USING THIN-CLIENT ARCHITECTURE TO ACCESS THE LEGACY TRAINING DATABASE WITHIN THE FEDERAL AVIATION ADMINISTRATION ACADEMY

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NOMENCLATURE

3GL	Third Generation Language
4GL	Fourth Generation Language
5GL	Fifth Generation Language
ADTN	Automated Data Terminal Network
AF	Airway Facilities
AIO	Office of Information Services, Federal Aviation Administration
AMI	Office of Information Services, Mike Monroney Aeronautical Center
API	Application Programming Interfaces
ASP	Application Service Provider
ATM	Asynchronous Transfer Mode
CAMI	Civil Aerospace Medical Institute
CBI	Computer Based Instruction
CIO	Chief Information Officer
COBOL	Common Business Oriented Language
COTS	Commercial Off The Shelf
CPMIS	Consolidated Personnel Management Information System
CUPS	Consolidated Uniform Payroll System
DAFIS	Department Accounting and Financial Interface System

DB/URL	Database Management User Request Language
DBMS	Database Management System
DOS	Disk Operating System
DOT	Department of Transportation
FAA	Federal Aviation Administration
FMFIA	Federal Manager's Financial Integrity Act
FOIA	Freedom of Information Act
GDI	Graphical Device Interface
GUI	Graphical User Interface
HOL	Higher Order Language
HTML	Hypertext Mark-up Language
IAF	Internet Application Framework
IBM	International Business Machines
ICA	Independent Computing Architecture
IDC	International Data Corporation
IP	Internet Protocol
IPPS	Integrated Personnel and Payroll System
IPX	Internetwork Packet eXchange
IRB	Institutional Review Board
IS	Information System
ISDN	Integrated Services Digital Network
IT	Information Technology

IVT	Interactive Video Teletraining
JVM	Java Virtual Machine
LAN	Local Area Network
MIR	Management Information Resource
NAS	National Airspace System
NetBEUI	Network Basic Input/Output System Extended User Interface
NC	Network Computer
OCC	Office of the Comptroller of the Currency
OJT	On-the-Job Training
OS	Operating System
PC	Personal Computer
PPP	Point-to-Point Protocol
PSS	Personnel System Specialist
PWNN	Project With No Name
RAM	Random Access Memory
RDBMS	Relational Database Management System
REGIS	Regional Information System
RMM	Remote Maintenance Monitoring
SCO	Santa Cruz Operation
SMO	Service Maintenance Organizations
SNA	System Network Architecture
SPX	Sequenced Packet eXchange

SQL	Structured Query Language
StatMUX	Statistical Time Division Multiplexing
TCO	Total Cost of Ownership
TCP/IP	Transmission Control Protocol/Internet Protocol
VHLL	Very High Level Language
WAN	Wide Area Network
WINGS	Workforce Information Next Generation System
Windows NT	Windows New Technology
Y2K	Year 2000

CHAPTER I

INTRODUCTION

In today's business environment the commonly accepted accounting practices do not allow data or information to be shown as an asset on a company's balance sheet. Yet in many of today's organizations, data is a far more valuable asset than many of the physical capital assets. Many businesses are burdened by legacy information systems–existing systems that contain valuable data but lack the power or agility to meet current organizational requirements (Brodie & Stonebraker, 1995). An organization's legacy data is worth preserving. The irony is that many organizations that are determined to preserve this legacy data have simultaneously decided to scrap most of their legacy software–for example, the tens of millions of lines of assembler and COBOL that have been painstakingly coded over the past 25 years. Since this code embodies the business rules for manipulating those legacy databases, it raises the question of how the organization can afford to scrap it, unless the business rules have been judged obsolete, or unless the organization has finally admitted to itself that the code is utterly unmaintainable. Indeed, to take advantage of today's new technologies, many organizations are faced with a massive task of reengineering legacy databases that may have been designed 25 years ago. The most radical approach to reengineering involves scrapping the data model because of logical errors, inconsistencies, or redundancies, but maintaining the operational data itself (Pickering, 1994).

Without the luxury of discarding these legacy systems and starting over, organizations need to preserve and capitalize on the huge investment in these databases. They also need to leverage the wealth of data accumulated in the legacy systems to build new applications that reengineer outdated processes and capitalize on mission-critical functions.

Current client/server technology allows data design to overcome limitations in the response, behavior, and general nature of an embedded non-client/server system. This allows a system design to incorporate the features available in a client/server environment that cannot otherwise be obtained with the older legacy system being interfaced.

In order to be truly "Client/Server," a piece of the program code runs on a primary computer, the server, and another piece of code that is resident on a secondary computer, the client, talks to it. This communication between software programs pieces that are on separate machines is the defining characteristic of client/server software. This opens up the possibility for an information brokering system that allows the easy retrieval of information from a data repository or corporate data warehouse (Watterson, 1995).

Thin-client software and thin-client devices offer a more efficient model of the client/server paradigm. Thin-clients provide format and display the application interface. The central server does most of the work and hands off results to the client for display. In a fat-client architecture the client does more work. In addition to format and display of the application interface, it is responsible for crunching some numbers (N-tier

Architectures, 1999). The thin-client computing model connects thin-client software or a thin-client hardware device with a server using a highly efficient network protocol (Dewire, 1998). The client machine performs very little data or application processing. This architecture enables 100% server-based processing, management, deployment, and support for applications across any type of connection to any type of client hardware. The client processes only the output for the screen display. The client hardware can include terminals, desktop personal computers (PCs), network computers, Apple Computers, or UNIX devices. A thin-client computing model extends the life of an organization's computing infrastructure by allowing existing software to evolve while leveraging the existing hardware, operating systems, software, and networks.

Background

The Federal Aviation Administration (FAA) Academy conducts technical training for employees stationed at locations worldwide. The FAA is operating and developing over 400 information systems in order to carry out its mission and support functions. The Consolidated Personnel Management Information System (CPMIS) was developed by the FAA in the early 1970s and was established as the personnel system for all Department of Transportation (DOT) administrations in 1981 (FAA, 1998). The system is used as a personnel management tool to track employee information, including training records. CPMIS is currently used as a personnel management database by all modes of the Department of Transportation. Each mode's access is limited to its own records. CPMIS was written in a unique language called "Database Management User Request Language"

(DB/URL). This language is proprietary to the DOT and its modal administrations (FAA, 1997). Although CPMIS was a great innovation and state-of-the-art in its day, it has become an albatross to the agency. This legacy system is slow, lacks user friendliness, and has extremely limited accessibility.

CPMIS has been targeted for replacement for over ten years (FAA, 1998). It was reported to the President and Congress in 1989 and again in 1990, as containing material weaknesses under the Federal Manager's Financial Integrity Act (FMFIA). Several attempts have been made to convert CPMIS to a newer database. The funding and time costs have been significant. The end products have been disappointing and resulted in abandonment and redirection to alternate solutions.

One previous study commissioned by the FAA revealed that one of the reasons for previous failures to replace CPMIS was the project teams' failure to identify and fulfill the most fundamental goal constructing a cost effective system that would serve the needs of the end users (Coopers & Lybrand, 1996). The development teams' emphasis was on the database structure containing the student records and administration information. Had there been a heavier emphasis on cost effectiveness and serving user needs, user friendliness and ease of system access might have been a higher priority while looking for a model that would minimize the cost of the replacement design..

The Agency

The FAA is responsible for administering the National Airspace System to maintain the flying public safety. To accomplish this mission, the agency is divided into separate services, each with a distinct role in the overall mission. The FAA employs 47,000 personnel at over 1000 locations. These locations are primarily within the United States, although the agency maintains international liaison offices in foreign locations as well.

Agency Information Technology Policies

With the rapid advancement of technology and a glut of information available, the FAA created a position for a Chief Information Officer heading the Office of Information Services (AIO). AIO provides the guiding principles and framework for implementing a corporate data management program. The strategy and program are being developed and implemented in collaboration with the lines-of-business and represent an agency-wide approach to establishing sound data management practices. This office provides agency information technology policy and direction for the use of information technology resources. AIO has published a data management strategy for the agency outlining policy and guidelines for a data management program. The strategy recognizes that information systems have evolved over the past 20 to 30 years, each designed to meet specific and unique requirements. The proliferation of data systems with redundant and/or obsolete information has caused the agency to struggle with defining a strategy to bring the situation under control. The FAA has over 400 individual information technology systems on which it spends approximately $2.1 billion annually- around 20% of the total agency budget (FAA, 1999b).

Over the years as data systems have evolved there has also grown an increasing need to share information with the public. Additionally, it is necessary for the agency to find avenues to internally share information in order to take advantage of best management practices such as Total Quality Management and teaming concepts. The agency is breaking the paradigms of government employees who tightly controlled information as a means of controlling power. Information must now be distributed freely to external and internal customers (FAA, 1999b).

Even as the FAA attempts to implement a corporate data management program it recognizes that few public or private organizations have been able to do so. The FAA data management program, therefore, is attempting to narrowly focus on areas with the greatest potential benefit for the agency. The vision outlined in its program includes the following facets (FAA, 1999c):

1. Data are viewed as a corporate resource used to make informed business decisions.
2. Data are available in timely, easily accessible, and understandable format to all users who need it.
3. Core data are standardized for increased interoperability and increased accuracy.
4. Maintenance and development costs are reduced by eliminating redundant and obsolete data, and through data reuse.
5. Data development is coordinated across lines of business using a standardized methodology.

6. Data are managed throughout its life cycle from creation to disposition.
7. AIO is the focal point for corporate data management activities.

The primary goal of the FAA data management program is to make reliable information available quickly. To accomplish this goal, the agency is looking for methods to improve data availability in terms of timeliness, access, and quality, and to leverage the existing data infrastructure. FAA data is viewed internally as a corporate resource used to make informed business decisions. As such it must be made available in a timely, easily accessible, and understandable format to all systems and users who need it.

The FAA employs a life-cycle management approach to databases, data, and related systems from creation to disposition. The process should be evolutionary with emphasis on collaboration between lines of business where it makes sense, and focus on discrete projects that address the areas of greatest need. Any project to create or revise data management systems should consider the following fundamental questions (FAA, 1999b):

1. How can data be shared in a timely manner?
2. Where do the greatest data problems exist?
3. What is the cost of gathering and maintaining existing data?
4. What are the hidden costs to ongoing operations and new development caused by unknown, inaccessible, or nonstandard data?

While sharing of data across the agency is a fundamental emphasis in the data management strategy, it should be noted that this strategy does not envision making modifications to legacy systems solely for the purpose of data integration and standardization. Instead, integration or standardized data will be accomplished during the upgrade of legacy systems or the development of new systems. In order to leverage existing data while developing new applications, a corporate metadata repository will be used and referenced to ensure data does not already exist (FAA, 1999c).

In examination of the over 400 information systems existing or under development, the FAA must decide which information systems to buy *off-the-shelf*, which to develop and build, which to retire, and which to upgrade. Under its five-year strategic plan the agency will implement selected information system services on a priority basis. The goal is to maximize movement of such systems to common platforms, services, and infrastructure (FAA, 1999b).

Technical Training Administration

The FAA Academy was established to conduct a standardized national training program for each of the agency's technical services. The primary areas of instruction are Air Traffic, Airway Facilities, Regulatory Standards, Airports, Logistics, and Security. Employees from field offices around the world are sent to resident training classes at the FAA Academy located in Oklahoma City, Oklahoma. In addition to resident classes the Academy administers an extensive distance-learning program comprised of directed study courses, interactive video teletraining, and computer-based-instruction. In 1999 the FAA Academy conducted 2,365 classes and accomplished 32,745 training completions (FAA, 1999a).

Administration of the national training program varies from service to service within the agency. The most complex administration programs are those associated with the larger services. The largest national program is conducted for the Airway Facilities service. This service is responsible for training technicians and engineers who maintain the equipment associated with the National Airspace System.

Nationally the agency has 33 Service Maintenance Organizations (SMOs) that operate the air route traffic control centers and airport operations within their designated areas (FAA, 1995). Each SMO reports to its regional office. Within each regional headquarters office, Airway Facilities maintains an operations office that has personnel responsibility for oversight of training administration within that region. These administrators interface with the SMO training personnel, who are designated as Personnel Systems Specialists. The flow of training administration information is from the Academy to the regions, regions to SMOs, and SMOs to affected personnel. The timeliness and accuracy of this information are essential for efficient program operation.

Problem Statement

Increasing costs and lack of sustainability of the CPMIS legacy database mandate that the FAA find a viable alternative. To avoid repeating previous replacement failures any new system must meet the needs of the users both in functionality and usability.

The FAA Academy has a large amount of training data in CPMIS legacy database system. The interface with this system is slow, clumsy, and lacks user friendliness. The proprietary language in which CPMIS was developed is becoming increasingly difficult to maintain. Few of the language developers still remain within the FAA. The language is unique and the basic data structure does not follow today's database standards for the industry, therefore the time and cost to train new personnel in the language are unusually high and exporting or mining of the system's data is problematic at best. As the needs of the system's users to access and utilize types of data have exceeded the capability of the original legacy system, ad-hoc databases have arisen to fill the void. Keeping the data in these secondary databases synchronized with the records of CPMIS in order to verify accuracy has become an administrative burden. The cost to convert the legacy system as well as to integrate the ad-hoc supplemental databases to a new database information system is significant. A cost-effective alternative to the current system can net the agency savings over the life cycle of the system, and target those savings to fund critical safety related projects such as modernization of the National Airspace System.

Previous attempts to replace the database system have been unsuccessful. The Coopers and Lybrand audit of the projects, conducted on behalf of the FAA, indicated several factors contributed to the failures. One of those factors was inadequate involvement by users in developing the initial requirements. Programmers concentrated on the functionality of the end product at the expense of the user interface. The resulting product was a system that managed the data handling and processing requirements, but was overwhelmingly rejected by the users because of the difficult and ambiguous user interface (Coopers & Lybrand, 1996).

The agency cannot afford to continue to sustain legacy systems such as CPMIS, nor can it afford a lengthy and costly development project that may have marginal results.

What is needed is an architecture and a strategy that can incorporate its information systems into an enterprise-wide tool that can integrate data to perform mission-critical functions and make informed management decisions. Any proposed architecture must also allow an incremental migration approach that deploys needed systems, such as CPMIS, in stages in order to put the system tools into the hands of the users as rapidly as possible.

Purpose of the Study

This descriptive study was designed to identify considerations in the development of an alternative to replacing the CPMIS legacy system by examining the use of new client/server technologies and database migrations. The literature review discusses how large enterprise organizations have handled their legacy system problems using thin-client architecture interfacing with the data of existing legacy systems while preparing for migration or replacement. The review examined what factors should be considered while designing the user interface. The study laid the foundation for initiating the design of an incremental migration project by capturing lessons learned from previous CPMIS replacement attempts. Finally, the study captured initial user interface preferences to determine requirements of the targeted system. The results of the research can be used to analyze strategic gaps between the actuals of the existing CPMIS interfaces and the optimals of newly designed user interfaces.

Research Questions

To aid in the design of an effective model, the following research questions were addressed:

1. What are the "lessons learned" from previous replacement attempts?
2. What features of an information system are most desired by the end user?
3. What characteristics of a thin-client system architecture could benefit the FAA in future CPMIS replacement efforts?

Context of the Study

This descriptive study was accomplished by conducting interviews, focus groups, and surveys of personnel responsible for administering the technical training program within the FAA. Responsibility for administration of technical training is divided into two distinct segments. The first segment is the FAA Academy and Washington headquarters offices that are responsible for maintaining the centralized information and records, then distributing the information to field office personnel. The second segment is the field office personnel who are responsible for using the centralized information systems and databases to effectively manage training for employees under that office's responsibility.

Limitations

One of the main limitations of the study was the ability to gather first hand accounts of the previous replacement effort failures. Few of the personnel involved remained employed with the agency or the responsible organizations. The remaining and accessible personnel were very sensitive to the issue of association with the previous projects. The amount of time elapsed since the efforts also negated the ability to access first hand project documentation.

The end user requirements research was limited by the geographic separation of the personnel needed for conduct of the focus group. The response rate of the survey instrument posed an additional limitation. The instrument was sent to only personnel within the Airway Facilities line of business within the FAA.

Summary

This chapter has presented an overview of the nature of the problem facing the FAA to update its training administration database. This overview has provided the statement of the problem, stated the purpose of the study, and formed the research questions. The context and method of the study have been established along with an explanation of the rationale for this approach.

