requirements*

Investigative question six inquires as to, "How are Electrical and Utilities Mission Data Sets used in meeting mission requirements?" The MDSs were used at CLC in varying fashions with most of the usage occurring at the work center level. One of the most common uses identified by respondents was that the MDS, coupled with the G-Tab maps, facilitated the location of underground infrastructure components. For example, the Utilities Work Center stated that in the event of a water leak, they now had the capability to determine what valves to turn, who would be out of water, and how to minimize the outage by rerouting water around the break.

The AFF 103 program, *Civil Engineer Work Clearance Request* (Digging Permit), has also benefited from having the MDSs available. What was once a process that required visits to numerous work centers over a period of days or weeks as the information was not available in one location, is now being accomplished by a single visit to only one office – "The Dig Permit Office." As the MDS maps have been updated, the Dig Permit office personnel have been able to approve the AFF 103 without having to visit the work location. If the MDS indicated an infrastructure component was present, work crews would be dispatched to mark the area so that the individual digging would not hit the buried component.

The Electrical Work Center uses the MDS routinely in the RWP program in that all the electrical components are labeled and numbered and are loaded into the MDS. For example, all power poles have all been numbered in such a way as to identify the particular pole within a certain electrical circuit. Should a repair need to be made to a pole, the work center is able to access the database and determine the pole's location, the electrical circuit, and where to de-energize the power lines if needed.

*MDS and Work Center Impact*

Investigative question seven queries, "How does use of Electrical and Utilities Work Center Mission Data Sets impact the work efficiency within the work centers?" Work center personnel stated that having access to the MDS reduces response times and appears to be a positive impact to the work center. The assumption from some of the respondents was that the impact was centered on an increase in work center efficiency in that less time spent in locating underground infrastructure components. While some work centers indicated that they still relied on the wall mounted paper-based maps, the reliance on the MDS was starting to increase. It was expressed that the component's locations within the MDS were more accurate than the old paper-based maps. For example, an unimproved road was surfaced and the electrical manholes were not raised to the new surface. By having the GPS coordinates for those manholes prior to the roadwork, the Electrical Work Center could, if needed, locate the manholes without having to damage large sections of the road. The Utilities Work Center stated that they used the MDS along with locating radio beacons to identify their manholes when there was a thick layer of snow.  The MDS, they stated, gave them a starting point from which to located buried components.

While the GeoBase program and the MDS are becoming more and more complete and accessible, all stated that they believed the Electrical and Utilities Work Centers would continue to use the MDS even if not directed to do so.  The Electrical Work Center stated that even though the work can continue without the MDS, it is much better when they are used; there is more information (attributes, locations, etc.) available in a single location – the MDS.  The old AutoCAD® maps were never updated which frustrated the work centers; but with maps that are updated and accessible with a web-based viewer, their use increases.

*MDS Usage Summary*

The MDS usage was varied and based upon the individual work center.  Each work center had differing applications – Electricians for RWP and Utilities for locating buried components – but as a whole relied upon the data for work center operations.  By having the MDSs available, the AFF 103 processing time was reduced to a matter of an hour or two down from days or even weeks.  With GPS coordinates of key infrastructure components loaded into the GeoBase database data tables, the work centers could more quickly achieve repairs to the various utilities systems.  One factor was relayed regarding the continual usage and that was that the data must be current and accurate for benefits to be realized.

*Summation*

CLC appeared to have a greater interaction with and oversight from its parent MAJCOM.  The MAJCOM issued directives on how the MDS were to be designed and what features and attributes the data would have as defined by the SDSFIE. Electronic drawings formed the foundation for the MDS at CLC and realizing that the data was erroneous, the GIS technicians, working with the Electrical and Utilities Work Centers, re-gathered and re-validated the data.

Accuracy of the data was maintained by constant reviews and by communications between the GIS office and work centers so that as components were exposed or newly placed, the GIS office could capture or re-capture the data. The work centers were able to access the new data by using a web-base viewer in which the user had the capability to select the features to be displayed and, if needed, printed. By accessing the MDS online and printing specific maps, the work centers used the MDS in their daily operations, mostly for locating underground components. Although the MDSs were not complete, the work centers were beginning to realize the benefits in using the MDS and realizing an increase in work center efficiency.

*Case Location D*

Recalling from Chapter III, advice was solicited from HAF, AFCESA, and MAJCOM GIOs for recommendations for case locations based upon criteria established. Case Location D (CLD) was recommended as several processes were developed at CLD that rely heavily upon MDS usage. It was decided that CLD would serve as a case location in that it is in a different MAJCOM than the other three case locations and provides a different perspective based upon the parent's mission orientation. The mission orientation is operational in nature as the MAJCOM has a direct war-fighting mission and the function of CLD is to ensure the installation is able to meet the wartime tasking.

The organization chart of CLD is such that the GeoBase program is located within the Engineering Flight, Plans and Programs office (see Figure 9). The GBPM is in charge of the GeoIntegration Office (GIO); however, CLD is unique in that a MAJCOM contractor oversees the daily operations of the GeoBase program. GIS technicians that are assigned to the Engineering Flight as well as the Operations Flight take work directions from the contractor, (indicated by a dashed line) but are not supervised by the contractor. This organizational structure permits the GBPM to focus on the management aspects of the GeoBase program. The GBPM is not directly responsible for the daily maintenance of the GeoBase server, but is responsible for the GeoBase software and managing the CIP and all MDS.

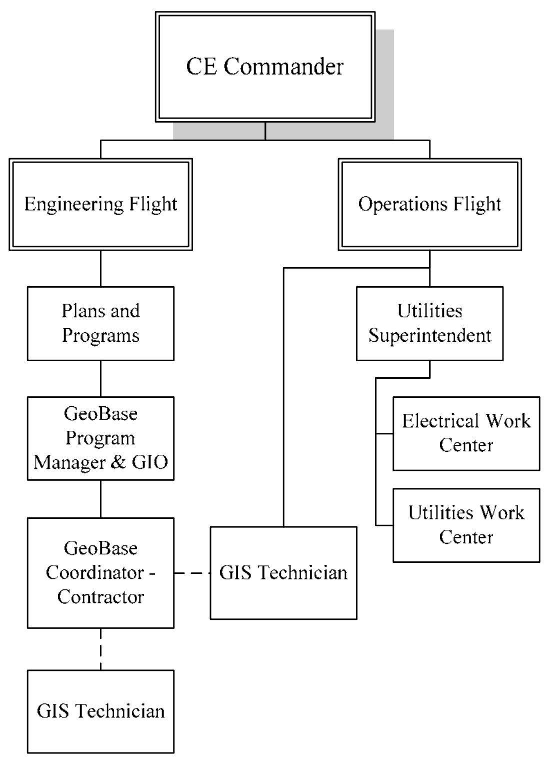



*Figure 9. Case Location D Organization Chart*

*MDS Design Issues*

As stated previously, investigative questions, 1 – 3 speaks to MDS design issues at the case location under study. These questions concentrate on the different processes that were used to design the Electrical and Utilities MDS at CLD.

*MDS Design and Creation Processes and Issues*

As discussed previously, investigative question one inquires, “How were Electrical and Utilities Work Centers’ Mission Data Sets created?” The foundation for the MDS at CLD came from existing CAD-based electronic files that were maintained by the Drafting Section. Electronic CAD files (G-Tab maps) were converted to ESRI ArcGIS by using drawing conversion features embedded within the software suite. The new ArcGIS files were inspected to ensure the layers had the proper features, and change the map symbols to points so that lines could be drawn point-to-point. Additionally, aerial photography and GPS coordinates were used to identify, locate, and pinpoint features such as valves, fire hydrants, and transformers. All data was attributed in a GIS format based upon the SDSFIE. It was stated that the components identified on the old G-Tab CAD drawings were designed only to be a representation of the component’s location as opposed to an actual location.

The GeoBase technicians accomplished the majority of GIS data loading into the GIS database. The MDS databases did not contain full attribute data (make, model, serial number, etc.) so it was decided that the work centers could assist in collecting the data, as they would have the corporate knowledge of what components comprised their respective systems. To assist in the MDS data collection, a detailed document was created that outlined the processes and procedures for collecting the attribute data and in what format.

Indications were, at the time of the site visit, that the data collection was an ongoing process.