CHAPTER II

LITERATURE REVIEW

Introduction

Increasing costs and lack of sustainability of the consolidated Personnel Management Information system (CPMIS) legacy database mandate that the Federal Aviation Administration (FAA) find a viable alternative. To avoid repeating previous replacement failures any new system must meet the needs of the users both in functionality and usability. To aid in the design of an effective replacement model study addresses three questions:

1. What are the "lessons learned" from previous replacement attempts?
2. What features of an information system are most desired by the end user?
3. What characteristics of a tine-client system architecture could benefit the FAA in future CPMIS replacement efforts?

This chapter contains a review of literature that first centered on the CPMIS database, its structure and interrelations, and their correlation with the database management practices of today was reviewed. System architecture reviews were made to highlight the infrastructure considerations when planning a new system implementation. After covering infrastructure needs, an examination of basic client server principles lead to the review of thin-client vendor options. The review turned next tow hat is involved with migrating a legacy database into a new system, followed by how to determine the user needs of both the new system and the migration project. No review of a large-scale project would be complete without looking at cost considerations, known as Total Cost of Ownership (TCO). Bringing all of the acquired information together to form a plan required a look into project management principles. Finally, case studies of how businesses and government organizations have attempted similar issues and system migration projects were reviewed.

CPMIS

The CPMIS training subsystem became fully operational in July 1975. It, along with yet other subsystems of CPMIS (budget, labor relations, personnel, security, and civil rights), uses one central data base accessible via on-line terminals located in each FAA region and center, as well as each Department of Transportation (DOT) administration headquarters (FAA CPMIS User Manual, 1976). The system interfaces with nearly 60 different systems within and outside the Agency and the Department of Transportation.

Computers are designed to process, retrieve, and store programmed information. Typically, they can respond only to electronic signals that correspond to binary numbers. Programming languages are designed to translate human language into commands that the computer can understand. There are currently five "generations" or levels of languages available. Machine language, or first-generation language, consists solely of binary numbers. Machine languages are computer dependent and therefore every type of computer has its own machine language. Assembly language, or second-generation language, which came into use in the mid-1950s, uses a shorthand notation of letters and numbers to communicate with the computer in place of binary groupings (Hook, 1995). Assemblers are then utilized to translate the assembly language into machine language. Assembly language is still computer-dependent and therefore results in a unique assembly language for every type of machine. Higher order language (HOL), or third-generation language (3GL), which came into use in the 1960s, consists of statements which more closely resemble the spoken language, and therefore are easier to read and write because they require fewer statements per function. Special programs, or compilers, must then translate the HOL statements to assembly or machine language. Expanding upon this, fourth-generation languages (4GLs), or Very High Level Languages (VHLL), also use instructions that resemble the spoken language, but they allow the programmers to define "what" they want the computer to do without necessarily telling the computer "how" to do it. Typically, the compilers, or interpreters, for 4GLs are not as efficient as HOL compilers in using available memory and processing speed. Finally, the highest level of programming, fifth-generation languages (5GLs), would involve a computer that responds directly to spoken or written instructions, or English language commands. There exist only a few 5GLs or "natural languages," and they are typically used in artificial intelligence applications (Date, 1975).

CPMIS was written in a unique language called "Database Management User Request Language" (DB/URL). Programming experts within the FAA created the language. This language is proprietary to DOT and its modal administrations (FAA, 1997). Unlike traditional database languages, DB/URL is a second-generation language that communicates to the mainframe directly using machine language code. The CPMIS database may be proprietary, difficult and expensive to maintain, hard to change, and difficult to program, but it is fast. Each record has a set of pointers within the text stream to set up the relational ties to other records. This eliminates the need for tables and keys seen in today's standard database structures. It also makes the code very compressed and efficient. The purpose of this was to save space at a time when memory and disk space, even on a large mainframe, were precious and limited commodities (FAA, 1996).

Data within the CPMIS is organized into files. Each file is a collection of data about a particular kind of subject. For example, the training file contains data about training courses, and the personnel file contains data about DOT employees. Each file is divided into records. A record is a collection of data about one particular subject. For example, there is a record in each training file for each training course, and a record in the personnel file for each DOT employee. The CPMIS data files are segregated so that a given user can access only records pertinent to his or her DOT administration. Therefore FAA users can access only FAA records (FAA, 1996).

It was reported to the President and Congress in 1989 and again in 1990, that the agency's Consolidated Uniform Payroll System (CUPS) and CPMIS contained material weaknesses under the Federal Manager's Financial Integrity Act (FMFIA) (FAA, 1998). Major weaknesses included:

1. Limitations in supporting management information requirements;
2. Data discrepancies between the two systems;
3. Old and inefficient software;
4. Increasing operational costs; and
5. Overall long-term maintainability questions.

In 1992, $21.3 million dollars was authorized for a replacement project with five phases to be completed in August 1996 (Coopers & Lybrand, 1996). This replacement system was called the Integrated Personnel and Payroll System (IPPS). The first few phases encompassed the design of an interface system that would allow a limited number of desktop users at FAA facilities to have direct access to the CUPS and CPMIS mainframes. The later phases would then replace the mainframe legacy systems with new architectures in a transparent data migration. In late 1995 only Phases 1 and 2, the interfaces, were completed, the entire $21 million dollars was expended, and it was recognized that the remaining phases would cost an additional $12 million. The project was halted at that point to allow the agency to reassess its position and determine the feasibility of restructuring the program.

Although IPPS provided direct access to CPMIS and CUPS for some users, the new system encountered great animosity from the user community. The number and level of users permitted access was still very restrictive compared to the user community needs. The user community was very vocal about its displeasure with the interface design. It was generally considered to be cumbersome, obtuse, and connections were unreliable at peak usage times. The increasing hostility of the users was as much a factor in the determination to halt the project as were the cost overruns (Coopers & Lybrand, 1996).

A new mission need statement was formulated to explore the alternatives for the CUPS and CPMIS system. Alternatives ranged from retaining the systems as they are to full-customized development and replacement. Unfortunately the addition of the IPPS

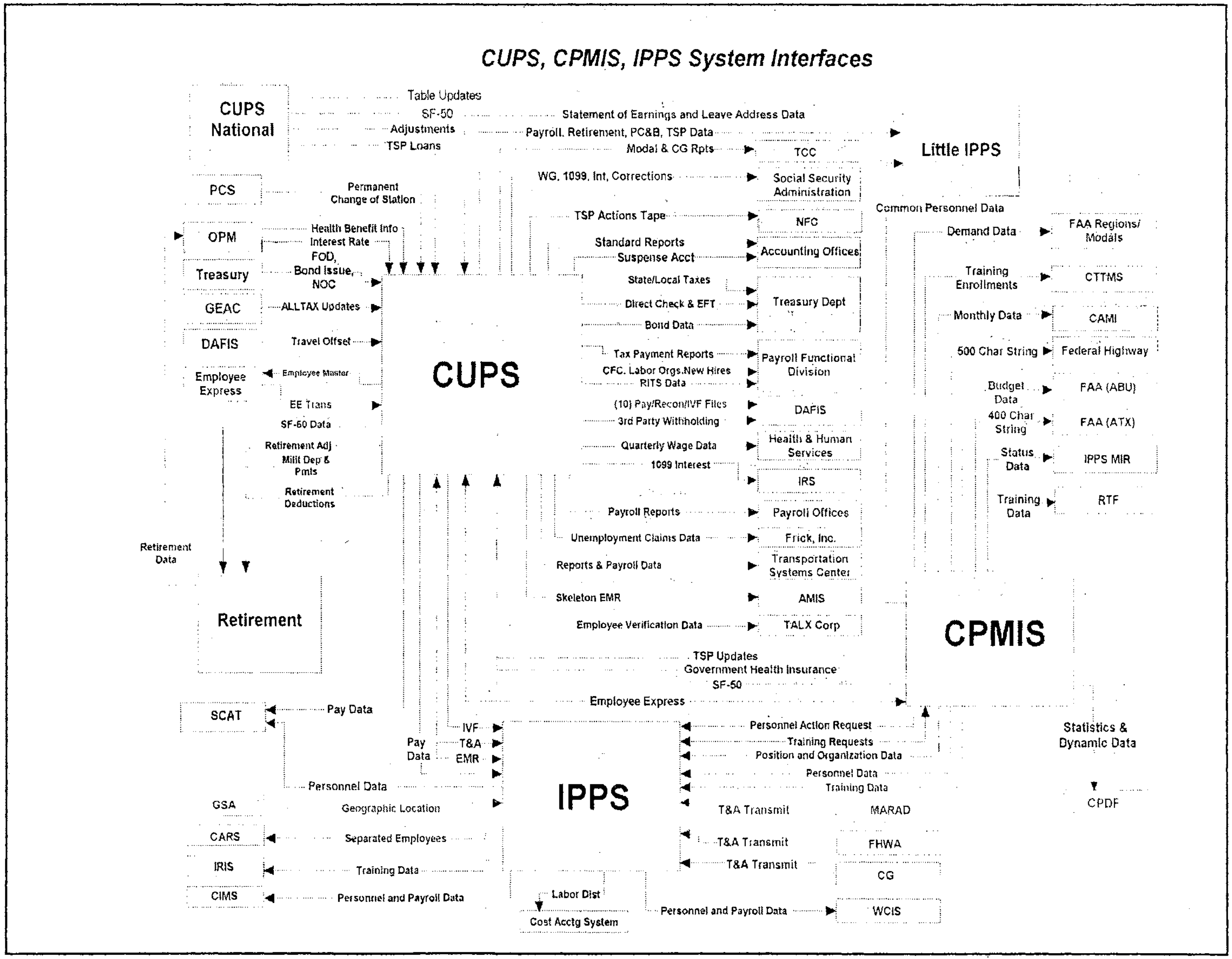

Figure 1. CUPS, CPMIS, IPPS System Interfaces.

interface now added to the complexity of proposed solutions. A graphical representation of the CUPS-CPMIS-IPPS relationships is shown in Figure 1. The analysis found the cost of maintaining the status quo as unacceptable both in terms of cost and lost opportunities to implement best business practices. A new project, titled Workforce Information Next Generation System (WINGS) was formulated. Cost estimates projected a total cost of $34.8 million with a four-year implementation period (FAA, 1998). Stinging from the previous project failure, the WINGS project was denied funding and canceled by Congress.

System Architecture

System architecture is a set of rules, procedures, conventions, standards, protocols, hardware, and software that encompass and comprise the system in total. The ideal architecture is one that is transparent to the user; like a well-managed utility, it should be so reliable that users do not observe its existence (Chorafas, 1989). The architecture designed to efficiently accomplish database management must coordinate and control all of these functions.

Any architecture design must measure up to the six prime aspects of a quality system (Johnson Computer Software Team, 1998):

1. Functionality – If a system doesn't do the things the user needs it to do then nothing else matters.
2. Ease of use – Intuitive interfaces allow the user to concentrate on performing the task, not the system.

3. Performance – With the ever-increasing speeds available to the computer world, users will not tolerate a replacement architecture that does not improve the performance of the legacy system being replaced.
4. Robustness – The goal is to replace weaknesses in the legacy system with the strengths of the new architecture.
5. Extensibility – Also referred to as scalability, it means the information technology experts can continue to enhance and change the system as the system and needs of the users grow.
6. Maintainability – This means how easy will it be to fix the system if something should go wrong. The hidden cost to any new architecture is the support costs of the future.

In producing a model of a system an attempt is made to determine how that system will behave under various conditions. The system performance will be affected by interactions from a potentially large number of interactions with other systems and system components. It is best to confine the original scope of the modeling to a broad look at the platforms and processes involved at a high level. Refinement can then be part of further research and development efforts. Each of the system components will exhibit its own pattern of behavior. The modeling should be concerned only with the internal workings of a component insofar as the externally apparent behavior of these components is affected (Duxbury, 1997).

Modeling can be seen as a top-down hierarchical breakdown of the behavior of the system under various conditions. A number of questions need to be considered:

1. What are the inputs that drive the system?
2. From where do these inputs come?
3. How will the system react to the inputs?
4. What outputs need to occur as a result of the activity in the system?
5. What receives these outputs?

Model inputs consist of a number of variables to be evaluated in the system. These can include the workload, number of accesses to the system, frequency of workload initiation, and resources expended by the workload. Outputs will be used to determine the necessary design tradeoffs. They include considerations of response time, utilization, and areas of performance sensitivity (Spellmann, 1996). Determining the work pattern and needs of the user to access the system and applications is a key element in determining the requirements of the model.

An intranet is a network internal to an organization that applies Internet-related technologies to deliver information to the desktop with minimal cost, time, and effort (Curtin, 1997; Guengerich, Graham, Miller, & McDonald, 1997). Intranets can utilize the World Wide Web to create a private, small scale internet that is not accessible to anyone outside of the organizations. The widespread acceptance of the Internet and its underlying Web technology has paved the way for intranets. In 1996 one study showed that 28.8 million United States citizens aged 16 and older had access to the Internet, 16.4 million used the Internet, 11.5 million used the Web, and 1.51 million used the Web to purchase something (Hoffman, Kalsbeek, & Novak, 1996). Intranets, which run on open transmission control protocol/Internet protocol (TCP/IP) networks, enable organizations to employ the same types of servers and browsers used for the World Wide Web for internal applications distributed over their own local area network (LAN). Most organizations of the future will use intranets to disseminate important information to employees within the organization. It is apparent that some form of intranet is the most innovative and cost effective way of freeing information from the inaccessibility of expensive to maintain legacy systems (Morant, 1996).

An extranet extends an organization's intranet out onto the Internet or via remote access, to allow customers, suppliers, and mobile workers to access data and information. An extranet enables outside organizations to collaboratively engage in business applications. Intranets and extranets offer the most innovative, cost effective way of freeing corporate information from the inaccessibility of expensive-to-maintain legacy systems (Chou, 1998). An added consideration with an extranet is the increased need for network security. The main goal of network security is to protect network components from unauthorized access. Selection of the appropriate software provider must keep this consideration in mind.

Network security is always a major concern not only for extranets, but also for intranets. A full-service intranet should provide security services such as single-user login, and access control for safeguarding confidential data transactions. These security services need to work for every client, independent of the platform or application being used.

TCP/IP is the main protocol used in an intranet. However, it is not designed to offer secure communication services. Some security problems need to be solved by network managers, such as (Netscape Communications Corporation, 1997a):

1. How do I authenticate users to make sure they are who they claim to be?

2. How can I perform authentication without sending user names and passwords across the network in the clear?
3. How can I provide single-user login services to avoid costly user names and account maintenance for all the servers across the enterprise?
4. How can I ensure that these services not only work on my intranet, but also scale to the Internet?
5. How can I protect the privacy of my communications, both those in real time and those with store-and-forward applications such as e-mail?
6. How can I ensure that messages have not been tampered with between the sender and the recipient?
7. How can I safeguard confidential documents to ensure that only authorized individuals have access to them?

Another consideration is the network infrastructure supplying access to the system users. With a geographically dispersed organization the users will require access to the network in a wide variety of manners. The network infrastructure must provide high-speed communications for both local and remote users, wireless access to data and virtual private networks (Miller, 2000). This will add complexity to the hardware and software integration to maintain a centralized administration with user log-ons and authentication.

In order to keep network communications smooth and seamless, some proactive planning may avoid possible bottlenecks and limitations. Intranet "any to any" connectivity greatly increases traffic flow in the data communications network. Several issues to consider for network growth are (Chou, 1998):

1. Growth management;
2. Bandwidth management;
3. Security control; and
4. Speed management.

As the network continues to grow, it needs to monitor and analyze network traffic in order to optimize its support for applications. It also needs to give users sufficient bandwidth to keep traffic flowing smoothly. Intranets may assert significant security risks, especially if they are connected to the Internet. Finally, selecting high-speed technologies for meeting network growth is a reasonable strategy.

The responsibility of network management is to ensure regular operation of a network. Determining factors of the running of a network are the cooperation of the different functions of the components of the network and the way users act (Siegl, 1993). The way users act means how people use the network and which software they apply. From a technical viewpoint, a network should offer the best possible bandwidth and availability that the users will demand.

Applications deployed across the network lead to the managerial issue of scalability. In other words, applications scale from LAN to intranet for enterprise usage. The provisions of scalability will benefit organizations by allowing workers to collaborate with their colleagues throughout the entire organization (Chou, 1998).

Browsers are another consideration in planning an intranet and the available toolset for the intranet. Browsers are largely responsible for the ease of use and scalability of the current information services. An organization can choose to design and build its own customized browser, but one of the advantages of using the TCP/IP architecture of the Web is that it allows an organization to use off-the-shelf Web Browsers. The appeal of using a Web browser is that it makes life easier for developers and users. The following items are the general criteria for choosing a browser (Guengerich, Graham, Miller, & McDonald, 1997):

1. Performance;
2. Multimedia support;
3. Language support, such as HTML and Java
4. Usability, such as user interface metaphor, online tools, and help facilities; and
5. Vendor support.