Both the electrical and utilities MDSs were in the process of being designed at the time of the site visit. The Utilities MDS was the first that was initiated but data collection was still in progress. The water and gas valves GPS coordinates had been collected and were loaded into the MDS and work was continuing to annotate the corresponding water and gas lines. The organization had also written a contract to have the electrical components surveyed for incorporation into the MDS. The electrical survey used the old CAD drawings as a starting point captured the GPS locations for those components that were at ground level or above.

The MDS component data re-validation was also an ongoing process. While the visible features were the easiest to for the contractor to re-validate, the buried components were more difficult. The use of ground penetrating radar was explored, but it was determined to be too cost prohibitive. Some of the features were able to be located as marking tape was placed on top of the component prior to being buried. A concern was voiced when the tracing the component into an area that was known to be congested with other components; it could not be known if the feature identified was in fact the correct one. Single line references for non-congested areas were loaded into the MDS as being valid and accurate, but in areas of convergence or congestion, it was decided to annotate the lines as “point-to-point.” If there were an open trench, the GIS office would use GPS data collection equipment to capture the feature and attributes. Notes were inserted in the attribute data tables indicating the component was identified as only a partial segment and the remainder of the line could not be verified. As new components were being installed, the goal was to capture the data at that point.

Some of the respondents expressed some concerns regarding the data capture after MilCon and SABER projects. Stipulations were being written into contracts that required that GPS survey data be provided to the GIS office at specified times throughout the project thereby providing a "near real-time" update. It was expressed that receiving the survey data as a provision of the contracts would increase the costs of the contracts potentially making the data delivery cost prohibitive. As a result, the GIS office would, when notified, visit the contract work location and capture the data without relying on the contractor. It was stated that the data collection after in-house work was less problematic in that information regarding the work was given to the GIS office directly from the work centers.

*Data Elements*

Investigative question two, "How did the Electrical and Utilities Work Centers determine what data elements to put within the Mission Data Sets" seeks to explain the identifying, labeling, and naming of the different infrastructure components. The data elements were pulled from the latest SDSFIE naming schema. Along with the data elements, symbols and color-coding which identified the specific infrastructure component (water line, sewer line, electrical line, etc.) were loaded into the MDS. The color-coding aided in the AFF 103 Work Clearance Request processing by readily identifying what the infrastructure component was in the work location. The majority of the responses focused on the fact that the MDS data elements were based on the SDSFIE.

*Hardware/Software Usage*

As stated previously, investigative question three asks, "How was hardware/software used to capture these mission data sets?" The primary data collection was accomplished by using the Trimble XRS Pro® backpack mounted data collection unit. The reasoning given was that the Trimble unit was the easiest to use for data collection and for updating and uploading the data. The organization had purchased specialized radio equipment – transmitters and receivers – that were capable of performing real-time access to the MDS, but at the time of the site visit, had not installed the antenna. The access, once enabled, would permit the updating and accessing of the MDS real-time.

*Design Summary*

The MDS design was achieved by using the existing AutoCAD® electronic drawings as a foundation. An additional above ground electrical survey was conducted to capture the components for inclusion into the electrical MDS. It was stated that the re-validation of underground components would be an ongoing process that as features were uncovered, the data would be collected and uploaded into the MDS. Utilities MDS data was designed by first using the old G-Tab maps with the Utilities Work Center and GIS office re-validating the MDS data. The data-naming schema followed that of the most current version of the SDSFIE. Color-coding and symbology deviated from the SDSFIE but was still usable for the work centers.

*Implementation Issues*

Investigative Questions four and five focus on how the MDS data quality is maintained and how the MDSs are made available to the end users. As the SDLC model demonstrates, after a system has been designed, it must be implemented. Several issues and processes relating to MDS quality and end-user access were indicated.

*Information Quality*

Investigative question four seeks to determine MDS quality by asking, "How is the information quality (e.g. accuracy, currency) of these Mission Data Sets maintained once they are developed?" Maintaining the MDS quality was an ongoing process between the GIS office and work centers. When data was found to be inaccurate such as the wrong component was indicated on a map, the work centers would identify what was wrong and would provide the correct information or data when possible. As components were either excavated or installed, data was collected and uploaded into the MDS, by the GIS technicians, thus providing the most current data available. Additionally, when paper-based maps were used, as in the AFF 103 program, work center personnel annotated changes as work was performed and delivered new data to the GIS office for updating. When MilCon or SABER projects were completed, "As-Built" drawings were provided to the GIS office for incorporation into the proper MDS.

According to the GBPM, MDS data on the server is, at most, seven days old. The goal CLD is to have the most current and most accurate data available on the server. The MDS data collected at work sites is accomplished by using Trimble GPS units. The collected data is then input into the specific MDS database ensuring the most accurate MDS data is available in the GeoBase system.

Validating the data is a process that is on going and evolving. An effort is underway with the MilCon and SABER construction inspectors to have GPS or feature and attribute data provided to the GIS office at predetermined points in the construction process. The example that was given was when a new facility was constructed, the GIS office had to rely on surveying the facility in order to obtain the footprint versus having foundation GPS coordinates provided prior to any walls being constructed. The GIS office expressed the desire to have MDS data at the earliest time possible in the construction process as this increases the accuracy of the MDS. Currently, the "As-Built" data is not generally accurate or delivered in a timely manner.

Responsibility for the MDS data was also addressed in that there had not been a formal designation of who "owned" the data. All respondents indicated that there was no one person who was contacted regarding specific data, just that the GIS office managed the data. The GBPM indicated that the GIO should fill more of a quality assurance or quality control role versus direct data management as the work centers have a greater knowledge of the components and features of their specific infrastructure systems. It was stated that the goal was to have data stewards designated who would be responsible for the quality and accuracy of their specific data.

*MDS Access*

As identified previously, investigative question five asks, "How is Mission Data Set (mapping layer) information accessed by users?" The primary method for accessing the MDS data at CLD is by using the ESRI's web-based ArcIMS viewer that is loaded on the individual workstations and desktop computers, which are connected to the installation's LAN. ArcReader, another "read-only" application, is also loaded on those desktops computers that have direct access to the MDS and CIP maps. The GIO indicated that the focus for access is on the user and user needs. The goal, he stated, is to present the users with the tools that best meets their requirements. Regardless of the software used, the user is able to determine what data and information he or she wants to display. Users can click on a feature, such as a primary water line, and see only those components that relate to the selected feature as well as their specific attributes.

Access at the work site was not possible at the time of the site visit as a wireless network was not available. Additionally, there was no portable computer equipment available for work center to use at a specific work location. As such, the work centers rely on paper-based maps. The GIS office was responsible for printing the maps that were requested. The requested maps were generated by using the GIS viewing software as the work centers generally have a requirement for maps that are 8 ½" x 11".

At CLD, an effort has been made to develop electronically a gallery of most frequently requested maps, as well as those that might have widespread usage. This gallery is posted on the GeoBase web page, in a .pdf format and is accessible and printable using either the ArcIMS or ArcReader viewers. This process, the GBPM indicated, has reduced the work load in the GIS office thus permitting the office to focus on other GIS tasks – gathering and updating data – as well as permitting users ready access to maps that may have taken up to a week to obtain.

*Implementation Summary*

Ensuring MDS data quality was an ongoing effort from all involved. As data was collected, it was uploaded into the MDS thereby ensuring current and accurate data was available to users. If a question was raised regarding the accuracy of the data, the GIS and work centers re-validated the data prior to being uploaded into the MDS. The MDS databases were updated at night after changes or updates had been made to the MDSs. Data from MilCon, SABER, and in-house work was uploaded as it was received. A coordinated effort was in place to ensure that the data given to the GIS office throughout the construction process.

*MDS Usage Issues*

While not a specific phase of the SDLC model, the MDS usage is essential to the research. The work centers need to be willing to make use of the MDS in their daily operation whether in an electronic or paper-based format. Investigative Questions six and seven address the issues surrounding the MDS usage.

*MDS Usage in Mission Requirements*

Recalling from previous discussions, investigative question six asks, "How are Electrical and Utilities Mission Data Sets used in meeting mission requirements?" The MDSs are used within the work centers with the primary usage being the AFF 103 *Civil Engineer Work Clearance Request* (Digging Permit) program. CLD has developed an application that queries the various MDS databases and produces a color-coded map highlighting buried components in relation to the work location. Using the maps generated by querying the MDS, the work centers are able to locate infrastructure components quicker, and expedite repairs if needed.