The hardware platforms already in place in an organization are greatly diversified. Selecting suitable intranet architecture should emphasize open standards that are neutral with respect to hardware architecture, operating systems, and windowing systems. The features of open platforms and standards save expenses on achieving hardware and software compatibility (Chou, 1998).

To meet the needs of an organization, to be truly business-critical, intranets must be more than just a network. They need to offer and support a variety of connectivity and communication standards and applications needed to integrate legacy environments into the intranet. They must evolve from being tactical deployments done in an ad hoc manner to being strategic components of the information technology strategy ("Metamorphoses," 1997).

Client/Server Strategies

In older database technology, each desktop computer runs a database program that calls for large data files from the file server, spends time sorting and searching the files, and then generates a report with the desired information (Orfali, Harkey, & Edwards, 1996). With the client/server model the task is distributed. In the client/server environment, processing is divided between the client system and the server. The client computer is a single user workstation that provides the graphical interface and appropriate processing, as well as connectivity to a network. The server side of client/server is one or more multi-user processors with shared memory that provide computing, connectivity and database services relevant to the business need (Smith, 1994). In simpler terms the server provides services across the network while the client consumes the services.

Monolithic mainframe applications are replaced with applications that are split across client and server lines. The client computer sends a request to a special program called a database engine, running in the file server, which indexes, sorts, and searches the shared files without sending them over the network. The database engine, or database server, responds only with the specific files or results requested by the client computer. While the database engine does its work, the client computer can use its resources to run other applications. The network traffic is reduced to queries and responses from the database server rather than sending the entire database file back and forth. Users are not limited to one type of system or platform. In a client/server environment, the workstations can be IBM-compatible PCs, Macintosh, UNIX workstations, or a combination of these, and can run multiple operating systems (Watterson, 1995). Clients also are not limited to location. Clients and servers do not need to be directly connected to one another. The server could be communicating over a network with the client located in the same room, or could be separated by wide geographic space communicating over telephone networks. The server can be located anywhere without affecting what the client sees. This is called transparency of location (Orfali, Harkey, & Edwards, 1996).

Applications capable of running in a client/server environment can be split into a front end that runs on the client and a back end that runs on the server. The front end provides the user with an interface in the form of a graphical user interface (GUI) for launching the application, giving commands, making requests, providing input, manipulating data, and displaying results (Mullet & Sano, 1995). The person using the desktop computer typically uses an on-screen form to specify the request. In a document management system, the form might allow the user to request a search of a library of documents to find a specific group of documents by using the author's name, a few words inside each document, or other criteria as the search key. The software in the desktop translates the form into a request using SQL. On the back end, the server waits for the request from its clients. When it receives a request, the server processes it and provides the requested services to the client. Server programs manage shared resources and perform processor-intensive operations, such as record sorting in the case of a database or protocol translation in the case of a communications server. The database engine in the file server runs through all the files using the search key, compiles the results, and then returns either the actual files or the statistical results to the client computer (Watterson, 1995). This separation, or encapsulation, of tasks between the client and server allows servers to be upgraded without affecting the client.

Application deployment across a network is an important managerial issue today. A single, universal client program can display data from a myriad of different servers that may speak different protocols and deliver documents in a variety of formats (Chou, 1998). The Internet Application Framework (IAF), for example, is a comprehensive set of open protocols, standards and technologies and application programming interfaces (APIs) for building and deploying applications for the Internet or intranet (Netscape Communications Corporation, 1997b). Its universal client eliminates many of the hidden costs of client software licenses associated with most of today's client-server applications. This function also reduces support and training costs, eliminates support headaches of maintaining multiple versions of the same applications, and allows users on different platforms to view help documents (Chou, 1998).

Client/server computing allows PC and Macintosh computers to access very large libraries of data without drowning in the information or swamping the network. Using client/server techniques, applications running on client computers with modest processing power that are connected by slow long-distance circuits can have detailed and efficient access to huge information databases. Client/server techniques are significant to workgroup productivity programs because many such programs operate in a monitoring, or background, mode. They share the computer's processing power with other programs such as spreadsheets and word processing products. Client/server techniques allow the workgroup productivity programs to regularly access a lot of information without taking computing power away from other active applications (Krantz, 1995).

Client/server is the combination of three major technologies: relational DBMS, networks, and client interface (GUI, one of the key elements of a client workstation) (Shafe, 1994). Each element contributes to the overall platform with very specific roles but is independent of the others in performing its functions. An efficient client/server structure does not consume more time and effort coordinating the elements of the system than in getting tasks done (Chorafas, 1989).

Tiers are the physical platforms on which client and server applications reside. Two-tier client/server applications utilize two collaborating computing platforms. The front-end application, residing on the client workstation, provides the application interface and most of the business processing. The back-end application component, residing on one or more hardware processors, provides the database services including data access, management and integrity services.

With a geographically widely distributed organization, such as the FAA, two-tier architecture breaks down as the client moves farther away from the server and as the local machine's computing requirements increase. These problems are inherent to the traditional client/server architecture, which emphasizes client-side computational power.

To address some of the limitations of the two-tier architecture, three-tier (also called n-tier or multi-tier) client/server architecture was created. Multi-tier client/server architecture requires the restructuring of an application into three or more parts. The presentation service application executes on the client PC, which may also perform a portion of the business logic functions. Application servers or intermediate servers are inserted into the infrastructure, executing the rest of the business logic. One or more back-end database servers handle the data access.

The deployment of client server architecture across the network poses additional security challenges to the network administrator. This is because in traditional client/server architectures, business-critical applications and data live on both the server and the client desktops spread throughout the world. Not only does this increase the risk of unauthorized access, but it also increases the risk of lost or stolen information.

One of the rules of thumb used to calculate the financial impact is that most client/server systems are more expensive than the systems they replace. Client/server technology will likely cost you more than the host environment. The capital investment required to place full PCs at each employee workstation in place of a dumb terminal is the primary development cost. Programmers must now develop software for two systems, not just one. But even if client/server is expensive, it delivers real business value because it enables rapid, incremental delivery of needed application function in support of reengineered processes as they adapt to constantly changing business conditions. In April of 1994, the Gartner Group of Stamford, Connecticut, released a study titled, "A Guide for Estimating Client/Server Costs." It is quite detailed and is one of the best vehicles to date to quantify this strategy of client server (Yourdon, 1994).

Federal agencies have a further incentive to move from mainframes to client/server. Client/server systems generally consist of more standard hardware and software components than mainframe systems. This standardization complies with federal mandates intended to keep agencies from becoming locked into a single systems supplier. Standardization tends to increase vendor competition by leveling the playing field. Federal agencies also are under orders to consolidate and streamline their mainframe computing operations. The Office of Management and Budget is pressing agencies to reduce the overhead costs they incur by maintaining many data centers. As they inventory their mainframe systems and plan for consolidation, agencies are taking a new look at the costs and benefits of their legacy systems (Ferris, 1997).

The X Window System (sometimes referred to as "X" or as "X Windows") is an open, cross-platform, client-server system for managing a windowed graphical user interface in a distributed network. In general, such systems are known as windowing systems. In X Window, the client-server relationship is reversed from the usual. Remote computers contain applications that make client requests for display management services in each PC or workstation. X Window is primarily used in networks of interconnected mainframe, minicomputer, and workstations. It is also used on the X terminal, which is essentially a workstation with display management capabilities but without its own applications. The X terminal can be seen as a predecessor of the network PCs or thin-client computers that are now beginning to be widely installed (Jenkins, 1996).

The X Window System was the result of research efforts in the early 1980s at Stanford University and MIT, aided by IBM, to develop a platform-independent graphics protocol. The X Window System is an open standard that is managed by the X.Org consortium. Although Microsoft has its own platform-dependent windowing system (an integral part of the Windows 95/98/NT operating systems), there are vendor-supplied X Windows products that can be installed to run on these systems (Jenkins, 1996).

Thin-Client Architecture

The flexibility and cost efficiency of thin-client computing have caused a virtual explosion of acceptance within large organizations. Shipments of thin-clients topped 305,000 during the first half of 1999, an increase of 83 percent from the previous year, according to market researcher International Data Corporation (IDC), Framingham, Massachusetts. By 2003, IDC expects thin-client sales to reach six million units. Another research firm, the Aberdeen Group, Boston, Massachusetts, predicts that thin-clients will have grown to nearly 30 percent of all desktop platforms by then (Collett, 1999).

Thin-client terminal-based computing is similar to a centralized host, or mainframe environment, in which multiple terminals connect to a host computer. A user can log on at a terminal, and run applications on the host computer, accessing files, databases, network resources, and so on. Each terminal session is independent, with the host operating system managing conflicts between multiple users contending for shared resources (Kanter, 1998).

There are three significant differences between the traditional mainframe environment and thin-client terminal-based computing, the user interface, devices and connectivity.

1. The dumb terminals in a mainframe environment provide only character-based input and output. Thin-client, on the other hand, provides a complete graphical user interface.
2. Mainframes support terminals designed for their architecture. Thin-client can support a variety of input/output devices, such as dumb terminals, intelligent terminals, and small computer desktops for terminal emulation. To perform terminal emulation, thin-client provides client software to enable a Windows, DOS, Macintosh, or UNIX desktop to connect to a thin-client server in order to display Windows-based applications. These combinations allow users access to 16-bit and 32-bit Windows applications from virtually any desktop or terminal.
3. Connectivity between the host computer (server) and end user (client) differs from mainframe environments where most terminals are connected through a dedicated network; thin-client technology allows the use of existing networks (World Wide Web, Phone Lines, Wide Area Networks, and so forth) as conduits for input and output between a user and the host computer (Kanter, 1998),

In thin-client/server computing, all applications and data are deployed, managed, and supported at the server. In addition, 100 percent of the application executes at the server. The application logic is separated from the user interface at the server and transported to the client. This separation means that only screen updates, mouse clicks, and keystrokes travel to the server. The thin-client software accesses and takes advantage of the server system software. The server allows multiple concurrent thin-client users to log on and run applications in separate, protected sessions on the server.

With the server splitting the execution and display logic, only keystrokes, mouse clicks, and screen updates travel the network. Therefore, applications use just a fraction of the normal network bandwidth usually required. Because applications require fewer resources, they can be extended from one location across any type of connection to any type of client with extraordinary performance. Using this extremely efficient network protocol, the user experience with many software applications is the same as if the application were running on the local computer, with the advantage of a full complement of application and operating system software. In a thin-client/server session, users can cut and paste between sessions, save to local storage devices, and print to local or network printers.

As bandwidth requirements for network applications continue to grow, more and more information technology departments are opting to deploy client server applications across low bandwidth connections using the thin-client/server model to improve system performance. Because users are already familiar with the applications, the information technology department's objective is to configure the universal thin-client to be as transparent as possible (Kanter, 1998). The server and technology can be completely hidden from the user, typically through auto log-on and application launching features. These same features can be applied to applications whether they are accessed remotely or via a local area network (LAN), regardless of whether the application is a client/server application or a productivity application.

If an organization requires multi-tier client/server architecture, the thin-client/server model is an extremely efficient method for delivering these applications. The application procession can be distributed in any manner that can best optimize performance. Rather than the presentation services application residing on and executing on the user's local machine, the network can use either a thin-client display protocol or a dedicated hardware device. Using the thin-client model to complement the multi-tier client/server architecture allows for rapid deployment of applications on any device and through any type of network.

One of the advantages of thin-client architecture is to allow the most recent versions of mission critical or information applications on different devices along with existing native applications. This allows an organization to maximize its return on investment in technology while minimizing the cost involved in doing so. All these cost benefits fall collectively under what is termed *Total Cost of Ownership* (TCO). These costs can be broken into two categories: hard costs and soft costs. Hard costs include all capital costs, such as hardware or software. Soft costs are associated with, for example, end-user support and training, as well as maintaining the production environment itself (Mathers & Genoway, 1999).

Additional benefits are realized in a thin-client environment by virtue of the centralized system management. Application installations and upgrades are performed only on the terminal servers and not on the client desktops. Organization-wide deployments can now happen in minutes instead of days or weeks. Operating system upgrades are now centralized to the servers themselves, and when upgraded, will automatically be available to all users. Another common problem with a client computer is disk capacity. The movement of applications off the desktop and onto the terminal server helps to minimize these concerns. If an application needs additional storage requirements the additional capacity needs to be added only once to the server, and then it will service all the clients connected to the network.

An area of concern for a geographically dispersed organization such as the FAA is how remote clients will access applications. This is known as an extended enterprise. Extended enterprise access requirements can be handled through remote access features or via the World Wide Web as an intranet or an extranet. Remote access can use a traditional remote mode (a network emulation that causes remote connection to emulate LAN connections) or a direct dial-in (in which the user's modem dials directly to a modem attached to the server).

No matter how powerful and robust the server, in the end the success of the project will be measured by the client's usability (Mathers & Genoway, 1999). Proper planning and an understanding of what will be most important and most noticeable to the users will greatly enhance the chances for a successful deployment. Thin-client architecture clients fall into six general categories:

1. Desktop replacement;
2. Windows desktop in a non-Windows environment;
3. Application replacement;
4. Terminal replacement;
5. Mobile workers; and

6. Wireless workers.

Desktop replacement involves moving all the applications that reside on a user's desktop to the thin-client server. The user runs no local application except for the thin-client and retains no local data. Most often, targets for complete desktop replacement are task-based workers who perform a specific job function with a common set of applications. Customer help call centers are good examples of this use. Hardware needs for the user in this configuration are relatively minimal. A 486Mhz or equivalent processor with as little as 12MB of RAM and 100MB of hard drive storage is adequate. Although the user's current hardware may be inadequate to run most of the applications that are running on the thin-client server, they may be more than adequate for the thin-client client.

Unlike desktop replacement where the user's entire desktop is moved back to the server, Windows desktop integration involves introducing the thin-client desktop to a user who runs a non-Windows operating system. Desktop integration can be achieved by running the clients on platforms such as Macintosh and UNIX. It will also work with some Web browsers on non-Windows clients. The desktop integration is used most often to standardize a business on a common set of Windows applications without having to standardize all users on a Windows operating system. This is important because many users, such as architects, graphic artists, and engineers, require non-Windows computers to perform certain job functions.

Although desktop replacement has a certain amount of appeal, it is not always the most practical solution. Many users may continue to require certain applications to run locally. In this situation, instead of replacing the entire desktop, only selected applications are migrated to the thin-client server and removed from the client's desktop. Application replacement is a common method used during initial implementation of thin-client architecture as it allows for configuration management and fine-tuning of the environment before all applications are moved to the server.

Terminal replacement gives organizations that have a substantial investment in traditional client/server architecture a financially feasible solution to migrating to a more competitive PC Windows based environment. Often the organization has a large number of dumb terminals that were used to access the traditional mainframe server. These dumb terminals can be phased out gradually as opposed to a large capital investment of replacing the terminals all at once. Running Windows applications from the thin-client server, as in the desktop replacement architecture, still allows the organization to maintain the centralized manageability that it had with the dumb terminals. At the same time this scenario provides users access to the latest Windows software. This provides a more gradual introduction of Windows applications for the dumb terminal users. And there are no limits on the number of stations thin-clients can serve. A network can be configured from 15 seats per office to multi-thousand employee organizations (Landriault, 1999).

Mobile workers have been a key target market for the thin-client architecture. Even as early as the 1960s, computer experts such as Murphy (1968) were recognizing the need for organizations with far-flung field offices to be able to use data at a distance to manage and operate efficiently. He recognized that an effective data communications network would allow the remote offices to spend less time reporting, process transactions faster, respond rapidly to customer inquiries, and in general, increase the productivity of the collective organization. The delivery of near LAN speed access to applications over a dial-up line is a crucial factor of thin-client success (Collett, 1999).

The virtual office and the telecommuting worker are two areas that benefit greatly from thin-client technology. The benefits of thin-client over a traditional dial-up are noticeable when running applications from the server. With traditional dial-up solutions, all data must travel across the connection to the local computer for processing. By contrast, with thin-client only screen update information is transferred, using an efficient compression algorithm. This makes the apparent speed for the client user comparable to that of an application running directly on the client workstation, and makes it much easier for the organization to provide location-independent access to key applications (*Different Strategy*, 1999).

Thin-clients have benefited from enterprise desktop upgrades necessitated by the year 2000 problem and the decision of network managers to replace older terminals and legacy PC desktops (Briody & Trott, 2000). In the near future, the biggest boost may come from the emerging popularity of application service providers (ASPs) that manage and deliver software applications to organizations from data centers across a network. Thin-clients enable the ASPs to deliver application access in an affordable, manageable, and secure manner, so the device's popularity is expected to grow with demand for the new service (Edwards, 1999).