The AFF 103 program was not the only process that had seen benefits of using the MDSs. During a recent Military Family Housing construction program, the MDS maps were provided to the contractor. Using the utilities MDS, the contractor was able to determine the most advantageous location for connecting lateral water supply lines to the main water line. This process precluded the need for the installation of new main water supply lines and assisted in determining how to route water lines around problem areas.

Another use that was indicated for the MDS was with RWP program. Within the RWP program several electrical and utilities components were identified that required periodic maintenance. By using the MDS, the work centers were able to schedule work to those components and if service outages were to occur, notify affected facility occupants well in advance of any disruption in service. One work center stated that another use they had found for the MDS was for training new personnel in map reading (i.e. identifying symbols, tracing lines, etc.) as well as base familiarization. All respondents stated that the use of the MDS has had a positive impact on the work centers.

*MDS and Work Center Impact*

Investigative question seven inquires, "How does the use of Electrical and Utilities Work Center Mission Data Sets impact the work efficiency within the work centers?" All respondents stated that the impact to the work center has been positive in that time to effect work repairs has been reduced. As one worker explained, "If you want to flush the base's water lines, you know what end to start at versus starting in the middle and realize that you have to go to the high end and start all over." Work center personnel stated that by using the MDSs the time spent in locating underground components was reduced. They stated that someone could query the database and then direct a worker to the component's location versus having to visit an office to obtain a paper map and then give the map to the worker.

By using the MDSs, the work centers were also able to make predictive "what-if" analyses affecting their specific systems. One such analysis examined the various sewer lines and helped anticipate areas of potential problems especially when selecting locations for new facility construction. The Electrical Work Center, using its MDS, was able to analyze power requirements on various circuits to determine if a problem, such as a circuit overload, might be encountered or could be anticipated. As such, the Electricians were able to determine the best solution that would have the least impact to customers.

All work centers indicated they were seeing positive impacts to the degree that the work centers would continue to use the MDSs even if given the option to do so. While all agreed that the data was not 100% accurate and probably would never be, it was much better than the old paper-based G-Tab maps. One benefit of using the MDS, one worker stated, was that a large roll of maps was no longer needed. All respondents agreed that the key to the continued use of the MDS and GeoBase program was the maintenance and updating of the MDS data.

*MDS Usage Summary*

The AFF 103 Work Clearance Request program makes the most use of the MDS. Additionally, the MDS were used for the RWP process as well as training new personnel. The impact to the work centers has such that a reduction in time spent identifying problems and effecting repairs has occurred. All added that key to the sustained usage was keeping the MDS data current.

*Summation*

At CLD MDSs were designed based upon digitized CAD drawings that were converted into a format that was both GIS and SDSFIE compatible. Validation and re-validation of the data was an ongoing process that involved contractors, the GIS office, and the individual work centers. The goal of the GIS office is to have the most up to date data available to the users. Repetitive map requests from various organizations have led to the development of a map gallery where users access commonly requested maps. Meeting mission requirements has been achieved by using the MDS. Even knowing that the data was not 100% accurate, the work centers stated that they would continue to use the MDS.

### *Chapter Summary*

This chapter presented the results and analysis of the data collected at the four case locations. At each case location, personnel knowledgeable of the GeoBase program were interviewed and those interviews provided the research data. The data that was obtained was discussed in relation to the investigative questions as the questions related to the design, implementation, and usage issues as outlined in the Systems Development Life Cycle model.

# V. Summary

This Chapter discusses the summary of the research by using the SDLC model and will discuss the design, implementation, and usage issues as they relate to all case locations. A summary matrix is provided in Appendix E. Following this discussion, implications of the research project will be discussed. Next, recommendations, based upon the research findings will be put forth. The limitations of the research will follow. Finally, the chapter will conclude with suggestions for future research.

## *Results and Analysis*

### *Design Issues*

The research showed that the Mission Data Set design process was primarily founded upon data that the case location already had, namely the utilities infrastructure G-Tab Maps. Each case location imported the data from electronic AutoCAD® files using the ESRI ArcGIS software suite embedded file conversion capabilities. Three locations used AutoCAD® to assist in the importation of electronic “As-Built maps for inclusion into the MDSs. Additionally, each location re-validated the MDS data by conducting infrastructure surveys; three used a contractor while the other completing the re-validation in-house.

Several issues were raised as to having contractors conduct surveys for locating the infrastructure components. Most notably was that there was no one method that was totally reliable for identifying the underground components. Ground penetrating radar use was limited to objects greater than six inches in diameter as those components that were smaller than 6” generally could not be distinguished from the substrate. Also noted was that the absence of tracing wire or tracing tape that hampered locating and identifying buried features. While not totally accurate all case locations determined that a point-to-point representation of an infrastructure system’s probable path would provide the greatest level of precision. As new components were installed, or if original components were excavated, all case locations stated that the GIS office personnel would visit the work location so that the data could be captured by using Trimble ProXRS and/or GeoXT GPS data collection devices. Once the data was collected, the GIS technicians would update the specific MDS.

Data collection from MilCon and SABER projects occasionally proved to be problematic. Contract requirements, such as requiring contractors to install tracing tape or tracing wire when burying utility lines, contractors providing GIS data at key times during the construction process, or contractors not notifying the GIS offices when components were installed, were not enforced. All locations stated that they were working toward a solution though none had a definitive resolution.

Only one location stated that it had direct guidance from the parent MAJCOM regarding the MDS design. The direction the location received outlined the specific MDS data to collect, the attributes of the MDS data, and the legends for displaying the MDS features. This guidance enabled the case location in all steps required for MDS design including how the MDS data was to correspond with the SDSFIE. The parent MAJCOM also required quarterly accounting of compliance. This was not to say the other case locations did not have guidance; if they did, it was not as evident.

Although each location followed a different approach to MDS design, each thought that their respective data was complete enough for use and began the implementation phase.

*Implementation Issues*

The implementation phase for the MDS process was one that varied greatly from one location to another, with one common theme reverberating from all respondents, the necessity of accuracy of the components' data as it related to the location of the infrastructure components. All case locations agreed that obtaining 100% accuracy was not possible. In an ongoing effort to increase the data accuracy, the GIS office personnel were visiting work locations and capturing the data using the Trimble handheld and backpack data collection units. If the GIS office was unable to visit the work location, the work center personnel were providing hard copy prints with changes indicated and providing them to the GIS office for MDS updates.

Ensuring the data quality was an ongoing effort from all involved. Data from MilCon, SABER, and in-house work was also being provided to the GIS office, or when necessary, the GIS office would visit the work or construction location to capture the data. The data would then be uploaded into the respective MDSs. The goal at all locations was one in which all updates were entered into the system as soon as possible thereby ensuring the most accurate data was available for the work centers to use.

Of the four case locations, only one had an appointed data steward responsible for the specific MDS. The other three locations had an understanding that their specific organization should have data stewards, but none could identify who the steward was.

The GBPMs did recognize the need for data stewards, but were not able to appoint anyone to take responsibility for the data as they had not been granted that authority.

At the time of the site visits to the individual case locations, no portable computer equipment was in place that permitted workers to access the MDS from the work location. Workers were able to access the CIP and MDS via a network connection to the GeoBase server located within CE and available via the base's LAN. Using the ESRI ArcIMS web-based viewer workers could, based upon need and permissions, display different data layers so that necessary maps could be printed. When the work centers were not able to access the CIP and MDS, whether within the work center or at the work location, the GIS Office provided maps. One location had developed an online map gallery with hyperlinks to the most requested and commonly used maps.

*Usage Issues*

The primary use for the MDS at all case locations was for locating underground infrastructure components and for the AFF 103, *Civil Engineer Work Clearance Request* – Dig Permit. All locations had, to some degree, a Dig Permit program in place that relied heavily upon the MDS to validate the presence or absence of underground infrastructure components. All locations were also using the MDS for locating buried infrastructure components. It was stated at all case locations that as a minimum, the MDSs provide a starting reference point for locating underground components.

Some locations were using the MDS for the planning of reoccurring work along with routine job and work order planning. These locations stated that by having access to the MDS data planning times were reduced and they were more able to schedule accurately the work. Additionally, by using the MDS, all the organizations were able to determine the impact to facilities serviced by the system should a utility outage occur and how best to reroute services to minimize the impact of the outage. The respondents indicated that the impact of MDS usage to the work centers had been positive in that the time spent in both analyzing problems and effecting repairs had been reduced. Additionally, the work centers indicated that they would continue to use the MDS even if not required to do so. Key to the sustained usage was keeping the data current.

As stated, accuracy of the data was the key determinate regarding the daily use of the MDS. Work center personnel indicated that the data that indicated component locations on their paper-based maps and/or individual corporate knowledge were sometimes more accurate than the MDS. Changes and updates were given to the GIS office to be incorporated into the MDS and when made, new maps were printed and distributed to the work centers. The work centers indicated that they were pleased with the MDS in that the data was stored in a central location that could be easily accessed but still discussed that updates were not timely or not made at all.

*Discussion*

The research findings indicate that MDS design and implementation processes vary across organizations; however, fundamental similarities do exist. These similarities include the use of digitized maps, data files, and infrastructure surveys to create the MDS foundations. Maintaining the data accuracy was an ongoing effort that involved the GIS technicians as well as the work center personnel. While an MDS data accuracy threshold had not been determined at any of the four case locations, each location was working toward having accurate data available within the GeoBase system. At the same time, an evolution and maturation of these processes was evident.

As for MDS usage within the Electrical and Utilities Work Centers, it was found that MDS usage is increasing; however, data quality is a limiting factor. All locations indicated that the MDS data accuracy was the key determinate on how the MDS were used. Where the MDS data was considered, by the case location, generally accurate and acceptable, efficiency within the work center was increasing as time to locate infrastructure components and effect repairs had been reduced. An additional factor that MDS usage was based on was the ease of MDS access. Those locations that could readily access the MDS from the work center made greater use of the MDS. Based on the research findings, recommendations are put forward for improving wing/base-level GeoBase program design, implementation, and usage.

### *Recommendations*

#### *Data Stewards*

The first recommendation of the research relates to the maintaining the accuracy and currency of the data. A data steward needs to be appointed and accountable for the data within the MDS. It is not enough for an organization to design MDS data layers; the MDS data should be consistently maintained. The Engineer Assistants receive GeoBase training at their Technical School, but that does not automatically, nor by default, make the EAs the data stewards. The data steward must have detailed knowledge of the specific infrastructure system (i.e. electrical, water, sewer, etc.) as well as a working knowledge of the data collection techniques, the SDSFIE, and how to update the MDS databases. The data steward's duties do not relieve the GIS office of ensuring that all data is SDSFIE compliant, but the data steward and GIS office need to work together to ensure accurate data for the work centers to use to meet mission requirements.

*GIO/GIS Chain of Command*

The second recommendation relates to the GIO/GIS Chain of Command. The need for a chain of command is a necessary component within any organization as not only is it a method of relaying information from leaders to workers and vice versa but also establishes lines of responsibility. It is with this in mind that a standardized chain of command should be established between the commander – who ultimately is responsible for the GeoBase program – and the GIO/GIS office. If the GIO/GIS office is placed in the chain of command too far from the commander, time sensitive answers and decisions may not be afforded, while too close within the chain of command and the possibility of micromanagement exists. This research is not suggesting a specific placement within the organization; that decision should be made at the MAJCOM or higher level. Rather, this research is suggesting that the shortest possible chain of command be used between the commander and GIO/GIS.

*Data Accuracy and Collection*

The third recommendation is central to MDS usage -- data accuracy. The research found that there was not a set level of acceptable accuracy and therefore a level should be established. None of the case locations could quantify their level of MDS data accuracy; they stated that they were working toward accurate data by re-validating the MDSs. It is recommended that a minimum acceptable threshold for the level of data accuracy and accountability of infrastructure components validated be established by the

MAJCOM or higher level. Work center personnel stated that accuracy was the driving factor in whether MDS usage would continue.

To achieve a high level of MDS data accuracy, all personnel associated with the MDSs, from the GIS office to the individual worker, needs to be trained in MDS data collection techniques and on the data collection devices. Time spent for a GIS technician to travel from his office to a remote work location to capture a component's features and attributes while work center personnel are there already is a waste of time and resources. If the workers were trained in data collection techniques, the MDS data could be collected immediately versus waiting for the GIS technician to arrive at the work site. The GIS technicians would still be responsible for updating the MDS, but by having the workers trained in data collection, the GIS technicians can focus more on keeping the MDS updated and current.

*Funding*

The fourth recommendation relates to funding. As with any program, its success resides in how well the program is funded. Each case location stated that money was needed for training, software, hardware, and personnel. All case locations understood that the fiscal resources were scarce, nevertheless, all stated that the installation might have to help fund the GeoBase program if it is to be successful. Funding should focus on two main areas: training and MDS data re-validation. Those working directly with the data collection and maintenance needs to be trained to use the equipment and software as addressed earlier. Coupled with that, the MDS data re-validation should also be funded. This means that a contract or contracts would be written and executed for the MDS data re-validation or equipment could be purchased for in-house data collection. It is recommended that if a contractor is to be used for data collection, the contract should be written so that individual utility system (electric, water, sewer, etc.) data is collected by surveying the installation in sectors.

*Construction Contracts*

The fifth recommendation concerns construction contracts. As discussed earlier, AutoCAD® "as-built" drawings are not accurate and are generally provided to the GIS office at the end of a construction project. While it may require additional funding, construction project contracts, including SABER projects, should have stipulations included that the contractor provide GPS, feature, and attribute data for utility infrastructure components at specified times in the construction process. By collecting the GPS data throughout the construction project, an accurate depiction of the utility path can be achieved thereby improving the overall accuracy of the specific MDS. Future projects, in-house or other construction projects, can benefit from having accurate MDS data in that cost estimating can be more precise as well as reducing work time in having to locate buried components. Additionally, construction contracts should include the requirement that contractors place tracing wire/tape with the infrastructure components that are buried. This recommendation is in addition to requiring the collection of GPS data. The placement of the tracing wire/tape can help clarify any future questions relating to the actual placement of the infrastructure component.

*Computer Access at Work Locations*

The final recommendation addresses MDS access at the work location. Organizations could provide portable computer equipment (laptops, tablet PCs, Personal Data Assistants) to the work centers for use at the work site. The computer equipment would have MDS viewing tools installed along with electronic copies of the MDSs. Several respondents stated that having access to the MDS at the work site could decrease the time spent in locating components, such as water valves, so that repairs could be expedited. The researcher had been present at several emergency repairs for broken primary and secondary water lines and observed countless man-hours wasted in determining the presence or absence of infrastructure components by waiting for other work center personnel to respond to the location to mark buried infrastructure components. If the Utilities personnel had immediate access to MDSs at the work location, the section of water line that was broken could have been isolated, water services rerouted around the break, and valuable Air Force money saved by not having had other work centers respond to search for their respective buried components. Also aiding in the MDS access at the work location is the addition of a base-wide wireless network. While the installation of a wireless network was beyond the scope of this research project, it could be of benefit to not only to the Electrical and Utilities work centers, but to other agencies (Fire Department, Security Forces, etc.) as well. Having immediate access to MDS data located on the local GeoBase server could increase the response capabilities as well as reducing the time needed to make potential life and death decisions by an on-scene commander.

*Implications*

The implications of the research were such that the Systems Development Life Cycle provided a solid foundation and guideline for the investigation of design and implementation of the Electrical and Utilities Mission Data Sets. In the introductory chapter, it was stated that there were organizations that did not know where or how to begin the MDS process. Using the SDLC model as a guideline along with the findings of this research, organizations may have a road map to follow in establishing their own Mission Data Sets. This roadmap is not limited to strictly the Civil Engineer community, but to other organizations that have a high reliance on geospatial data and/or maps. Such organizations might include the Communications Squadrons/Groups and Security Forces. While it might be possible for these organizations to develop their respective MDS without assistance, the benefit of coordinating with CE is that these organizations' MDS would integrate seamlessly into the CIP and compliment MDSs.

### *Limitations*

There were several limitations that had an impact on the research. First of all, it had been determined very early in the research process that Case Location A should be the pilot study location with two additional case locations to added to achieve a literal replication for external validity. As stated previously, as a condition of funding the research sponsor directed the addition of a fourth case location. While adding a fourth location should strengthen the external validity, exact literal and theoretic replication was difficult to achieve as this location differed greatly from the other case locations, as a contractor was responsible for the majority of the organization's daily operations. Full discussion of this issue was addressed in Chapter III.