Research by Zona Research Inc. indicates that the future of thin-client is tied closely with both the integration of legacy applications and expanding access to Microsoft Windows based applications to the workforce. Zona conducted a survey of medium to large sized enterprises using Web server technology. When specifically asked the question. "How important will running Windows applications be to you during the next 18 months?" the average rating was 8.68 out of 10 ("Hitting the Elephant," 1996). The importance attached to Windows applications is related to the need for personal productivity tools (Office, Lotus) and the need to run Windows-based client/server applications. The longer-term desire of enterprises is to have a single user interface metaphor and interoperability infrastructure that delivers both legacy and personal productivity applications.

Thin-Client Options

As the thin-client market surges in growth the number of vendor options climbs as vendors seek a piece of the profitable market. IDC describes thin-clients as emerging desktop technologies that compete with PCs and traditional terminals as enterprise network solutions (IDC Research Corporation, 1999). According to IDC, the United States will account for 81 percent of all thin-clients shipped worldwide. That share is expected to drop to 60 percent by 2003 as the need for more cost-effective desktops develops throughout the world and the international infrastructure to support thin-clients strengthens.

Thin-client is a term that includes the NetPC, based on an Intel Corporation processor and Microsoft Windows software, as well as the network computer (NC) backed by Oracle Corporation and Sun Microsystems Inc. (As More Work Is Done, 1999). In addition to vendors that offer thin-client hardware devices a number of companies, such as Citrix and SCO, offer a range of software options. Some are hardware dependent while others offer a more universal configuration to allow consumers the ability to mix and match for the best fit, most cost effective alternatives. Each needs to be considered to determine what the best solution for a given environment will be.

Until recently, SCO's thin-client offering, Tarantella, was confined to a UNIX environment. SCO lets a UNIX server or server farm run applications and send the screen display to green-screen terminals and Wyse terminals. It also had the ability to send X Window applications to any browser that contains a Java Virtual Machine (JVM) (Sosinsky, 2000). Virtual machine is a term used by Sun Microsystems, developers of the Java programming language and runtime environment, to describe software that acts as an interface between compiled Java binary code and the hardware platform that actually performs the program's instructions. If a Java Virtual Machine has been provided for a platform, any Java program (which, after compilation, is called bytecode) can run on that platform. Java was designed to allow application programs to be built that could be run on any platform without having to be rewritten or recompiled by the programmer for each separate platform. Java's virtual machine makes this possible. SCO uses an optimized protocol to send data packets over a dial-up IP connection (Sosinsky, 2000).

Tarantella provided a heterogeneous client access to UNIX and mainframe application servers, but until its new release it was effectively shut out of the windows-based application server arena. The most recent version of Tarantella, released in January of 2000, now runs applications on a Windows NT platform as well an on UNIX (Mathewson, 1999).

By slicing the client/server application architecture at the presentation layer -about as thin a layer as one can hope to engineer–the vendor Citrix has established early dominance in the thin-client software market ("Different Strategy," 1999). Citrix's Winframe software turns Microsoft's Windows NT Server into a multi-user operating system. With that capability multiple sessions of Windows applications software can be run on the server, with each dedicated to a remote user. What makes Citrix the "thinnest" client/server option compared to other available products is its Independent Computing Architecture (ICA) protocol. The Winframe software intercepts a Windows application's Graphical Device Interface (GDI) and translates it on the fly into ICA protocols ("Peddling the Cycle," 1997).

Citrix ICA includes a server software component, a network protocol component, and a client software component. On the server, ICA has the unique ability to separate the applications logic from the user interface at the server and transport it to the client of a wide variety of standard network protocols–IPX, SPX, NetBEUI, TCP/IP and PPP–as well as over popular network connections–asynchronous, dial-up, ISDN, Frame Relay and ATM (Citrix, 1999c). With Citrix the server allocates separate instances for each user and each user can reboot his or her own Windows session without affecting other users.

The flexibility of the Citrix ICA protocol to interface with other systems and the client software for presenting the user interface of Windows applications of the network has given Citrix a commanding lead in the market. Citrix shipments accounted for 73 percent of all thin-clients in 1999, an increase from 51.8 percent in 1997 ("The Thin-Client Market,"1999).

Many thin-client vendors are jumping on the network computer bandwagon and launching a variety of terminals that provide support for X Windows protocol, and many provide support for access to Windows applications through the use of the ICA protocol. Users who fear losing their own personal computer in exchange for a "dumb" network terminal are lined up in an opposing camp with an almost religious fervor. According to many analysts, however, the world is not likely to suddenly shift to an entirely new model of computing any time soon. A hybrid model will undoubtedly emerge that leverages the advantages of both thin-client and desktop computing (Briody, 1999).

New Moon Software, Inc., offers a product called Liftoff. For Liftoff, distributed computing means taking a single application, traditionally executed on a PC, and distributing most of the processing workload to one or more centrally located servers. It performs its distribution duties from small software modules stored on the client and server systems. The modules intercept program commands and pass them to either the client or the server, depending on the application and the capabilities of the client PC (McGarvey, 1997).

Although New Moon's offering in the thin-client market offers a very cost competitive product, its shortcoming is that it is a Windows-only system. It is unable to access applications or platforms that are in the Mainframe, Macintosh, or UNIX environment. Liftoff requires fewer server resources than Citrix because a single instance of an application is shared among all users; but this has a disadvantage. If one user experiences problems, it can bring down the entire server (Eads, 1997).

Another vendor that is beginning to gain attention in the market is GraphOn. The GraphOn product, Bridges, specializes in the remote display of Microsoft Windows applications and Linux desktops with X Windows. GraphOn's technology enables multi-platform access of 32-bit Windows applications over the Internet (GraphOn Turns Up the Heat, 1999). GraphOn is partnering with some application software vendors, such as Corel, to integrate the Bridges software into the applications. Once a user accesses these applications over a network, the applications will appear the same as they would if they were being run locally. Bridges' current limiting factor is that it is designed for Web access only. It does not offer dial-up capability, and if the Bridges software is not bundled to the application, the application is limited to running within a standard Web browser environment.

An encapsulated side-by-side comparison of the three vendors providing thin-client software solutions. (SCO Tarantella, Citrix Winframe/Metaframe, and GraphOn Bridges) is presented in Table 1. The information in this table was assembled by combing the information provided in product literature and brochures. The vendors were also contacted by telephone to clarify the information and ensure similar data was available for each product. Each vendor was asked the following questions:

1. What are the system requirements for the server?

2. How labor intensive is the system administration?

3. What are the system requirements for the client?

4. What training is available for use of this product?

5. How many clients will this product support?

6. What service support is available for this product?

7. What is the cost of this product?

The questions asked of the vendors were designed to verify characteristics of each product that may prove beneficial to the users.

The answers to the questions about the hardware requirements of the system provided the information to determine whether the products are compatible with existing systems within the FAA or if hardware purchases must be factored into the cost. Questions around training and support of the product were designed to determine if there were additional costs to the life-cycle support of the product that must be factored into any TCO analysis.

The results of the research and the interviews with the vendors were used to construct a reference table. This table was then used as a tool to compare features and capabilities of the products with the user preferences indicated by the survey results.

TABLE 1

COMPARISON OF THIN-CLIENT VENDOR PRODUCTS

Vendor	Server System Requirements	Admin. Labor Intensity
SCO Tarantella	• Application Server: Windows; Mainframe; Linux; Unix (including RDP, X11, TN3270, Wyse 60, VT52-420, Microsoft Windows NT Server 4.0, Terminal Server Edition, Windows 2000 server and Windows 2000 Advanced Server) • Thin-Client Server: Storage- 40MB; Memory- 32MB Min. w/ 4MB per user recommended; Processor- 100MHz min. (For multi processor, one processor per 20 clients) • Network Protocol: TCP/IP.	• Control Center Management Tool: Provides centralized management of all application types. • Drag-and-drop action. • Experiencing difficulties supporting some client functions. • Lacks support for local printers and common data file systems. • Lacks ability to cut and paste between applications from different systems.
Citrix Winframe/Metaframe	• Microsoft NT Server or Unix • Processor, memory, etc. is dependent upon # of users & applications to be provided. The key is to optimize the amount of memory, speed of processor, etc. for the performance the user desires.	• Centralized system administration • Same administrative tools as Windows NT • Administrator can remotely control client device from the server
GraphOn Bridges	• Digital Tru64 Unix 4.x (formerly Digital Unix); HP/UX 10.x, 11.x; IBM AIX 4.2/4.3; Solaris 2.5/2.6/2.7/2.8; SunOS 4.1.3; or Red Hat Linux 5.1/ 5.2.	• Centralized System Administration • Somewhat difficult due to diversity of products. A different Bridges software package is needed for each type of server to client interface needed.

TABLE 1 - Continued

Vendor	Client System Requirements	Training Availability
SCO Tarantella	• Operating System: Unix, Windows 3.1, Windows 95, Windows 98, or Windows NT • Processor-Intel 486 Min., Pentium recommended; Memory-16MB Min., 32MB recommended; • Network Protocol: TCP/IP	• Some web-based training available. • SCO partners offer on-site training with the purchase of the product. • Some partners have developed and offer customized training classes.
Citrix Winframe/Metaframe	• Operating System: Unix, Macintosh, Windows 3.1, Windows 95, Windows 98, orWindows NT • No real hardware requirements for the client in a Winframe environment. Clients can use whatever existing hardware they have in place.. The speed of the processor or memory is unimportant because the server drives everything. • Network Protocols: TCP/IP, any standard network, or dial-up modem.	• Citrix certification training is comparable to the Microsoft certification training. • Training is available from any of several hundred sites across the nation.
GraphOn Bridges	• Operating System: Windows NT, Windows 95/98, or IBM OS/2 (through a Windows emulator) • Processor-386, 486, or pentium with 450Kb of hard disk space; • Network Protocols: Standard serial network or TCP/IP across a LAN.	• Only informal on-the-job training at time of installation is available. • Cost is typically $150 per hour.

TABLE 1 - Continued

Vendor	# of Clients Supported	Service Support
SCO Tarantella	• Dependent upon desired performance and the ability of the network infrastructure to support performance. • Licensing: Single server package can license and support up to 500 clients.	• Downloadable service packs • Web posting boards with Frequently Asked Questions (FAQs) • Additional support on a subscription basis: Cost from $2724 (single year, 1–35 users) to $6750 (three year, 100 users)
Citrix Winframe/Metaframe	• Citrix recommends bench testing. This is the key to determining optimum performance configuration. • Licensing: Unlimited clients with 15 concurrent users. Additional concurrent users may be licensed.	• Nationwide network of "partners" that provide training & on-site support. • Telephone service support available on a subscription basis. Cost is dependent upon the geographic spread of the clients.
GraphOn Bridges	• Dependent upon the server size and performance capability. • Licensing: Up to 100 concurrent users per server.	• Technical notes, FAQ's, user manuals are on-line. • Telephone service support available on a subscription basis. Cost is dependent upon # of client supported, length of agreement, and hours of support.

TABLE 1 - Continued

Vendor	Cost
SCO Tarantella	• Server license: $750. • Client License: Initial cost is $395 for a single user license. The price drops to $200 per user with the addition of up to 45 concurrent licenses before additional servers and server licensing are required.
Citrix Winframe/Metaframe	• The initial license fee for Citrix Winframe is $4,995 for 15 concurrent users, (per user expense of $333). • Additional license packs are available. The average cost per user decreases with the amount of concurrent user licenses.
GraphOn Bridges	• Cost is on a per client concurrent user basis. The average cost runs about $350 per concurrent user.

Database Migration

Database users face many new and difficult tasks. They need to make data more accessible for analysis, even if it resides on nearly impregnable legacy systems (DBMS Update, 2000). With the integration of databases, especially legacy ones, into intranets and the Internet, organizations will quickly exhaust the number of discardable applications that can be deployed. Sweeping out applications that provide a competitive advantage can hamstring an organization for years-but so can writing expensive interfaces to applications that could have been discarded. In fact, according to experts, once you include the data conversion and integration work, creating interfaces between new enterprise system software and other systems typically accounts for 50 percent of an implementation's labor and consulting budgets (Asbrand, 1999).

To avoid wholesale revamping of their entire business process, organizations need to be able to effectively integrate their historical data stores. To accomplish this, DBMS technology needs to become an integral part of the business-critical intranets. Key technologies that will evolve in this realm include distributed-object models, object bridging and directory services, and distributed-object-oriented application development ("Metamorphoses-The Information Chain," 1997).

Database management performs functions of data collection, data transmission, data processing, data storage, and information display (House, 1974). According to Davidow and Malone (1992), information stored in legacy and newer databases becomes a vital management support system as the application of the information is expanded to support strategic thinking, operational decisions, and other management control processes. They feel over time that better information can translate into a decisive competitive advantage. Competitors equal in all other respects will battle for supremacy in the information market, with the one that makes the best use of information emerging as winner.

Reengineering legacy databases, with a particular focus on transporting those old databases into a client-server environment, has become an area of research emphasis. Yourdon (1994) views client-server technology as both a promising technology and a transition problem--promising because of the possibility of providing enterprise information needs and problematical because of the difficulty of moving ancient legacy data into the new environment. In addition to the business, managerial, and political aspects of such a project, the technical issues are critical. The objective should be to position legacy databases as a collection of servers able to meet client needs without physically changing databases. This approach has an object-oriented flavor to it. "The process is a series of steps to examine legacy data, prepare that data for encapsulation, and develop the necessary methods to implement data services" (Yourdon, 1994, p. 4).

There are three main reasons to choose to migrate a legacy system from mainframe to a client/server architecture (Jenkins, 1996). These reasons are:

1. The mainframe's inability to support ad hoc queries from the user. This severely restricts the format and types of data available to the user.
2. The inability to quickly modify mainframe programs. Older mainframe programs were written in cumbersome, difficult to use programming

languages. Additionally, it becomes increasingly challenging to find programmers that are still proficient in these older languages.

3. The high maintenance and support costs for keeping a mainframe running. The technology and supporting software are expensive, and again it becomes challenging to find qualified personnel able to support these older systems. What few personnel that are available command a premium price under the law of supply and demand.

The financial impact of migrating the mainframe system can be intimidating. A more palatable alternative to replacing the mainframe is to integrate it into the new system architecture. Often the mainframe can remain and continue to act as a server within the client/server system. This helps to leverage the existing investment and offset the cost of the transition. Substantial capital investment has been sunk into the existing system so it is fiscally sound to use it as fully as possible. Ninety percent of information services dollars go to maintain the existing systems (Smith, 1994). Yet major benefits are gained primarily from new systems. The promises of those benefits plus the reduction in the cost of new technology can help to cost justify a changeover.

Financial considerations aside, the task of migrating an existing legacy database to a new architecture can seem overwhelming. According to Smith (1994, p. 57), "It only took God seven days to create the world because he didn't have an existing environment to deal with."

As more and more businesses looked for ways to recover legacy information from their aging systems the data mining industry was born. Data is migrated from the legacy mainframes to data warehouses where it can be managed and recovered for analysis through use of data mining software tools (Toigo, 1999).

A data warehouse is a copy of data specifically structured for querying and reporting (Kimball, 1996). A data warehouse can be normalized or denormalized. It can be a relational database, multidimensional database, flat file, hierarchical database, object database. Data warehouse data often gets changed. And data warehouses often focus on a specific activity or entity. The data warehouse system is likely to be interfaced with other applications that use it as the source of operational system data (Gupta, 1997). A data warehouse may feed data to other data warehouses or smaller data warehouses called data marts. Data warehousing systems have become a key component of information technology architecture (Kemp, 2000).

One of the most important steps in building a data warehouse is loading data into the warehouse database. Delivering a data warehouse with high user concurrency requirements, that can access data stores in the terabyte range and beyond, requires some re-thinking of the traditional data warehouse (Antonello, 1999). Before beginning to load the data warehouse it is necessary to assess the current state of existing source data (Williams, 1997). Questions to ask are:

1. Is your data complete and valid?
2. How sound is the structural integrity of both the legacy system and the new database/data warehouse?
3. How well does your data reflect and work with your business rules and data standards?

4. How well will your data work with the conversion process?

The simplest way to move data into the warehouse repository is to replicate the data that resides in the source databases. This is fast, simple, and very dangerous. Many companies try this approach, only to find later that the ease of data population is more than offset by the arduous process of cleaning up bad data in the destination database. One way to circumvent this scenario is to use proven data extraction and migration tools along with dependable processes and techniques (Bohn, 1997). Many companies program data migration applications in Cobol or other development tools. Cleansing of the data, also called normalization, will include examining the data for the following factors:

1. Replace missing data values;
2. Correct field values to match field definitions;
3. Remove unwanted duplicates;
4. Establish storage and data presentation standards;
5. Standardize abbreviations;
6. Remove unwanted or unnecessary characters and data types;
7. Check the consistency of data across files; and
8. Test data integrity rules.