A limitation regarding the researcher must also be addresses. This research project was the first ever attempted by the researcher, the lack of experience might have resulted in unintentional bias. The researcher had personal bias regarding the GeoBase program in that he believes that the program, regardless of MDS data accuracy, is an invaluable tool that will benefit all organizations, not just the Civil Engineers. This personal bias could cloud the interpretations of the data.

Several potential limiting factors regarding the interviewees might exist. Concern was initially raised during the case selection process from a location's commander that the research might be seeking to identify and publicize problems associated with the organization's GeoBase program. Assurances were given that that was not the case, but rather the research was attempting to learn "best practices" that could be expressed to other organizations beginning their own MDS design and implementation processes. The concern regarding the exact nature of the research as well as the uncertainty of possible repercussions associated with answering the interview questions may have produced incomplete answers. While every attempt was made to assure the respondents that what was said during the interviews would only be used in general terms and that every effort would be made to protect respondent's identities, there was still some hesitation and concern on the part of the respondents when answering the questions. For these reasons, the data might not be complete.

Time constraints might also contribute to flaws limitations with this research project. Travel time for conducting interviews was limited to a two-week window in which the four case locations were visited. Each site visit was scheduled for two consecutive days in which interviews and observations were to take place. At one location, time had to be reduced due to pending severe weather. The location's POC was able to schedule personnel to ensure that a sufficient pool of personnel was available, but time was limited for a thorough investigation. A follow-up visit was not possible.

Additionally, as the site visits were conducted toward the end of the fiscal year, some potential respondents were on leave and unavailable.

The research data itself may be a limitation to the project in that there was an excess amount of interview data. While every attempt was made to glean the relevant and pertinent data from the interview transcripts, the sheer volume of data was difficult for a single researcher to sift through. Additionally, as the researcher transcribed all interviews, the potential information overload was increased.

### *Future Research*

Several recommendations were discussed regarding possible improvements for an organization's GeoBase program. Among these improvements was the appointment of a data steward. Possible follow-on research would be to conduct case study research of organizations that have appointed data stewards who are held accountable for the accuracy and completeness of the MDSs. As the GeoBase program will expand and encompass other organizations, a study of how these other organizations have designed, implemented, and use their respective MDSs might prove useful. Finally, a survey instrument might be developed seeking to examine several GeoBase issues. These might include the level of MDS data accuracy, organizational emphasis regarding GeoBase training (who is trained, how is training accomplished, how is training funded, etc.), and where in the organization the GeoBase/GIS functions are located.

Though no single case location had a "perfect" GeoBase program, as a whole they marry together to form a foundation and guideline for other bases to emulate in order to have a successful program. By using the lessons learned during this research, other bases can more readily see what the design, implementation, and usage issues are. Additionally, those reading this report can discover how these case locations were able to overcome, or make suggestions on how to overcome them as well as having the shop level perspective on how GeoBase can be used in the work centers and what is necessary for that usage. The success of the design and implementation is in the usage.

*Summary*

This chapter discussed the design, implementation, and usage issues as they related across all case locations. The implications of the research were discussed and how the research might apply to other organizations. Next, based upon the research, recommendations were put forth to bolster a Civil Engineer's GeoBase program. Limitations of the research were also discussed. The chapter culminated in the discussion of possible follow-up research projects.

## Appendix A: Abbreviations

AFF – Air Force Form

CAD – Computer Aided Design

CAT – Crisis Action Team

CD – Compact Disc

CIP – Common Installation Picture

CLA – Case Location A

CLB – Case Location B

CLC – Case Location C

CLD – Case Location D

CONOPS – Concept of Operations

COTS – Commercial of the Shelf

CS – Communications Squadron

DAF – Department of the Air Force

DoD – Department of Defense

DRU – Direct Reporting Unit

ESRI – Environmental Systems Research Institute

GBPM – GeoBase Program Manager

FFP – Firm-Fixed-Price

FGDC – Federal Geographic Data Committee

FOA – Field Operation Agency

FOL – Forward Operating Location

GIO – GeoIntegration Office

GIS – Geographic Information System

GPR – Ground Penetrating Radar

GPS – Global Positioning System

HAF – Headquarters Air Force

IS – Information System

IT – Information Technology

MAJCOM – Major Command

MDS – Mission Data Set

MMO – MAJCOM Mission Orientation

MilCon – Military Construction

NCC – Network Control Center

NCOIC – Non Commissioned Officer in Charge

NEPA – National Environmental Policy Act

OPR – Office of Primary Responsibly

POC – Point of Contact

PWS – Performance Work Standards

QA – Quality Assurance

RWP – Reoccurring Work Program

SDSFIE – Spatial Data Standards for Facilities, Infrastructure, and Environment

SDTS – Spatial Data Transfer Standard

SSN – Social Security Number

TSSDS – Tri-Services Spatial Data Standards

USMARC - U. S. Machine Readable Cataloging

## Appendix B: Interview Questions

Interview Questions

1. How were the Electrical and Utilities Work Centers' Mission Data Sets created?
2. How did the Electrical and Utilities Work Centers determine what data elements to put within the Mission Data Set?
3. How was hardware/software used to capture these Mission Data Sets?
4. How is the information quality (e.g. accuracy, currency) of these Mission Data Sets maintained once they are developed?
5. How is Mission Data Set (mapping layer) information accessed by users?
6. How are Electrical and Utilities Work Center Mission Data Sets used in meeting mission requirements?
7. How does use of Electrical and Utilities Work Center Mission Data Sets impact the work efficiency within the work centers?

The sub-questions are key issues that the researcher is attempting to investigate. They may or may not be asked, depending on the answers given during the interview.

1. How were the Electrical and Utilities Work Center's Mission Data Sets created?
    a. Were different processes used when developing the electrical and utilities work centers' MDS?
    b. What were the steps followed?
    c. Did you complete one MDS first, i.e. electrical before utilities or were they developed simultaneously?
    d. How did you validate the location of underground infrastructure components?
    e. How are additions to the infrastructure captured after in-house work, construction, or SABER?
    f. Is the MDS data placed in single or multiple layers (one layer showing mains/primary, another showing laterals/secondary, etc)?

2. How did the Electrical and Utilities Work Centers determine what data elements to put within the Mission Data Set?
    a. How were those elements determined?
    b. Do you have a set legend for the elements?

3. How was hardware/software used to capture these Mission Data Sets?
    a. Was COTS used? Was GPS equipment used?
    b. What CAD software was used and why?
    c. Were any portable computer components used? If so, what were they and how were they used?
    d. Where are the individual MDS stored, such as an internal network, base network, and/or local computer?

4. How is the information quality (e.g. accuracy, currency) of these Mission Data Sets maintained once they are developed?
   a. How often are the MDS updated?
   b. How is new and/or updated information input into the MDS?
   c. How is new and/or updated information validated?
   d. Does the organization have an individual who is the MDS data steward and, if so, how was that individual selected?

5. How is Mission Data Set (mapping layer) information accessed by users?
   a. How do you access the MDS?
   b. Can you access the MDS from the work site? If so, how?
   c. Can you selectively determine what you see (turn on/off layers)?
   d. Do you print out hard copies, if so, how often?

6. How are Electrical and Utilities Work Center MDS used in meeting mission requirements?
   a. How does your work center use the MDS?
   b. What shop work makes the most use of MDS?
   c. Are the MDS used on a daily basis, why or why not?
   d. Are the MDS used for planning routine and emergency work, if so, how?
   e. Have you found any other uses for MDS besides work planning and execution, and if so, what are they?
   f. Are the MDS used for specific programs/processes such as AFF 103 clearances?

7. How does use of Electrical and Utilities Work Center MDS impact the work efficiency within the work center?
   a. Has using the MDS impacted daily operations in your work center? If so, how?
   b. Have you seen any benefits to using MDS? If so, what are they?
   c. If the commander indicated that you did not have to use MDS in your work center, would your work center continue to use the MDS, why or why not?

8. If you had to start the MDS design and implementation processes from the start, is there anything that you would do differently, why or why not?