Normalization is a prominent aspect of relational database theory. It addresses how data ought to be organized within a database in order to make the database as compact and as easy to manage as possible and to ensure that it produces consistent results (Unidata, 1999). Normalization rules provide guidelines for defining the schema, or design. of a relational database. The rules specify how a database should be divided into tables and how the tables should be linked together. There are two major objectives of normalization:

1. Minimize the duplication of data; and
2. Minimize the number of attributes that must be updated when changes are made to the database, thereby making maintenance of the data easier and reducing the possibility of error.

Moving data from the legacy system involves still more complexity than just the transfer of the data considerations described above. It also involves trying to transfer the information while the legacy system remains operational. The criticality of the legacy system requires it to be operational 100 percent of the time. Many legacy databases or files require weeks to dump or download. Even if the rewritten information system (IS) and data warehouse are fully operational, there are no techniques to migrate the live data from the legacy system to the new system within the time that the business can support being without its mission-critical IS (Brodie & Stonebraker, 1995). This lends a strong argument to using an incremental approach to replacing the system.

Migration of the legacy system involves incrementally selecting and migrating parts of the legacy system to become new parts of the incrementally constructed target IS. During the migration the two systems form a composite IS which collectively provides the mission-critical IS function. In the composite IS the legacy IS and target IS are connected by a gateway (Brodie & Stonebraker, 1995). Gateways play a key role in migration architectures. A gateway is a software module introduced between operational software components to mediate between them.

While incremental migration proceeds there is no longer one common data store. Without effective gateways the target system and the legacy system cannot dynamically share data, resulting in two logically separate data stores being maintained. This would result in an inconsistent view of the data to users. The gateway connects to one of the target and one of the legacy data servers, and automatically propagates any changes made to one data store through to the other, and vice versa, resulting in a single logical data store and a consistent view of the data to user applications (MacArthur, 1999).

Gateways are bi-directional and are composed of two components: a forward part and a reverse part:

1. Forward - A set of logic to convert a request from the legacy IS format and functionality to the target IS format and functionality.
2. Reverse - A set of logic to convert a request from the target IS format and functionality to the legacy IS format and functionality.

Depending on the system and gateway, this conversion may require a mapping of data types and structures, signal speeds, handshake protocols, and so forth. Both the forward and the reverse components need logic to determine whether a format or functionality conversion is required, because a request between legacy components or between target components will usually not require translation. Otherwise, a message passed from one component to another must map the functionality and format of the sending component to the functionality and format of the receiving component. For example, if a user submits a database query from a legacy terminal GUI, the gateway must first determine whether the query should be routed to the legacy application component or the target component. If the gateway determines the target component is appropriate, the gateway must transform the query's legacy format and functionality to the corresponding format and functionality of the target application (Olsem, 1997).

Interface migration is critical to both the end users and the external systems that interact with the composite IS. The legacy IS contains key corporate resources, and the user and system interfaces control all uses of the system and all access to those resources. Therefore IS interfaces are as critical to the organization as the databases and the applications. The system interfaces significantly influence the efficiency of all current and future ISs that interact with the target IS. If the system cannot access the IS it cannot perform its function. Interfaces are critical before, during, and after legacy migration. Indeed, the success of the migration depends on the interfaces to the composite IS (Brodie & Stonebraker, 1995).

The goal to migration of the legacy information is to leverage the existing database. This means that the organization needs to make better use of the data sitting in it. Fundamentally this means a better user interface for the existing application and possibly adding functionality. Developers can get away with a certain reduction in performance if they trade it for actual improvements in some areas. Reporting is an area where users generally are willing to trade performance in exchange for flexibility (Johnson Computer Software Team, 1998). Giving the users the ability to construct reports can be a real selling feature of the redesigned system.

The interface must also help the user to mitigate the complexity of the information system created by running the legacy system and the target system in tandem. This complexity, if not handled appropriately, can create separate log-on and administration of each application and force the user to sign on separately for file and print service. Integration of these infrastructure aspects is crucial to minimizing user frustration and enhancing chances of satisfaction (Miller, 2000).

User Needs

Two simple design principles underlie the development of products and services: (1) know your users; and (2) involve users early and continuously. Users may be experts in their requirements, and understand their goals and their tasks. However, users may not be good at describing, explaining, or predicting what they may need. Because users may not make good designers they must be involved in effective ways. In general, users can develop their own conceptual work model. This conceptual model is seldom, if ever, the same as the designer's model. That is why the users must be involved in the design process. Understanding the user's real requirements, rather than their requirements as perceived by the system developer, is absolutely critical to the development of successful information systems (Tuffley, 1996).

To achieve a high level of information technology quality (user-friendliness), it is essential that the statement of user requirements be developed. If this is done, the system that is designed will meet the user's needs, and will lead to user satisfaction. If it is not done, the system is likely to not meet the user's requirements, even if the software conforms to the specification and has few defects.

The key to setting system expectations is to be prepared. In order to meet the needs of the users it is necessary to measure what they have and use today with what the new system is intended to deliver. These measurements are known as benchmarks. Benchmarks are used to draw comparisons between the "as-is" legacy system and the "to-be" target system. This helps to highlight areas to the project manager where expectations can be exceeded, can be met, or are deficient. Benchmarks do not have to be complicated to be effective. It is important to gather information from the user to determine what characteristics of the system will be important to him or her (Mathers & Genoway, 1999).

User Interface Design

The user interface to information is the principle piece to deploying a successful system. But interfaces are one of the most demanding and misunderstood aspects of a migration and system implementation. If the information contained by a system cannot be distributed to the whole user population then the real purpose of the system is lost in the implementation (Stevenson, 1995).

Designing an interface for the users of a system requires first understanding the end-user's expectations. First they expect all information to be immediately accessible. They want to have whatever information they need, whenever they want it, wherever they want it, and however they want it (Yohe, 1996). They also expect an interface that is intuitively obvious–without regard to the different levels of intuition that render what is obvious to one person to be absolutely imperceptible to the next.

Project methodologies often fail to take full advantage of what is known about interface design. Designs are most flexible at their inception. Once the product's task is known, design the interface; then implement the interface design. The task definition will change as the interface is designed and the implementation will be influenced by the task definition as well. The place to start the implementation is to list exactly what the user will do to achieve his or her goals and how the system will respond to each user action (Raskin, 2000).

Effective human-computer interface design helps to reduce the learning time of the user. It will also increase the speed of the user in performing the task, reduce the rate of errors, and greatly improve the user satisfaction with the application (Schneiderman, 1987). According to Schneiderman the key to building an effective interface is to know the intended user. Users fall into three categories:

1. Novice User – This user has shallow knowledge of the task and possibly of computers themselves. The interface must be designed to ease the anxiety of the novice user.
2. Knowledgeable intermittent user – This user is knowledgeable of the task and computers, but will use the application only intermittently. The interface therefore must be easy to use and prompt this user to remember the steps required.

3. Frequent (power) user – The power user is familiar with the task and the computer. What this user demands is an interface that will allow accomplishment of the task in as few steps and rapid machine response as possible.

Often when designing a new interface to a legacy system, programmers already have a task lists. A crucial aspect to a successful design is to take the existing list and redesign how the tasks are performed.. Constructing detailed flowcharts to review how users are actually performing tasks given the current interface may reveal workarounds that users have created to improve efficiency, which can be incorporated into the new design (Hackos & Redish, 1998).

Many of today's interactive systems are inherently complex. That makes it even more imperative that interface designers make every effort to keep simple tasks easy or the user and complex tasks possible (Hix & Hartson, 1993). Simple tasks can be kept easy by using interaction objects that are natural to the user. For those aspects of the interaction that are difficult, programmers should attempt to make them as understandable as possible by breaking complex tasks into simpler subtasks, using objects that are natural to the user.

Watterson (1995) emphasized the importance of structured front ends designed to appeal to the end users. "Because of the impact on your bottom line, you need to understand the impact of GUI's. Most end users prefer GUI's to the character-based terminal displays" (p. 25).

With the increased popularity of using the Internet for remote access (mobile users) or using Web browsers to access company intranets, using a web browser user interface is another option to be considered. Applications that are hosted on the Internet are different from the applications typically found on LANs in client/server architectures and the applications typically hosted on mainframe platforms (Rennhackkamp, 1997). A Web browser application is usually more event-driven than a typical mainframe or older client/server application. The application must react to point-and-click actions from users, instead of guiding them through a predefined flow of control. Web browser applications are usually broken up into components that are downloaded to the Web browser when required. The Internet's architecture also places challenges and limitations on the types of applications it can support efficiently. Typical mainframe application users are usually quite stable with regards to working hours, but Web users are free to move and access the Web from wherever they are, whenever they want. A Web-enabled interface may have many more spur-of-the-moment access requests than the corresponding mainframe interface program.

However, there are many reasons for accessing a legacy database from a Web browser. Many organizations want to Web-enable their existing applications and their existing databases without having to reinvent the wheel or modify the existing host-based applications. This approach can extend the life of the legacy applications and legacy databases that probably required quite an investment to create and install in the first place. Accessing legacy applications from a Web browser also gives all of the old applications a common, modern look and feel.

There has to be efficient and reliable connectivity from the Web browser running on a client PC, to the Web server running on an intermediate platform, to the legacy application and database running on the mainframe. The second part of this communication chain is one of the key issues in Web-legacy integration. The protocols used between the Web browsers and the Web server, such as TCP/IP, were made for simple information transfer. However, business applications on a mainframe may require much more complex transaction and data communication functions, such as those found on system network architecture (SNA) networks. SNA is a large, complex network architecture developed by IBM in the 1970s (FAA, 2000). Legacy applications usually run in secure and stable network environments, but the Internet applications are designed to cope with unreliable communication and network failures. A multiprotocol solution is required to seamlessly access applications from industry-standard Web browsers.

Total Cost of Ownership

Typically technology by itself has no intrinsic value, but if properly used it can help to reduce costs. The deployment of technology has both cost and value. Poor implementation occurs when the costs outweigh the benefits, producing negative value. The Gartner Group, the recognized experts in calculating cost of ownership in client-server environments, estimates best practices can lead to cost reductions of about 30% and increase utilization of functionality as well as user satisfaction (Gartner Group, 1997).

When formulating initial plans for any new system, it is an inevitable and absolutely necessary task to consider the costs of the system and balance those against the benefits the system promises. Many models have been developed for estimating the total cost of information technology services, popularly termed "total cost of ownership" (TCO). Such models have typically analyzed the costs of owning and maintaining a PC or other specific forms of desktop computing hardware. This method is increasingly irrelevant in today's networked environment with geographically dispersed users (Kapoor, 1999).

Unfortunately, trying to determine the TCO of a thin-client environment has some inherent problems. First, information system costs can be very hard to pin down. Every installation is run with a different set of metrics. Cost assumptions will change based on the size and type of network, the work processes for which the network is being designed, the resources allocated to network operations, and the culture of the end user enterprise (Welcome to Thin Planet's Thin TCO, 2000). Second, some cost items are very hard to measure. Although purchased cost components or labor costs may have quantifiable price tags, some of the costs we need to accumulate lack visibility. Shared costs can disappear because they are charged elsewhere. Yet in order to calculate costs it is necessary to consider all of these.

Calculating hard costs for a thin-client architecture implementation project is relatively straightforward. It can be determined by adding the total cost of hardware and software required. The total hard cost for a thin-client architecture will vary depending upon the number of users for the system to be deployed. That will aid in determining the size and speed of the server, amount of hard storage required, and the number of end-users site licenses needed. By reducing or eliminating the requirement to purchase hardware for the users, thin-client helps to reduce the hard costs of TCO.

In estimating a cost benefit analysis for implementation of thin-client architecture it is important the project manager does not equate TCO with hard costs only. Long-term savings are generally realized through the soft costs of the system. Soft costs fall into three general categories:

1. Hardware maintenance: The cost of servicing the users' local hardware, including computer upgrades, monitor servicing, etc.
2. Application support: The cost associated directly with the applications that a user would run. This has to do mainly with application installations and upgrades.
3. End-user support: The cost associated with supporting the user. Providing assistance using an application, configuring printers, scanning and removing viruses, and fixing desktop configurations that have been changed by the user are only a few examples.

Complexity associated with information technology (IT) management and infrastructure in an organization is a major factor driving TCO. From a total cost of ownership perspective, more complex organizations and/or IT installations can expect higher planning, implementation, deployment, and retirement costs associated with a wide variety of technologies. However, more complex IT environments also tend to enable greater return on investment opportunities (Gartner Group, 1997). This is because more complex infrastructures are difficult to manage and therefore are often not cost-effective. Therefore, the more complex IT infrastructures often offer more inherent savings opportunities to exploit.

The Tolly Group performed TCO analysis using various scenarios and configuration with a variety of vendor based solutions in June of 1999 (Kapoor, 1999). Application of their own model for calculating TCO revealed a client-independent approach, such as Citrix's ICA, yields the lowest cost of application ownership of the models analyzed. Since applications reside and execute on the server, the time and costs of installing, configuring, and deploying applications to users is greatly reduced. Since only the graphical user interface to the application is distributed to the client, virtually any device can access even the most sophisticated application.

The Tolly Group also found that while server-based computing is usually perceived to drive up network usage costs, this is not the case with the Citrix ICA model. Only keystrokes, mouse movements, and screen updates are distributed to the client, so high performance is possible even over low-speed connections. This approach not only reduces network traffic, it can improve performance and productivity for wide-area network (WAN), Internet-connected and remote dial-up users by as much as 10 times while using existing network infrastructure. Organizations have been able to avoid the significant costs of network infrastructure upgrades for additional bandwidth and significantly reduce ongoing data communications cost.

Zona Research (1996) conducted a similar cost of ownership study for desktop clients in spring of 1996. The purpose of the research was to determine the overall five-year lifecycle costs of various alternative server-based network configurations, all of which were capable of delivering Windows applications to the desktop. The results of their study showed a 57 percent lower cost of ownership in models using Citrix ICA compared to other thin-client alternatives and configurations.

Project Management Considerations

The sheer size and complexity of a migration and system design project makes managing these projects difficult. There are really two basic sides to the project management: people and technology. In some cases the project manager may not be able to know who will be affected by an implementation, which can lead to some nasty surprises. It can also be difficult to get a clear vision of the technological portion of the implementation because of the vast combination of hardware and software involved (Trepper, 1999).

In any project it is important to identify clearly and precisely the expected results. A project charter or mission statement can help define the goals and scope of the project. The scope of the project must be considered when defining expected results. If an organization has more than one business unit or line, the project manager should decide which division to include in each phase of the rollout of the project. Typical areas to consider in order to help define the goals and scope are (Hughes, 1998):

1. User Satisfaction – Define user needs and expectations of system performance.

2. System Productivity – Determine the overall data throughput required of the system.

3. System Cost – Examine the cost of the system and weigh it against benefits expected.

Once the overall goals have been identified, a basic investigation into the system is performed. Interviewing key personnel and reviewing general system and application documentation typically accomplish this. A detailed project plan can then be created. The manager must identify the tasks, resources required, and intermediate milestones necessary to complete the project. The project plan should also account for project management functions, status reporting, and cost tracking.

As more and more government technology managers learn from past failures they are beginning to come around to a different way of thinking. More attention is being paid to projects during the planning and design phases, to get the input of the people who will actually have to use the systems. And managers are coming up with new approaches to guiding projects as they develop. They are scrutinizing and minimizing risks from the outset to establish tight controls at every step of the process, or else shift more of the risk to the vendors (Perlman, 1998).

Whenever a project development schedule is slipping badly and there is a crisis, the term *mythical man-month* is likely to be heard. The Mythical Man Month by Frederick Brooks (1995) is the bible for modern project managers. Brooks explained that if a project estimate shows one programmer requires 12 man-months of work for a given project, that does not equate to having 12 experienced programmers working simultaneously for one month. In fact, Brooks expounds that if you throw additional programmers at a project that is late, you are only likely to make it more late. The way to get a project back on schedule is to remove promised-but-not-yet-completed features, rather than multiplying worker bees.

Breaking a large project into smaller subprojects and tackling each incrementally increases the chances of success. According to the Standish Group International Inc., a market research and consulting firm, the success rate for technology projects that cost more than $10 million is zero. That is, none of the government or private sector projects examined were completed on time, on budget, and with all of the features and functions originally specified (Perlman, 1998). Therefore breaking a project into smaller segments can be beneficial. Each segment can be deployed, and then analyzed for successful and unsuccessful aspects. The successes should be celebrated and the unsuccessful elements used as lessons learned to adjust the next segment plan.

Case Studies

Many companies and government agencies are faced with the same problems of accessing legacy systems. Increasing numbers of those are looking for a combination of migration and thin-client technology as solutions. Reviewing some of these will validate the applicability of this approach.

The California Housing Finance Agency needed to access legacy software, a UNIX database, and integrate Windows applications from every desktop. It had been left with a mini-computer network by a company that had gone out of business and dumb terminals that needed to be replaced. They also had staggering amounts of legacy software and productivity applications on the mini. The database was ported to UNIX, so the agency created a plan to use an X Windows environment working on a server with mouse-driven software. They purchased network computers (NCs) from NCD using Explora, NCD's proprietary thin-client software. In the beginning the cost per desktop was about the same as a PC, but in the past two years they have spent nothing on upgrades at the desktop level. Support costs for the network dropped dramatically. With 200 thin-clients devices in place they have one system administrator and no dedicated help desk. The Agency is very happy with the solution and has plans next to create a Web-based intranet and to expand the thin-client base (California Housing Finance Agency, 1999).

With its headquarters in Ottawa and a state-of-the-art production facility in Winnipeg, the Royal Canadian Mint today employs approximately 500 highly-skilled and dedicated individuals involved in all aspects of coin design, production and marketing in one of the largest and most complex minting facilities in operation today. The mint originally chose to use Citrix MetaFrame to solve some Year 2000 (Y2K) compliance issues. They were pleased to find that this product would also permit them to retain some of their older desktop hardware while meeting their Y2K objectives. It also allowed access to non-Windows applications and other network platforms. Under the mint's original parameters, remote access, an inherent Citrix feature, was not a key desire, but speed of access was. As the Citrix product would accomplish both of these objectives, the mint chose to expand the original concept. The server, using MetaFrame, is being remotely accessed to provide Winnipeg staff members access to the inventory database program. The mint is pleased to find that this Y2K solution netted additional benefits that improve their business processes and internal communications (Royal Canadian Mint, 1999).

The Public Defender's office of Orange County was seeking a high-performance, cost-effective way to deploy its 14-bay CD-ROM legal libraries to a diverse user base, consisting of older 286 PCs as well as powerful Pentium PCs. Following the bankruptcy of Orange County, the already under-budgeted Public Defender's office had to deal with problems arising from monetary and staffing limitations. The underlying technology problem facing the County was the need to deploy its mission-critical 14-bay CD-ROM legal libraries to attorneys and investigators. The libraries would facilitate faster, easier legal research from home or the field to improve productivity. Because they couldn't afford to hire a larger secretarial staff, attorneys were preparing their own legal briefs using systems that ranged from older 286 and 386 PCs to powerful Pentium PCs. The office implemented Citrix's Winframe/enterprise multi-user application server software. The multi-user software has saved Orange County an estimated $6 million in costs because it helped them to do more with less available resources. It also maximized its return on technology investment by utilizing the older computers within the organization. With the significant increase in productivity the Public Defender's office was able to do a complete restructuring. It opened two new offices and hired more attorneys with the same systems staff. Citrix also saved Orange County money by providing County investigators in the field to access the network using Internet connections instead of long distance calls to a branch office (Orange County Public Defender's Office, 1999).

The Office of the Comptroller of the Currency (OCC) is creating an information architecture to help it build a data warehouse, one data mart at a time, over the next several years. The OCC plans to integrate the data marts together as the project progresses to avoid independent islands of information. Unless the office's plan combined the disparate data it would not make any improvement over the legacy database systems it now has. The first step to achieving its goal required the OCC to standardize information before entering it into the data mart. To get the data into the same format it set up what it calls a data warehouse staging area. In the staging area the office converts and standardizes data for inclusion into the data mart. OCC settled on Microsoft SQL Server and IBM DB2 software for the data marts. The data mart documentation and source data definitions are stored in a warehouse repository, separate from the front-end software. Keeping the information used by all data marts separate from front-end software will reduce retyping and give the office the freedom to use other software for future data marts. One likely change over the next few years, as the project progresses, will be to make the data marts accessible via an intranet (Mayer, 1999).

Contra Costa County, California's seventh largest county, boasts a population of 850,000, operates on an annual budget of close to $1 billion, and is home to such corporate giants as Pacific Bell, PeopleSoft Inc., Bank of America Corp., and Chevron Corp. County officials report that pressure to maintain the county's technology presence in the community is intense and constant. Forty-five LANs connecting 3,600 PCs in 75 locations make up the county's 10 megabit/second Ethernet WAN. The county depends on a variety of large-scale production systems including an IBM mainframe, several IBM RS/6000 servers, and about 100 Sun Microsystems Inc. workstations. It has begun to migrate over to using network computers with thin-client software. They estimate a savings of about 25% in up-front costs over a comparable PC. They are reporting major savings on sites where they perform multiple installations. Ongoing maintenance is dramatically reduced as they find they no longer have to worry about backups, virus protection, or the introduction or removal of proprietary information. The IT team chose Winframe from Citrix as the key software component. The thin-client/server system gives multi-user access and allows integration of all the users into the complex network configuration. Current plans call for expanding the network to 44 local courts (Wilcox, 1997).

Summary

The FAA has a number of legacy database systems. Two systems in particular, the payroll system and CPMIS, were identified as early as 1989 as a liability in the agency and targeted for replacement. Several attempts have been made to accomplish this goal, but were unsuccessful. The CPMIS system is very complex and utilizes a proprietary language and structure that adds complexity to the issue of migrating the database into something that conforms to modern database management rules. Migrating the system must also consider the system architecture that will support an information system structure that will allow the agency to take full advantage of the new system's capabilities. Client/server has become an industry standard for a method for replacing the antiquated mainframe approach. The newest technology offering in the client/server arena is thin-client. The thin-client arena has proven as a cost-effective method for implementing organization information systems and expanding networks beyond traditional boundaries. Whatever migration implementation is chosen will involve good project management skills. Foremost among these is the ability to gather and meet user needs in the design and implementation of the replacement system. These needs will allow the design of a user interface that will maximize the ease of use and productivity of the system. The next chapter looks at the research gathered to capture lessons learned from the previous replacement efforts, gather more specific information about specific thin-client product offerings, and an initial look into needs of the user community.

CHAPTER III

METHODOLOGY

Introduction

This study was designed to identify considerations in the development of an alternative to replacing the Consolidated Personnel Management Information System (CPMIS) legacy system by examining the use of new client/server technologies and database migrations, and user preferences for interface design to this technology. Increasing costs and lack of sustainability of the CPMIS legacy database mandate that the FAA find a viable alternative. To avoid repeating previous replacement failures any new system must meet the needs of the users both in functionality and usability.

The study identified considerations for initiating the design of an incremental migration project by capturing lessons learned from previous CPMIS replacement attempts. Finally, the study identified an initial set of user preferences to determine requirements of the targeted system. The results of the research were used to analyze strategic gaps between the actuals of the existing CPMIS and the optimals of a newly designed user interface.

To aid in the design of an effective model the following primary research questions were addressed:

1. What are the "lessons learned" from previous replacement attempts?
2. What features of an information system are most desired by the end user?
3. What characteristics of a thin-client system architecture could benefit the FAA in future CPMIS replacement efforts?

To answer the research questions posed by this project, three different methods were employed. The methods used were interviews, focus groups, and a survey instrument. A combination of these techniques was needed to adequately gather sufficient information to determine reliable findings. The topic areas addressed were:

1. Previous Replacement Projects
2. End User Design.

Previous Replacement Projects

Previous attempts to replace legacy systems within the FAA have the potential to provide valuable lessons learned to provide insight to any new project. These lessons learned can be in the form of what worked successfully in the replacement effort as well as what may have gone wrong. This would address the first research question:

1. What are the "lessons learned" from previous replacement attempts?

Two sources of information could provide the answer to this question. The first source was project assessments already conducted by the FAA. The requested reports were supplied. These documents were used for the literature review in Chapter II, as well as used for comparison with the second source of data for this research question.

The second source of data for lessons learned through previous replacement projects was interviews of personnel who worked on the projects. The manager of the responsible organization was queried about the availability of the previous project managers and personnel. Two individuals were recommended by the manager for interview, based upon their expertise with the current legacy system and their roles with the replacement projects.

Examination of previous CPMIS replacement projects was accomplished through structured interviews with the two recommended employees. These employees are currently responsible for operation and maintenance of CPMIS and were also associated with the previous projects. Each interview explored the issues surrounding maintenance and replacement of the legacy system. Inquiries were made into the efforts, past and present, to replace CPMIS.

A structured interview was used to gather this particular data, as opposed to using a survey instrument for two reasons. First, the small number of employees involved made an interview format a feasible option. Second, an interview format allowed the informants to respond in a freeform manner. The combination of structured questions with follow-up inquiries enabled the interview to follow the most natural path that could also adjust for the differences in the experiences of the employees. Both of the previous CPMIS replacement projects entailed replacement of the Consolidated Uniform Payroll System (CUPS) as well as replacing CPMIS. The answers and follow–up questions allowed the interviewer to break the information and extract only the portions pertaining to the CPMIS replacement.

The questions used for the interview were designed to look at the primary factors that caused the previous replacement projects to fail. These factors were cost and user dissatisfaction. The first three questions on the interview explored the cost of the replacement projects. These questions were intended to explore how the cost estimates for the projects were originally determined. The fourth and fifth questions explored how user needs and system requirements were determined. The last two interview questions focused on what portions of the previous projects were successful and should be included in future projects, as well as what portions of the project were unsuccessful. The questions were reviewed and edited by the human factors research group of the Civil Aerospace Medical Institute (CAMI) prior to their use. A copy of the interview questions is included in Appendix A.

End User Design

The two methodologies used for determining initial end user design considerations were a focus group and a survey instrument. Use of a focus group allowed access to a small representation of the user population in a setting that gave the researcher some flexibility for interaction, similar to ability to use follow-up questions in the project manager interviews. Results of the focus group session were then utilized to concentrate on key areas in the questions on the survey instrument. A survey instrument was employed to gather information from a broader representation of the population, both in terms of number and of geographic dispersal. The purpose of the focus group results and the survey instrument was to answer the second research question:

2. What features of an information system are most desired by the end user?

First the sample population used for the focus group and the sample population used for the survey instrument were chosen. The Airway Facilities (AF) Service is the second largest line of business within the agency with 11,500 employees. Over the past five years the AF organization has averaged 15,000 training completions per year, or just over 50 percent of all training completions for the FAA Academy. The end user evaluation was confined to the training administration personnel for this line of business.

Focus group participants were the principal training administrator from each of the nine regional training administration offices. Personnel in the regional training offices act as a liaison between the FAA Academy and the field locations. These specialists determine what training the personnel at each facility need, then prioritize those needs based upon available training capacity of the FAA Academy. If an available quota is less than what is requested by the field facilities, the regional training office specialists determine which facility will receive the available training. Regional specialists also act as oversight authority to determine that accurate training records are kept for personnel at all facilities. These are the personnel with far reaching historical experience of both the existing system and the previous replacement efforts. These individuals were chosen because of their key role as an interface between the field training administrators and the FAA Academy. They interface on a regular basis with the various levels of training administration personnel within their region. This places these regional personnel in a position to know enough of what the issues are for the other training personnel to help refine the instrument that will go to those personnel.

A facilitator was used to conduct the focus group discussion. An FAA Academy representative acted as the recorder. Minutes of the meeting were kept, with major topics and responses captured through use of portable print media (flip charts).

The questions asked of the group addressed broad issues regarding the need for the replacement of CPMIS. The questions used were:

1. What are the needs of the users?
2. What needs are currently met with CPMIS?
3. What needs are not currently met with CPMIS?
4. How might needs change in the foreseeable future?

Based on the responses of the focus group, the survey instrument was compiled and sent to the human factors research group of CAMI for review and editing.

The survey instrument was mailed simultaneously to a total of 142 individuals selected from three groups of field personnel responsible for administration of training for Airway Facilities, the largest user of the national training system. The first group was 36 regional training personnel. Nine members of this population were also participants of the focus group.

The second population group to receive the survey instrument was all 66 Personnel Systems Specialists (PSSs). Two PSSs are located at each of the 33 Service Maintenance Organizations (SMOs). These individuals work directly with the first level supervisors at each facility to determine the employee training needs. The PSS then works with the regional training representatives to obtain the needed training slots, and keeps the training records for all personnel within their SMO.

The final group to receive the survey was 40 remote-site training administrators. The remote-site administrator is responsible for relaying training needs to the PSS, and notifying employees of when they are scheduled for training classes. Generally the first level supervisor fulfills this responsibility, although some sites delegate this to a lead technician. Of the 160 training administrators at the most remote sites maintained by the Airway Facilities service, 40 were selected at random to provide a representative sample.

The survey was designed to determine the needs of the end users of CPMIS information and find a focus for any improvements to the system. By including this group in the research process, a more holistic solution was achieved in the overall quest for a cost efficient model that will serve the agency well. A copy of the survey was submitted to the Institutional Review Board (IRB) of Oklahoma State University and approval was received on March 16, 2000. A copy of the IRB approval is provided in Appendix B.

The survey instrument was used to provide scalar measurement of the preferences of the end users. Fourteen questions, incorporating a combination of objective scale techniques, were used. Nine of the items were closed choice. The choices given were based on information from the focus group session. One item was open response. Two items were a combination of closed and open. All of the responses on these two items were closed except for the final option, which allowed for an open response. Two items were a rank order of preferences. The items were then analyzed using descriptive statistics. A copy of the survey instrument with its cover letter is provided in Appendix A.

The first question on the survey was used to separate the respondents according to their job function. The second and third question then captured data regarding level of access required and frequency of system use, to determine if the different respondent groups use the system in the same manner. This information could be useful to explain differences or similarities in responses between the groups.

Question five was a combination of multiple choice and open response to gauge the satisfaction of the respondents to the current CPMIS system. The last choice was open ended to allow a free-form response that may differ from the focus group consensus.

The intention of the next three questions on the instrument was to determine how familiar the users are with the present system, and whether or not any dissatisfaction may be caused by lack of training on the system, or difficulties with the system itself.

The purpose of the remaining questions on the survey instrument was to provide additional understanding of the client requirements and preferences for features of a new system. Two of the questions were rank order preference format. The first question of the two was used to determine the user's priority of system capabilities. The second rank order question determined the user's need and priority for information access within the system.

The last question on the instrument was a system question to assist in determining cost factors for a replacement architecture. The intent was to determine the network access in place with the users and compare these with the architecture options supplied by the vendors.

Limitations

To determine the limitations for each methodology of data collection, the following assessment planner outline was used, based upon a training needs assessment model used by Rossett (1987). Figure 2 shows an outline used by the assessment planner to determine and organize the resources available to provide information and data needed, as well as any limitations to the research that may hinder gathering the data. Because each of the limitations could constitute a threat not only to the availability but also to the validity of the data, consideration was given to how to offset or minimize those constraints. Use of each data collection method was weighed in consideration of its possible limitations and the ability to overcome those limitations.

Topic	Resources	Limitations
Previous Replacement Project	Project assessments Interview Data	Security/Sensitivity Levels Accessibility of previous project managers
End User Design	Focus group results Survey Results	Geographic separation of key people Return of surveys

Figure 2. Available Resources and Limitations.

To facilitate the gathering information on the previous replacement projects, the researcher contacted the Director of the Mike Monroney Aeronautical Center. The Aeronautical Center is a centralized facility in Oklahoma City with the largest concentration of Department of Transportation employees outside the Washington, D.C. area. Included in its many organizations is the Office of Information Services (AMI). This organization is currently responsible for the maintenance of the agency's CPMIS system, and conducted the previous CPMIS replacement attempts.

The first issue discussed with the director of the center was the availability of the assessment reports from the previous replacement projects. The information in the reports is available to the public through a Freedom of Information Act (FOIA) request. These requests typically take a lengthy amount of time, however, as they are routed from office to office for review. Therefore, the option of using an FOIA request was discarded in favor of a direct request to the Director. This limited the documentation supplied to condensed versions of the projects in reports compiled by third parties, and whatever documentation was readily at hand by the responsible organizations.

The concerns and sensitiveness of AMI regarding the previous projects was also discussed with the Director. The Director contacted the manager of the project organization to apprize the individual that the research had the support and approval of upper management. The researcher then made direct contact with the project organization manager. The purpose of the study was explained, along with a good faith guarantee that there was no hidden purpose for the results of the study. Anonymity of the participants was also guaranteed.