## Appendix C: Informed Consent Document for Participation in a Thesis Research Project

### An Investigation of GeoBase Design, Implementation, and Usage within Air Force Civil Engineer Electrical and Utilities Work Centers

**1. Nature and Purpose:** You have been asked to volunteer to act as a subject in the research project named above. The purpose is research how Mission Data Sets are designed and implemented within your work center and what the impacts are of using Mission Data Sets on daily operations. The time requirement is for approximately 1/2 hour for the interview and 1/2 hour to review the transcript of that interview. The research is being conducted at

______________________________________________________ AFB, _________.

**2. Experimental Procedures:** An interview will be conducted in which you will be asked questions relating to the development/implementation of Mission Data Sets and what impact the use of Mission Data Sets has on daily operations. The interview will be conducted in a private, office-like setting and may be recorded if you consent. If recorded, you and the audio tape of your responses will be assigned an identification code that will be used by only me, the researcher. At no time will the code be reveled to anyone, nor will the code and audio tape be stored together. Your answers will be treated as confidential. At any time, you or I have the right to terminate the interview for any reason.

**3. Discomfort and Risks:** There are no risks associated with this interview, as you will not be asked to perform any physical tasks.

**4. Benefits:** You understand there are no benefits, direct, indirect, tangible, intangible, or monetary, associated with my participating in this interview.

**5**. **Alternative:** You have the right to refuse to be a participant in this study. If you choose not to participate, there will no negative impact nor will anyone know of your decision.

**7. Entitlements and Confidentiality:**
a. Records of your participation in this study may only be disclosed according to federal law, including the Federal Privacy Act, 5 U.S.C. 552a, and its implementing regulations.
b. The decision to participate in this research is completely voluntary on your part. No one has coerced or intimidated you into participating in this program. You are participating because you want to. MSgt Loeber, AFIT/ENV, DSN 787-3636 x 6050 has adequately answered any and all questions you have about this study, your participation, and the procedures involved. You understand that MSgt Loeber will be available to answer any questions concerning procedure throughout this study. You understand that if significant new findings develop during the course of this research, which may relate to

your decision to continue participation, you will be informed. You further understand that you may withdraw this consent at any time and discontinue further participation in this study without prejudice.

________________________________ ________________________________
Volunteer Printed Name, Grade/rank Volunteer Signature and Date

PAUL C. LOEBER, MSGT ________________________________
Investigator Printed Name, Grade/Rank Investigator Signature and date

**Informed Consent to Audio Recording**

I authorize the audio recording of my interview

________________________________ ________________________________
Volunteer Printed Name, Grade/rank Volunteer Signature and Date

PAUL C. LOEBER, MSGT ________________________________
Investigator Printed Name, Grade/Rank Investigator Signature and date

**Privacy Act Statement**

**Authority**: We are requesting disclosure of personal information, to include your Social Security Number. Researchers are authorized to collect personal information (including social security numbers) on research subjects under The Privacy Act-5 USC 552a, 10 USC 55, 10 USC 8013, 32 CFR 219, 45 CFR Part 46, and EO 9397, November 1943 (SSN).
**Purpose**: It is possible that latent risks or injuries inherent in this experiment will not be discovered until some time in the future. The purpose of collecting this information is to aid researchers in locating you at a future date if further disclosures are appropriate.
**Routine Uses**: Information (including name and SSN) may be furnished to Federal, State and local agencies for any uses published by the Air Force in the Federal Register, 52 FR 16431, to include, furtherance of the research involved with this study and to provide medical care.
**Disclosure**: Disclosure of the requested information is voluntary. No adverse action whatsoever will be taken against you, and no privilege will be denied you based on the fact you do not disclose this information. However, your participation in this study may be impacted by a refusal to provide this information.

**Informed Consent Document for "Quoting" Interview**
**An Investigation of GeoBase Design, Implementation, and Usage within Air Force Civil Engineer Electrical and Utilities Work Centers**

You have agreed to participate in the research study of how Mission Data Sets are designed and implemented within my work center and what the impact of using Mission Data Sets are on daily operations. You also were given the opportunity to consent to having your interview audio taped.

In addition to the above consents, you are now given the opportunity to consent to have portions of your interview "quoted." As indicated in the Informed Consent document, a copy of the transcript will be returned to you for your review. Using "quotes" may add validity to the research and make the final research product more functional and useful within the Air Force.

I understand that consent to "quoting" is strictly voluntary and will not affect my participation in this study in any way.

I hereby give my consent to be quoted in the research project.

| | |
|---|---|
| ______________________________ | ______________________________ |
| Volunteer Printed Name, Grade/rank | Volunteer Signature and Date |
| PAUL C. LOEBER, MSGT | ______________________________ |
| Investigator Printed Name, Grade/Rank | Investigator Signature and date |

**Privacy Act Statement**

**Authority**: We are requesting disclosure of personal information, to include your Social Security Number. Researchers are authorized to collect personal information (including social security numbers) on research subjects under The Privacy Act-5 USC 552a, 10 USC 55, 10 USC 8013, 32 CFR 219, 45 CFR Part 46, and EO 9397, November 1943 (SSN).
**Purpose**: It is possible that latent risks or injuries inherent in this experiment will not be discovered until some time in the future. The purpose of collecting this information is to aid researchers in locating you at a future date if further disclosures are appropriate.
**Routine Uses**: Information (including name and SSN) may be furnished to Federal, State and local agencies for any uses published by the Air Force in the Federal Register, 52 FR 16431, to include, furtherance of the research involved with this study and to provide medical care.
**Disclosure**: Disclosure of the requested information is voluntary. No adverse action whatsoever will be taken against you, and no privilege will be denied you based on the fact you do not disclose this information. However, your participation in this study may be impacted by a refusal to provide this information.

# Appendix D:  Investigative Question Summaries

*Table 4.  Case Location A Investigative Questions Summary*

| | Investigative Questions<br>Design Issues | Respondent 1 | Respondent 2 | Respondent 3 | Respondent 4 | Respondent 5 | Respondent 6 |
|---|---|---|---|---|---|---|---|
| Q1 | **How were the Electrical and Utilities Work Center's MDS created?** | Digitized CAD files placed in separate layers by attribute, validation in progress | Digitized CAD files formed foundation placed in multiple layers by sub-type validation unknown | CAD files and aerial photos placed in multiple layers validation unknown | CAD files and survey loaded in data tables placed in multiple layers validation unknown | Digitized CAD files placed in multiple layers by feature no validation | No response |
| Q2 | **How did the Electrical and Utilities Work Centers determine what data elements to put within the MDS?** | Based on SDSFIE | Based on SDSFIE and CAD | Experience | Unknown | Not Asked - no knowledge | No response |
| Q3 | **How was hardware/software used to capture the MDS?** | Hardware - Trimble Software - CAD ESRI Stored in Oracle® data server in CE | Hardware - Trimble Software - CAD ESRI In CE server | Hardware - unknown Software- AutoCAD® Server location unknown | Hardware - Trimble Software - Unknown CE server | Not Asked - no knowledge | No response |
| | **Implementation Issues** | | | | | | |
| Q4 | **How is the information quality of these MDS maintained once they are developed?** | MDS model is used data input using ESRI validated at site data steward - shop or 4 letter level | GIS office is QA data input using GPS validated at site data steward is GIS office | GIS and this office data input using GPS validated on site data steward - yes based on experience | GIS office is QA data input from files validated as needed data steward - unknown | Quality maintained - not done data validated - not done | No response |
| Q5 | **How is MDS (mapping layers) information accessed by users?** | Web-based viewer user can select what is displayed with prints made as needed | Web-based viewer user can select what is displayed with prints made annually for archive | Web-based viewer user can select what is displayed with prints made as needed | Web-based viewer user can select what is displayed with prints made as needed | Web-based viewer user can select what is displayed with prints made as needed | Web-based viewer user can select what is displayed with prints made as needed |
| | **Usage Issues** | | | | | | |
| Q6 | **How are Electrical and Utilities Work Center MDS used in meeting mission requirements?** | AFF 103, siting, prints, Work Order and facility management MDS are used daily | Emergency response, locates, aircraft accident response MDS are used daily | Verify Work Orders, AFF 103, hurricane planning MDS are not used daily | Reference, locates, AFF 103 MDS are used daily | Locates, AFF 103, long range planning, Reoccurring Work Program | Update maps, unknown for other uses or processes, MDS are not used daily |
| Q7 | **How does the use of Electrical and Utilities Work Center MDS impact the work efficiency?** | Increase efficiency as user interface is simplified, as results seen would continue to use | Some efficiency minimizes duplication, not asked about continued use | Unknown impact to efficiency, benefited construction contracts, would continue to use | Unknown impact | Unknown impact assumes so, would continue to use | Yes, if accurate, would continue to use if accurate |