The apprehension of the employees involved was eased by knowing that the manager and Director of the Aeronautical Center were aware of the research project and approved of the study. Using interviews instead of a survey instrument also allowed the interviewer to answer questions of the participants regarding the purpose of the research, to alleviate their apprehension about what and how much information was safe for them to share. The format allowed the participants to feel less threatened about participation in the interviews, given the sensitivity of the unsuccessful nature of their projects.

To overcome the geographic separation of the focus group participants, the focus group was conducted during one of many training administration meetings conducted by the agency. Typically these meetings are held three or four times a year, gathering the participants into a central location for face-to face sessions. During a national training conference conducted in Oklahoma City during the spring of 2000, a group of key training personnel were assembled for conduct of the focus group. The composure of the group was entirely made up of regional training administration staff. This lack of cross representation from the other segments of the training administration community was an additional limitation of the study.

The primary constraint for use of the survey instrument was obtaining a sufficient return rate to provide useful data. To encourage a high return rate the cover letter for the survey was put in an aesthetically appealing format. The letter emphasized the importance of the role that each participant played in the survey as well as the value of his or her expertise in the study. A bookmark was also included as an advance gesture of thanks to encourage response. A copy of the cover letter is attached in Appendix A.

Data Analysis Techniques

The first segment of the survey instrument was used to separate the respondents to determine if any significant difference occurred in the responses between the various population segments (regional training administrators, personnel system specialists, and remote-site administrators). The results of the survey were stratified, using the answers to question number one, according to the different levels of users. This separation was used whenever a difference in response could create a need for differentiation in responses.

Question number two was the open response item. It was analyzed according to the minimum, maximum and the mode of the responses, broken out by types of population segment based on the response to question number one. The items using forced response were evaluated by percentages relating each possible response to its part of the whole.

The two items that used a rank order technique were analyzed by using measures of central tendency and variation. Each item was evaluated for mode, median, mean, standard deviation, and variance.

Summary

To gather the needed information to answer the research questions three methods were employed.

1. Interviews
2. Focus groups
3. Survey instruments

Using these methods data were gathered from a selected population of former program managers and Airway Facilities training administration personnel. The combination of methods provided data that could be analyzed and interpreted using both narrative format and descriptive statistics.

CHAPTER IV

FINDINGS

Introduction

This study was designed to identify considerations in the development of an alternative to replacing the Consolidated Personnel Management Information System (CPMIS) legacy system. Increasing costs and lack of sustainability of the CPMIS legacy database mandate that the Federal Aviation Administration (FAA) find a viable alternative. To avoid repeating previous replacement failures any new system must meet the needs of the users both in functionality and usability. The data gathered is intended to lay the foundation for initiating the design of an incremental migration project by capturing lessons learned from previous CPMIS replacement attempts. The data also captured initial user interface preferences to determine requirements of the targeted system.

Using the methodology outlined data were gathered to address three questions posed by this research study:

1. What are the "lessons learned" from previous replacement attempts?
2. What features of an information system are most desired by the end user?

3. What characteristics of a thin-client system architecture could benefit the FAA in future CPMIS replacement efforts?

Interviews were conducted to assess the factors of previous projects that unsuccessfully attempted to replace the CPMIS legacy system. The data from the interviews was compiled in narrative format. Focus groups and a survey instrument were used to provide a correlation between the technology options and the end user needs.

Project Manager Interviews

Two individuals who were associated with the current CPMIS legacy system, the previous replacement projects, or the current replacement initiative were interviewed to clarify CPMIS technical issues and answer the prepared interview questions for the replacement projects. These interviews took place at the interviewee's own office setting to promote a sense of familiarity and comfort. Exploring the methodology and design decisions made on these projects provided insight into causes for past failures and an opportunity to identify the goals for any such replacement initiative.

Manager A

The first person interviewed, the project manager for the current CPMIS maintenance group that is responsible for correcting minor technical problems and running the daily operations of the system, referred to hereafter as Manager A, was a member of the team tasked with development and deployment of the Integrated Personnel And Payroll System (IPPS). After providing documentation on the current system to be used in the literature review Manager A responded to the questions regarding the IPPS project.

Project Manager Question One: What Was the Original Proposed Cost of this CUPS/CCPMIS Replacement? Manager A was unable to specifically determine the price of the replacement for either Consolidated Uniform Payroll System (CUPS) or CPMIS. The IPPS project was a complex project that was designed to provide interfaces between numbers of old legacy systems, including CUPS and CPMIS, in the initial phases. Then the legacy systems would have been redesigned and migrated into IPPS. The initial authorization in 1992 was for $21.3 million to complete five phases of development within four years. Retirement of CUPS and CPMIS was to occur in the latter phases scheduled for late 1995.

Project Manager Question Two: What Method Was Used to Determine the Cost/Benefit for Project Justification? The overriding mandate was to replace the existing systems to correct deficiencies that were identified by the Office of Budget Management (OMB). A number of options were considered ranging from modifying the current systems to replacing them with commercial off the shelf (COTS) software packages available. Cost requirements were determined using a project estimate methodology developed by Andersen Consulting. The Andersen method provides guidelines for creating estimates derived from all substantial factors and the development of a reliable estimate of workdays and resulting costs.

Project Manager Question Three: What Was the Result of the Cost Benefit Analysis? Manager A could not recall what the results of the cost benefit analysis were. After evaluating the available products and 15 other government owned systems the approach chosen was to do a "grounds up" development that would integrate and improve the current systems. It was based on this study that funding authorization was given.

Project Manager Question Four: How Were the User Requirements Determined (Methodology)? An intermodal workgroup was formed to determine what were the system requirements of each mode within the Department of Transportation. Representatives on this workgroup were tasked to gather the requirements for the mode represented by that member. Within the FAA ad hoc workgroups were called together to gather end user requirements to provide to the intermodal workgroup representative.

Project Manager Question Five: How Were the User Interface Requirements Defined? Manager A did not recall nor could find documentation on how the interface requirements were determined. By the time this individual had joined the project group the interface design had already been determined. It was Manager A's impression, however, based upon discussions with the other group members that the determination for which interface to use had been primarily based upon the cost of development.

Project Manager Question Six: Looking Back on the Project, What Three Things Would You Repeat (Consider Successful)? Manager A could only think of two things to be repeated on future developments. The first was the inclusion of both functional and technical people on the development team. The technical people tend to get too wrapped up in the mechanics of the development and forget about what the functional requirements of the system are. The functional specialists become so set in the way the system currently operates and do not readily see how through new technology those processes can be improved. Having both expertises within the team offers a balance to provide a better product. As a follow up question Manager A was asked to define a functional expert. Manager A's use of the term functional expert referred to the people responsible for operation and maintenance of the system. This excludes the end-user of the system.

The other aspect of the project that Manager A would repeat for future developments was to gather the best people from the various organizations to work on the team. The Office of Information Services at the FAA Mike Monroney Aeronautical Center is made up of several branches with different missions and tasking. Because of the high visibility and importance of the IPPS project the IPPS development team was allowed to pull the "best of the best" to work on the project. Manager A felt that was a successful decision that should be used again if given the opportunity.

Project Manager Question Seven: Looking Back on the Project, What Three Things Would You Do Differently (Consider Unsuccessful)? The first item that Manager A would do differently would be to manage the requirements better. Requirements were altered throughout the life of the project, creating havoc with project timeline and cost estimates. The changes were allowed in order to maintain support and buy-in from the users, but the changes were eventually the doom of the project, in this manager's opinion.

Manager A, although happy with the organization and makeup of the development teams, would have changed the management structure of the development effort. Because IPPS was an intermodal system it was funded by the Department of Transportation (DOT). This then put the primary management responsibility within the DOT, with each mode given equally representation in the management decisions of the project. Manager A pointed out that the FAA comprises approximately 75% of the DOT. The IPPS management structure left the user community that has the largest and most demanding requirements for the system with very little voice in the management of the project.

The final thing that Manager A would wish to see done differently in future projects is better acknowledgment by upper and senior management of the cost estimates. The development team had put together a plan with cost estimates that was supportable by the methodology used. The amount of funding actually allocated for the project was cut but the requirements of the system were not. Manager A felt that the success of future projects is dependent upon realistic expectations and support from management.

Manager B

The second person interviewed was the project manager for a subproject within the IPPS development and was assigned to the next replacement project after IPPS, a project titled Workforce Information Next Generation System (WINGS). Funding and authorization was withdrawn for the WINGS project shortly after its inception. This interviewee, hereafter referred to as Manager B, has remained to work with the next replacement project that is currently seeking funding and approval. This project is still in developmental stages and has no formal title. The group has dubbed it the Project With No Name (PWNN). Manager B provided answers to the questions both for the IPPS project and WINGS. Information for PWNN was also provided as applicable.

Project Manager Question One:. What Was the Original Proposed Cost of the CUPS/CPMIS Replacement? The original estimate for the entire IPPS project was $30 million with a timeline of five years. When the cost analysis went forward the senior management thought the estimate was too inflated so the request went forward as only $17.5 million with a completion estimate of four years. After 3.5 years, when the plug was pulled on the project, another cost analysis was done to determine what it would cost to complete the original effort. The analysis indicated that $13 million and another 18 months were required to finish the remaining phases. Manger A felt this validated that the original estimate was fairly accurate if it had gone forward as the original group recommended. The estimate for WINGS recommended implementation of a commercial off the shelf product instead of a customized development. The cost for this option was $37 million with a five-year implementation timeline.

Project Manager Question Two: What Method Was Used To Determine The Cost/Benefit For Project Justification? Both IPPS and WINGS used the Andersen II methodology for determining cost estimates. PWNN did not do a separate cost benefit study. Instead the project used the documentation and cost estimates of WINGS.

Project Manager Question Three: What Was the Result of the Cost Benefit? Manager B could not recall nor provide documentation showing the final cost benefit results for IPPS. The cost benefit for WINGS showed a probable cost benefit ratio of 1.3:1, with the breakeven point occurring 7 years after project initiation. PWNN has used this same documentation.

Project Manager Question Four: How Were the User Requirements Determined (Methodology)? IPPS did not have user requirements formally gathered. The designers used some fifteen considerations of system requirements as provided by the targeted legacy systems. These considerations were used to benchmark the COTS options under consideration. Functional specialists from the legacy systems were gathered on the project to brainstorm various requirements, as they understood them.

Project Manager Question Five: How Were the Interface Requirements Defined? No analysis was performed for interface requirements. The primary IPPS project manager had just completed the deployment of a replacement project for the financial database, known as Department Accounting and Financial Interface System (DAFIS). DAFIS had been deployed using a text input screen. The project manager decided to use the same interface screen for IPPS. Manager B recalls expressing disagreement with the IPPS manager at the time, but being overruled on the decision. As a way of compromise Manager B was allowed to be team leader of a subproject known as Management Information Resource (MIR). The MIR team chose a Windows GUI interface for that subproject. The MIR subproject was received with such success by the user community that it was decided that WINGS would also use a Windows GUI interface. PWNN will use a GUI interface within an Internet browser.

Project Manager Question Six: Looking Back on the Project, What Three Things Would You Repeat (Consider Successful)? The first thing that Manager B would definitely repeat is the use of the Andersen I structured methodology to outline the costs and schedules of the project. The information prepared through this method proved to be extremely accurate in its original estimates.

The second item that Manager B was very pleased with was the success of the MIR browser. This manager credited that to the fact that the browser was an easy to use tool that put the data within the reach of the users. The users could concentrate on the data and the ways the data could be used instead of struggling with the interface.

Finally, Manager B would repeat using the people from the existing legacy system maintenance group to work on the replacement project development. He felt that leveraging their talent and knowledge helped bridge any gaps between the old and new systems.

Project Manager Question Seven: Looking Back on the Project, What Three Things Would You Do Differently (Consider Unsuccessful)? The first and foremost thing that Manager B would insist upon doing differently would be to follow the information dictated by the Andersen I methodology. He felt the largest contributing factor to the failure was the fact that the costing estimates provided by the tool were manipulated to provide data more palatable to upper management. Given the opportunity project, Manager B stated he would be more forceful and stand his ground regarding the funding issued. If the amount granted was anything less than what the methodology projected, then he would insist that some of the system requirements be eliminated from the project.

The second item that Manager B would change dovetailed into the first, which was better management of the requirements. IPPS had suffered endless requirements changes, compounding the problem that the original requirements were never fully funded. Manager B would baseline the initial requirements, then ensure that any changes would mean that some requirements would drop off, or else additional funding would be required. If neither occurred, then the new requirements would not be added to the development.

The third item that Manager A would change would be to accomplish a more complete study of the technical architecture options for the system. Based upon the success of the MIR project he felt the agency should look strongly into three-tier client server architecture with GUI interface. Manager A was insistent he would not favor mainframe architecture with a text based natural programming interface as the IPPS project had used.

Focus Group Results

The purpose of the focus group was to gather information that was used to design survey instrument questions that concentrated on key areas of interest to the system end users. The participants of the focus group were the nine principal FAA regional training administrators. Plans for a new information system that will have modules that interface to CPMIS, known as REGIS (Regional Information System) were briefed to all of the participants of the training conference, including the members of the focus group, prior to the conduct of the focus session. The training representatives at the conference displayed a very negative reaction to REGIS. The negative reaction stemmed primarily from the fact that none of the field end-users, including themselves, were involved in the requirements gathering for the system. This created fear that REGIS would be another difficult to use, inadequate system, similar to the previous IPPS deployment. In fact the general consensus of the group after the briefing was that the REGIS did not adequately address their needs. Some of this negative reaction spilled over into the gathering of the focus group. The facilitator for the focus group struggled to keep the group focused on the questions for this study without letting feelings for REGIS bleed into the proceedings.

Focus Group Question One: What Are the Needs of the Users? It was generally agreed that the training community needs rapid access to CPMIS information. A number of "homemade" solutions exist, such as having one employee download information and then send the files via e-mail to others. The main problem with this method was not only the time of the personnel spent on the task but also the currency of the information after it was propagated out. Too often the individuals receiving the file will then use an old file rather than updating to the current file when it is sent. A great deal of discussion was spent on what level of information is needed by what type of personnel, due to privacy and security concerns. There was general disagreement as to whether read only access would be acceptable or whether write capability was also a requirement.

Focus Group Question Two: What Needs Are Currently Met With CPMIS?

Class schedules, course descriptions, equivalencies, and quota distribution were the features of CPMIS that were the greatest tools for this group.

Focus Group Question Three: What Needs Are Not Currently Met With CPMIS?

The greatest need not being met by CPMIS is the accessibility. The system has limited ports allocated to each region and it was generally agreed this is vastly insufficient. The next need not being met was the cross-referencing of course equivalencies to the prerequisite listings. This causes a great deal of manual work to be done by the training personnel to force the system to accept enrollments.

Focus Group Question Four: How Might Needs Change in the Foreseeable Future? Two changes were identified for future needs. The first was the need for more people at remote locations to have access to the information in order to make intelligent training decisions. The second was the need to be able to store certification record information within the CPMIS database.

End User Survey

A survey instrument was employed to gather information from a broader representation of the population, both in terms of number and of geographic dispersal. The purpose of the survey instrument was to answer the second research question:

What features of an information system are most desired by the end user?

Of the 130 survey instruments sent out, 61 surveys were returned. This was a 47% response rate. The following pages display the response percentages, followed by graphical displays of selected questions.

The results of the survey were stratified, using the answers to question number one, two, and three (Figures 3, 4, and 5). This stratification separated the respondents according to what training administration function they perform- regional staff, personnel system specialist, or remote site administrator. The second and third questions determined what the user levels would be. These questions asked how many time per week the user would need to access the CPMIS system, and what type of access, read and write or write only, is required. Respondents were classified as users with an average of

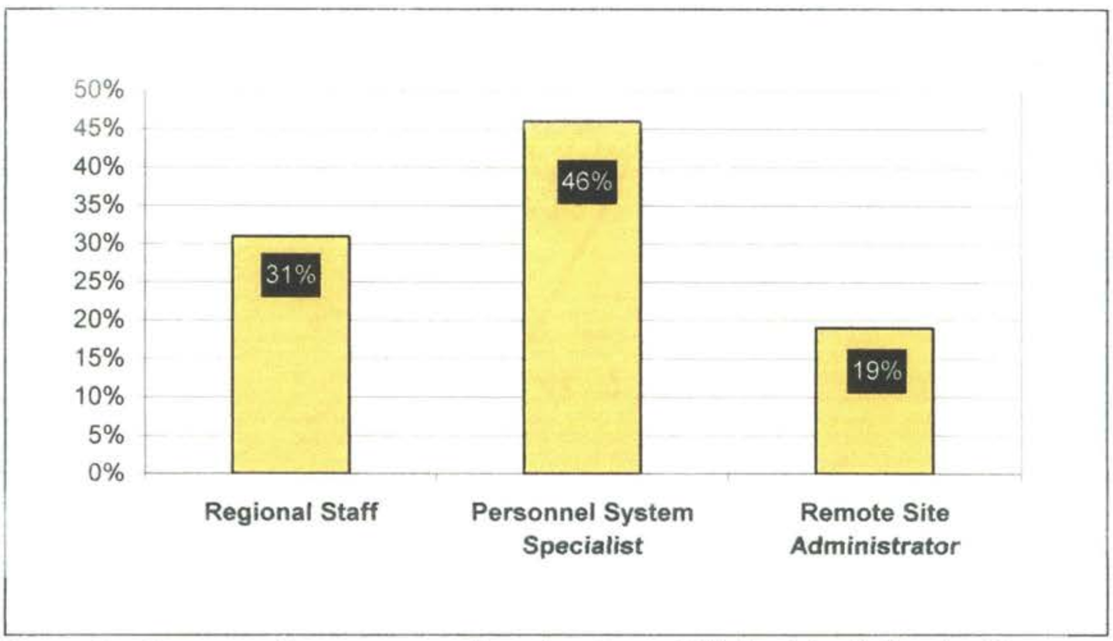

Figure 3. Response Percentages to Question One - Which of the Following Best Describes Your Role as a Training Administrator?

access 53 times per week, intermediate level with an average access of 19 times per week, and casual users with an average access of four times per week. Based upon the responses, the regional staff can be classified as the power users, the personnel systems specialists are intermediate users, and the remote site administrators can be classified as casual users.