*Table 5. Case Location B Investigative Questions Summary*

| | Investigative Questions<br>Design Issues | Respondent 1 | Respondent 2 | Respondent 3 | Respondent 4 | Respondent 5 |
|---|---|---|---|---|---|---|
| Q1 | **How were the Electrical and Utilities Work Center's MDS created?** | Digitized CAD, GPS survey and toning, completed at same time | Digitized CAD, GPS survey - connect the dots, in-house collection of new, single layers | Multiple digitized formats, completed at same time, not validated, digital "as-built" for new data | Contractor digitized, GPS validation of some, "as-built" for new data, single layer | Contractor GPS and convert to ESRI, individual survey, validated when surveyed, single layer |
| Q2 | **How did the Electrical and Utilities Work Centers determine what data elements to put within the MDS?** | Unknown | In-house developed, no set legend, | SDSFIE | Unknown | Based on funds for survey, used G-Tabs for reference, unknown on legend |
| Q3 | **How was hardware/software used to capture the MDS?** | GPS used, type unknown, AutoCAD® software | GPS used type unknown, data stored on network drive somewhere on LAN, | AutoCAD® software and GPS | Unknown hardware/ software used, MDS on network drive belonging to CE - somewhere on base | Trimble GPS with AutoCAD®, internal server on base network |
| | **Implementation Issues** | | | | | |
| Q4 | **How is the information quality of these MDS maintained once they are developed?** | Initial data from contractor bad, GIS office does, try to GPS when possible, no designated data stewards | Initial data from contractor bad difficult to locate, GPS open sites, GIS office does maps and data | Data maintenance ongoing, survey done compared to G-Tabs - no difference, GPS open sites, no data stewards | Data not maintained - not enough manning, GIS office told not priority - maps are, no data stewards | Updates based on info from field, drafting section updates, no data stewards |
| Q5 | **How is MDS (mapping layers) information accessed by users?** | Prints from GIS office, future web-based viewers, can select layers to be displayed | Prints from GIS office when needed, zoom in on display to see and select for prints | MDS loaded on one shop level laptop, prints made to redline maps, also used for making wall maps | MDS loaded on one shop level laptop, no work site access - paper only, selectively determine what is seen | Web-based viewer just loaded, traditionally hard print, selectively determine what is seen |
| | **Usage Issues** | | | | | |
| Q6 | **How are Electrical and Utilities Work Center MDS used in meeting mission requirements?** | Shops have RWP process that uses MDS, reference only - data not good, used for AFF 103 process | Used for AFF 103 process, used to locate adjacent utilities, used for some planning, used to orient new people | Prints for shop trucks, limited by contract, prints made for repairs, also used for exercises | Used for RWP, some data not accurate - use old G Tabs or corporate knowledge instead, also used for AFF 103 process | Used for AFF 103 process and contingency situations |
| Q7 | **How does the use of Electrical and Utilities Work Center MDS impact the work efficiency?** | Huge decrease as maps/data inaccurate, focus seems to be on short term cost v. long term benefits | data is erroneous in connecting the dots, clarification for digging, probably would continue to use | Used for locations for repairs, data not good enough for real use, would continue to use if data was collected | Data is vague, legends/symbols not correct, wastes time, would continue to use if data was accurate | Impact unknown, might want to go back to paper based, GeoBase not totally engrained |

*Table 6. Case Location C Investigative Questions Summary*

| | Investigative Questions<br>Design Issues | Respondent 1 | Respondent 2 | Respondent 3 | Respondent 4 | Respondent 5 |
|---|---|---|---|---|---|---|
| Q1 | **How were the Electrical and Utilities Work Center's MDS created?** | Converted from CAD to GIS, directed by MAJCOM, started at same time, connect the dots, collected as trench was open | MAJCOM directed, converted from CAD, completed together, connect the dots, "as-builts", one layer | Electric captured by GPS, collected at same time, "as-builts", one layer by attributes | GIS office collected points, connect the dots - not always accurate, GPS new components, both multi - single layer | Data collection - unsure, GPS'd components for validation, single layer but distinguishable |
| Q2 | **How did the Electrical and Utilities Work Centers determine what data elements to put within the MDS?** | Work Center inputs as to what they want and need | MAJCOM directives, work center inputs, compliant with SDSFIE | MAJCOM directed, limited work center input | Not sure how created but doesn't always match standards | Not sure how determined but are detailed and useful |
| Q3 | **How was hardware/software used to capture the MDS?** | ProXRS used by GIS and shops, ArcGIS 8.3 software, GeoBase server with Oracle in an IMS site | ProXRS and 5700, used AutoCAD with ArcGIS, Oracle based server on the base network | ProXRS mainly with GeoXT back up, ProXRS and GeoXT have input capability, server on the base network | Backpack unit name unknown, data available on network, concern raised regarding disclosure and access | Hardware/software not addressed, MDS access by requesting prints from GIS office |
| | **Implementation Issues** | | | | | |
| Q4 | **How is the information quality of these MDS maintained once they are developed?** | Spot checks surveys "as-builts", survey done with 5700, no official data stewards but need someone to take responsibility | Map books with grid system with changes indicated, updates done as info given, 5700 used for survey, data steward is shop | Discussions with the shops, review shop maps, updates not done often, will use 5700 to confirm and update, no one with data steward title | Contact GIS office with changes, not sure how long to update, not sure how data steward is might be someone in GIS office | Not sure how data is updated but when needed it is, not sure who is responsible for data |
| Q5 | **How is MDS (mapping layers) information accessed by users?** | ArcIMS from base's home page, no access at work site other than maps, can select what is viewed, prints made as needed | Tab maps on the web in .pdf format and map books, not accessible at work site, can select what is displayed, prints made as needed | ArcIMS server and map books, wireless not available, load on desktop in .pdf or PowerPoint, select by service type, prints as needed | Web not as accurate as GIS office prints, no access at work site, select by service type, prints as needed | Prints from GeoBase office and desktop app, select what is displayed, prints as needed |
| | **Usage Issues** | | | | | |
| Q6 | **How are Electrical and Utilities Work Center MDS used in meeting mission requirements?** | Planning and scheduling, also for locates, somewhat used for AFF 103 | Shops using web based viewers, AFF 103 uses MDS, updated maps posted weekly, also used for planning | Used for locates, not sure about other uses | Still use G-Tabs from time to time, used for locates and determine impact for outages, used extensively for AFF 103 | Used extensively for RWP and for scheduling, used with corporate knowledge, also used for locates |
| Q7 | **How does the use of Electrical and Utilities Work Center MDS impact the work efficiency?** | As data is updated assume increase in efficiency, benefit in archiving system, no impact if stopped as shops prefer paper maps | Should replace paper-based maps - could lose info if maps get wet, needs to be simple, will continue to use as they see the data | Reduces time spent in locates, would continue to use if the data was kept up to date | Shops not always using, not sure if use would continue | Speeds up tasks, can direct someone to exact location, know where components are, would continue to use - make job easier |

*Table 7. Case Location D Investigative Questions Summary*

| | Investigative Questions<br>Design Issues | Respondent 1 | Respondent 2 | Respondent 3 | Respondent 4 |
|---|---|---|---|---|---|
| Q1 | **How were the Electrical and Utilities Work Center's MDS created?** | Converted CAD to GIS, data SDSFIE compliant, Utilities started first then Electric, used point-to-point validation, MDS in single layer | Converted existing data sets and CAD to GIS, validate in open trenches, MDS in multiple layers | Began with drawing files then GPS'd components, MDS created at different times, validated based on corporate knowledge and GPS | Created in Drafting section, they come out and GPS the component, MDS on one layer |
| Q2 | **How did the Electrical and Utilities Work Centers determine what data elements to put within the MDS?** | Based on listing in SDSFIE, converted from short name to long naming schema, legend based on local color schema | Unknown how developed, but complex | Determined in the GIS office, shows everything, can specify what you want to see | Unknown, maybe from hard prints |
| Q3 | **How was hardware/software used to capture the MDS?** | Trimble XRS Pro, ArcView, ArcPad, iPaq, MDS stored on internal server attached to LAN | GPS equipment, previously used AutoDesk® and AutoCAD®, GeoBase server can access via the web using ArcIMS | Unknown hardware/software, stored on main CE network on a drive | AutoCAD®, access the internal network |
| | **Implementation Issues** | | | | |
| Q4 | **How is the information quality of these MDS maintained once they are developed?** | Hit or miss - CIP is accurate, CIP and well used MDS daily other data as needed, new data input by GPS done by survey, no data stewards | GIS office compares data with shops redlines and "as-builts" from contractors, no data stewards | Maintained by shop - if wrong GIS office will fix, constant updates, shop personnel assist with validation, data steward unknown | Completed projects to GIS office for updating, not sure how or who maintains data |
| Q5 | **How is MDS (mapping layers) information accessed by users?** | ArcIMS web-based viewer focus on customer, cannot access at work site, can select what to see, print special maps as needed | ArcIMS, can select what is seen, maps printed annually | Foreman can access from computer, shop uses GPS to locate components, can select by component or area, maps printed annually | Access via web to GIS/GeoBase address, all work center specific data displayed at once, print twice a month or more for locates |
| | **Usage Issues** | | | | |
| Q6 | **How are Electrical and Utilities Work Center MDS used in meeting mission requirements?** | Shop use more for schematic - unknown daily usage, main organizational use is for AFF 103 - drove how and why data collected | Main use is AFF103 - custom app based on ArcIMS, unknown about daily usage, used for planning and design work | AFF 103 and locates, planning job and work orders, used for RWP, training for new personnel on map reading and locates | Usually locates, not sure about daily use, hard maps to check component operability, validating contract work, trying to replace wall map |
| Q7 | **How does the use of Electrical and Utilities Work Center MDS impact the work efficiency?** | Not sure on impact, would continue to use as accuracy appears to be improving, MDS gives them good starting point | Significant over paper maps, can run queries on what they want to see, benefits in productivity, not sure if use would continue | Smoother and more organized, know layout for utilities - expedites work, would continue to use - no need for large roll of maps, accuracy is key | Cuts down locate times if accurate, troubleshooting - minimizes delays in identifying problem, would use if updated and accurate |

# Appendix E. Composite Investigative Questions Summary

*Table 8. Composite Investigative Questions Summary*

| | Investigative Question | Case Location A | Case Location B | Case Location C | Case Location D |
|---|---|---|---|---|---|
| | **Design Issues** | | | | |
| Q1 | **How were the Electrical and Utilities Work Center's MDS created?** | Digitized CAD files, MDS in multiple layers by attribute, validation unknown but in progress | Digitized CAD, used GPS survey for validation, connect the dots, completed at same time, as-builts for new data, MDS in single layer | Directed by MAJCOM, converted from CAD, used GPS to validate, connect the dots, use "as-builts", | Converted CAD to GIS - SDSFIE compliant, electric first, validated by GPS and corporate knowledge, MDS in single layer |
| Q2 | **How did the Electrical and Utilities Work Centers determine what data elements to put within the MDS?** | Based on SDSFIE and CAD | No set legend, in-house developed, used G-Tabs for reference | MAJCOM directed with work center inputs based on need SDSFIE compliant | Based on SDSFIE with local inputs |
| Q3 | **How was hardware/software used to capture the MDS?** | Hardware - Trimble, software - CAD ESRI, stored in CE Server | Hardware - Trimble GPS, software - AutoCAD® ESRI ArcGIS, MDS on base's network with server located in CE | Hardware - Trimble ProXRS, GeoXT, and 5700, software - AutoCAD and ArcGIS, MDS on base network - server in CE | Hardware - Trimble ProXRS, Software - ArcView, ArcPad, AutoCAD®, MDS stored on internal server connected to base network |
| | **Implementation Issues** | | | | |
| Q4 | **How is the information quality of these MDS maintained once they are developed?** | GIS office QA for data, GPS used to validate data at work site, data steward at 4-letter level or GIS office | Initial data bad, GIS office tries to GPS open sites and update data as received, no data stewards | Map books and "as-builts" given to GIS for updates, will survey with Trimble 5700, no data steward | CIP is accurate, GIS office updates MDS as received, Updates and new data from red lines and contractor "as-builts", no data stewards |
| Q5 | **How is MDS (mapping layers) information accessed by users?** | Web-based viewer, can select what is displayed, prints made as needed | Prints from GIS office, no access at work site, can select what is displayed, | ArcIMS web-based viewer, can select was is displayed, no access at work site, map books of prints made for work centers | ArcIMS web-based viewer, cannot access at work site, prints made as needed, prints made annually for archives |
| | **Usage Issues** | | | | |
| Q6 | **How are Electrical and Utilities Work Center MDS used in meeting mission requirements?** | AFF 103, locates, RWP, emergency response planning, validate work orders | RWP, AFF 103, used for reference only, used for locates, used during contingency operations | AFF 103, locates, planning and scheduling for RWP | AFF 103, locates, RWP, training, planning and design work |
| Q7 | **How does the use of Electrical and Utilities Work Center MDS impact the work efficiency?** | Impact unknown, benefited construction contracts, some efficiency in reduced redundancy, would continue to use if accurate | Data not good enough for daily use but will use for AFF 103, would continue to use if data was accurate | Decreased time in locates, benefit in archiving system, would continue to use if data kept up to date | Cuts down locate times, expedites work, more organized, minimizes delays in identifying problems, would continue to use if accurate |

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## Vita

MSgt Paul C. Loeber graduated from St. Paul's College High School in Concordia, Missouri. He entered junior college at St. Paul's College in Concordia, Missouri where he graduated with an Associate of Arts degree in 1984. He enlisted in the Air Force in October 1984 and was trained as a Carpenter Apprentice. His first assignment was at the 7275th Civil Engineer Squadron, San Vito Air Station, Italy in January 1995. In November 1986, he was assigned to the 92nd Civil Engineer Squadron, Dyess AFB, Texas where he worked as a carpenter, locksmith, and mobility NCO. In August 1992, he was assigned to the 37th Civil Engineer Squadron, Lackland AFB, Texas where he worked as the squadron's mobility NCO. Additionally, he graduated from the University of Texas at San Antonio with a Bachelor of Arts degree in Criminal Justice. In June 1995 he was assigned to 36th Civil Engineer Squadron, Andersen AFB, Guam where he supported JTF .PACIFIC HAVEN. In November 1996, he was assigned to the 375th Civil Engineer Squadron, Scott AFB, Illinois working a variety of positions within the squadron. While stationed at Scott, he led a 16-man deployment team to Al Dhafra Air Base, United Arab Emirates. Additionally, he graduated from the Community College of the Air Force with an Associates of Science Degree in Construction Trade Technology. In January 2001, he was assigned to the 92nd Civil Engineer Squadron, Fairchild AFB, Washington where he was the NCOIC Structures Section and SABER project manager. In August 2003, he entered the Graduate School of Engineering and Management, Air Force Institute of Technology. Upon graduation, he will be assigned to HQ Air Education and Training Command Civil Engineer Directorate.

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**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**
In 2001, the Office of the Civil Engineer, Installation and Logistics, Headquarters, United States Air Force, (ILE) identified Civil Engineer Squadrons as the central point of contact for all base-level mapping requirements/activities. In order to update mapping methods and procedures, ILE has put into place a program called GeoBase, which uses private sector Geographic Information Systems (GIS) technology as a foundation. In its current state, GeoBase uses the concept of a "Common Installation Picture (CIP)" to describe the goal of a consolidated "visual" that integrates the many layers of mapping information. The CIP visual is formed from a collection of data elements that are termed Mission Data Sets (MDS). There are varieties of MDS each of which contain data specific to a particular geospatial domain. The research uses a case study methodology to investigate how the MDS are designed, implemented, and used within four USAF Civil Engineer Squadron Electrical and Utilities Work Centers. The research findings indicate that MDS design and implementation processes vary across organizations; however, fundamental similarities do exist. At the same time, an evolution and maturation of these processes is evident. As for MDS usage within the Electrical and Utilities Work Centers, it was found that MDS usage is increasing; however, data quality is a limiting factor. Based on the research findings, recommendations are put forward for improving wing/base-level GeoBase program design, implementation, and usage.

**15. SUBJECT TERMS**
GeoBase, Geographic Information Systems, GIS

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