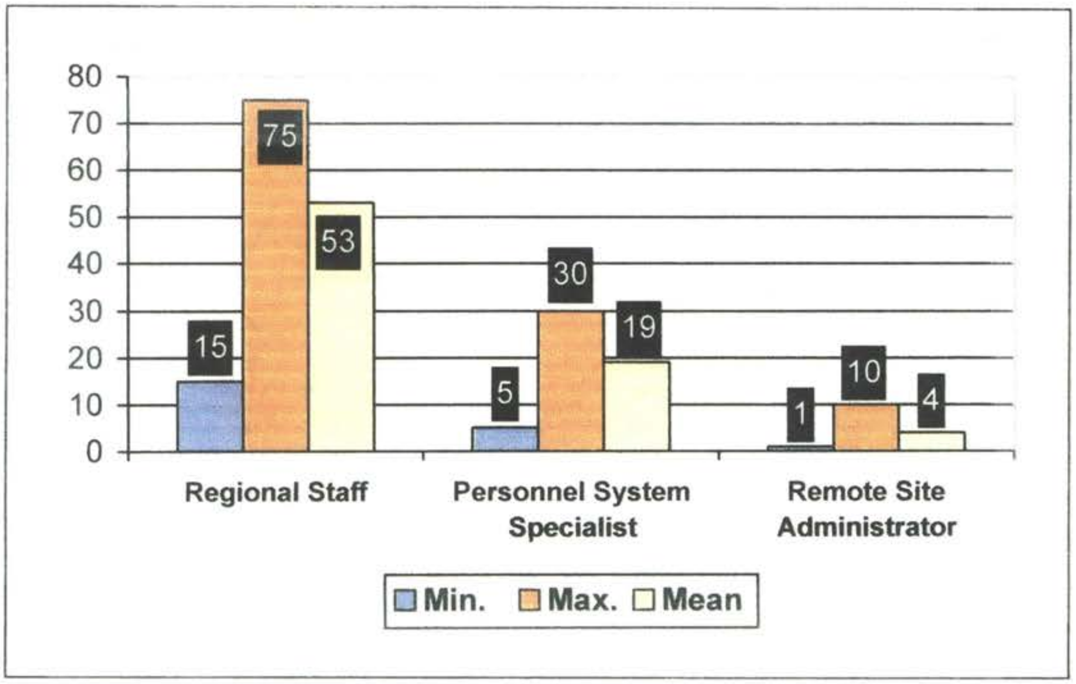

Figure 4. Responses to Question Two - How Many Times per Week Do You Need Access to CPMIS Data to Successfully Perform Your Job?

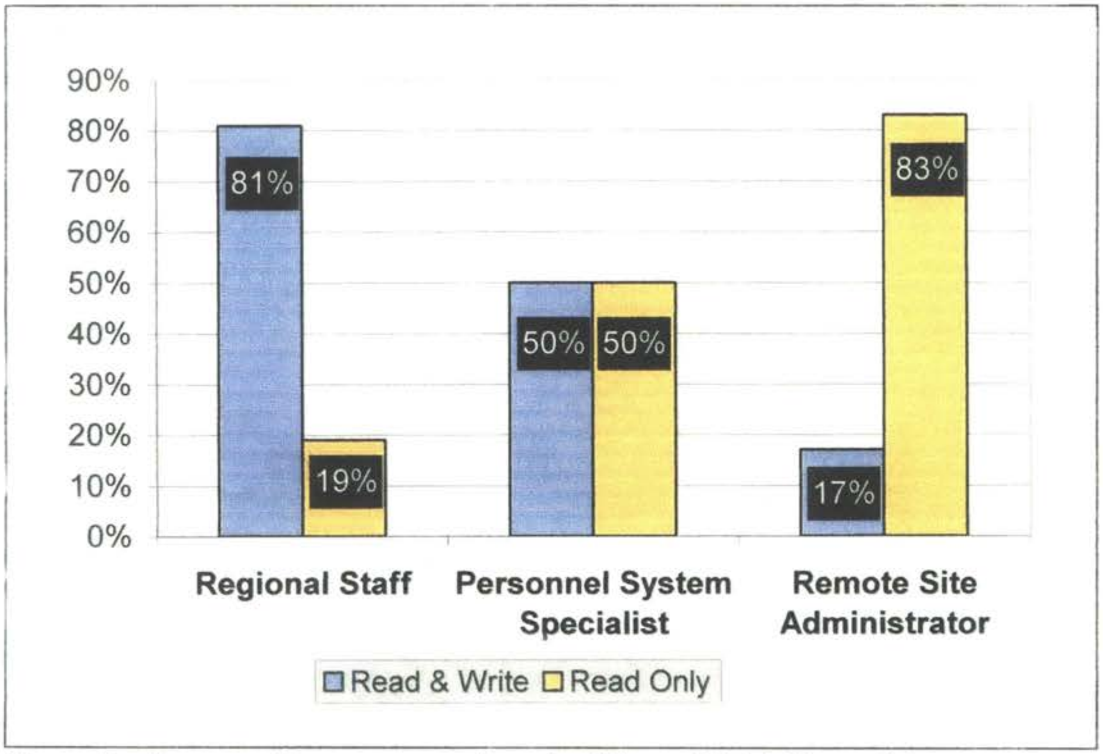

Figure 5. Response Percentages to Question Three - Which Type of Access to CPMIS Do You Need, AS A MINIMUM, to Successfully Perform Your Job?

Responses to question four, "*Do You Currently Have Direct Access To CPMIS?*" were used to filter out the user community that does not currently have access to CPMIS from the subsequent bank of questions regarding performance and satisfaction of CPMIS. None of the remote site administrators report currently having access to the legacy system. Only 18 percent of the personnel systems specialists have access while 81 percent of the regional staff has access (see Figure 6).

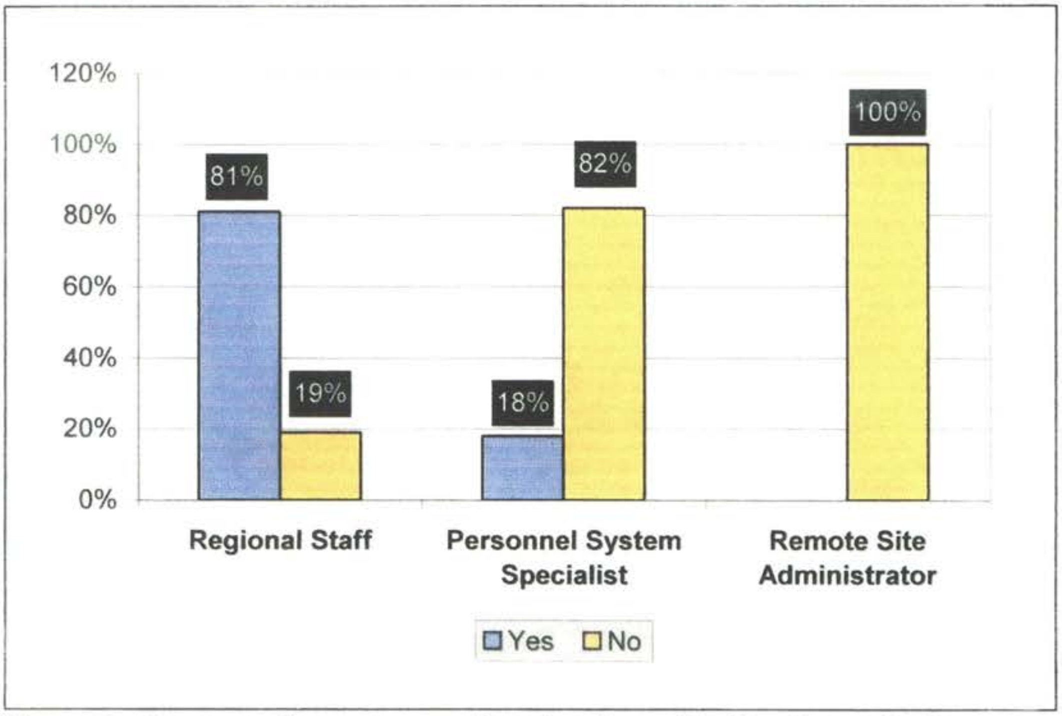

Figure 6. Response Percentages to Question Four - Do You Currently Have Direct Access to CPMIS?

Question five, "*Which of the Following Best Describes Your Opinion of CPMIS?*" used multiple-choice options which had incorporated the strongest responses from the focus group, along with an open response option (see Figure 7). The expressed opinions of the system show only marginal difference between each of the response groups. Thirty-four percent of the regional staff are satisfied with the system, while 40 percent of the personnel systems specialists expressed satisfaction. A similar number, 40 percent of regional staff and 50 percent of personnel systems specialists find the system difficult to use. Thirteen percent of the regional staff and ten percent of personnel systems specialists find the system unreliable. The only other expressed opinion on the system, was from the regional staff. Thirteen percent used the free-form response to report the quality of printing from CPMIS was unsatisfactory.

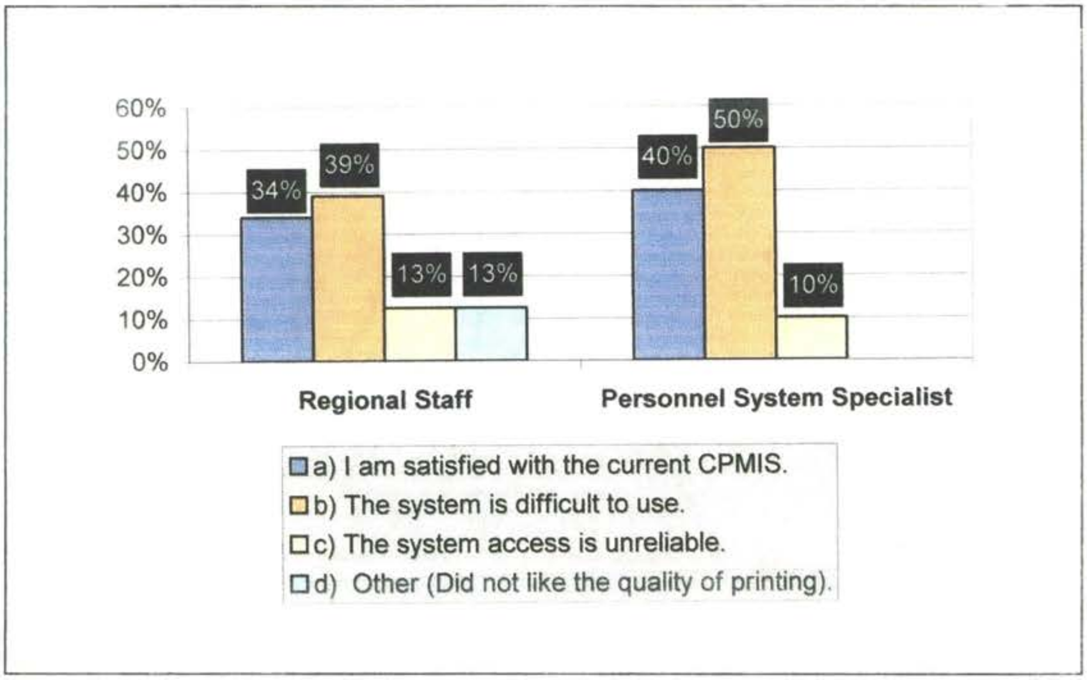

Figure 7. Response Percentages to Question Five - Which of the Following Best Describes Your Opinion of CPMIS?

Question number six, "*Did You Receive Training On CPMIS?*" was useful to compare with the responses to question five. Of the regional staff, 78 percent had received training, yet 39 percent still responded that they find the current system difficult to use. Only 40 percent of the personnel systems specialists had received training, but the level of dissatisfaction, 50%, was only marginally higher than the regional staff (see Figure 8). Many times dissatisfaction with any given system can be related back to an issue of inadequate training, as opposed to a weakness of the system itself. In this case, however, a significant number of respondents, particularly at the regional staff level, replied that they did have training on the current system. This indicates that training is not directly linked to the level of a users satisfaction with the current CPMIS system.

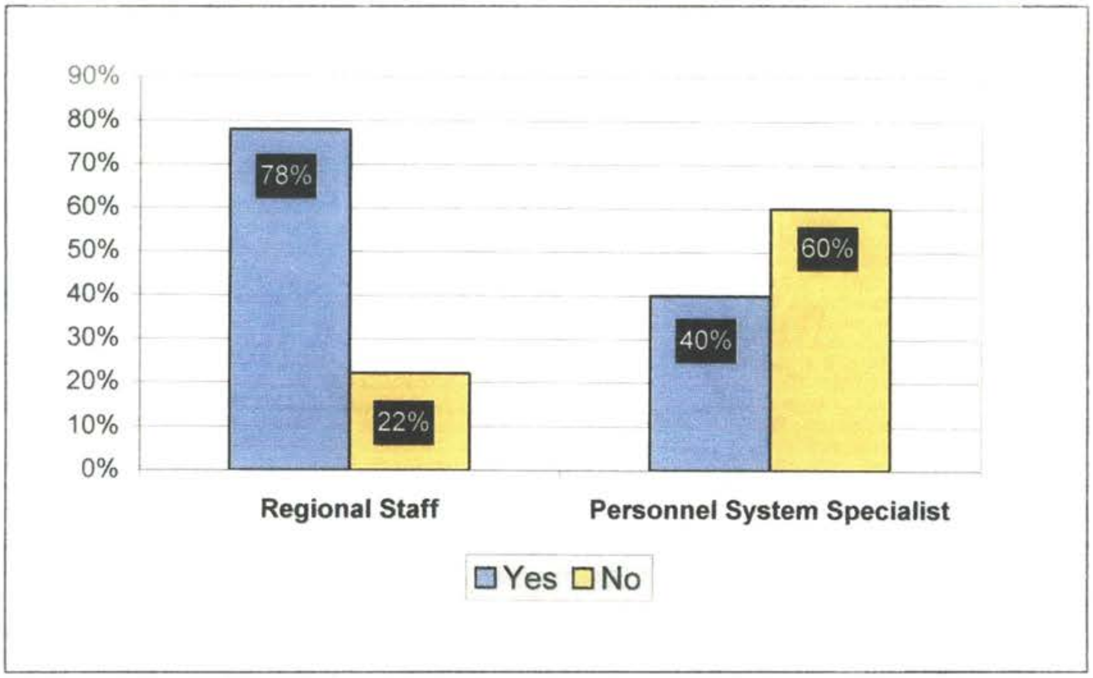

Figure 8. Response Percentages to Question Six - Did You Receive Training On CPMIS?

Another factor that needed examination to determine its possible relationship to user satisfaction/dissatisfaction was that of the system reliability. Responses to question number seven, "*Is Your System Connection To CPMIS Reliable?*" were used to compare with the responses to question five to aid in that determination. The responses show that the connection to CPMIS appears to be more reliable for the regional staff, with 89 percent reporting the system is reliable. Yet only 57 percent of the personnel system specialists responded that the system is reliable. Despite the stronger indication from the personnel system specialists that the system is unreliable, looking back to the response to question number five, the indication is that the difficulty of use is a stronger factor in their dissatisfaction than is the reliability of the connection (see Figure 9). Despite this, the strong negative response to this question should be kept in mind when designing a replacement system.

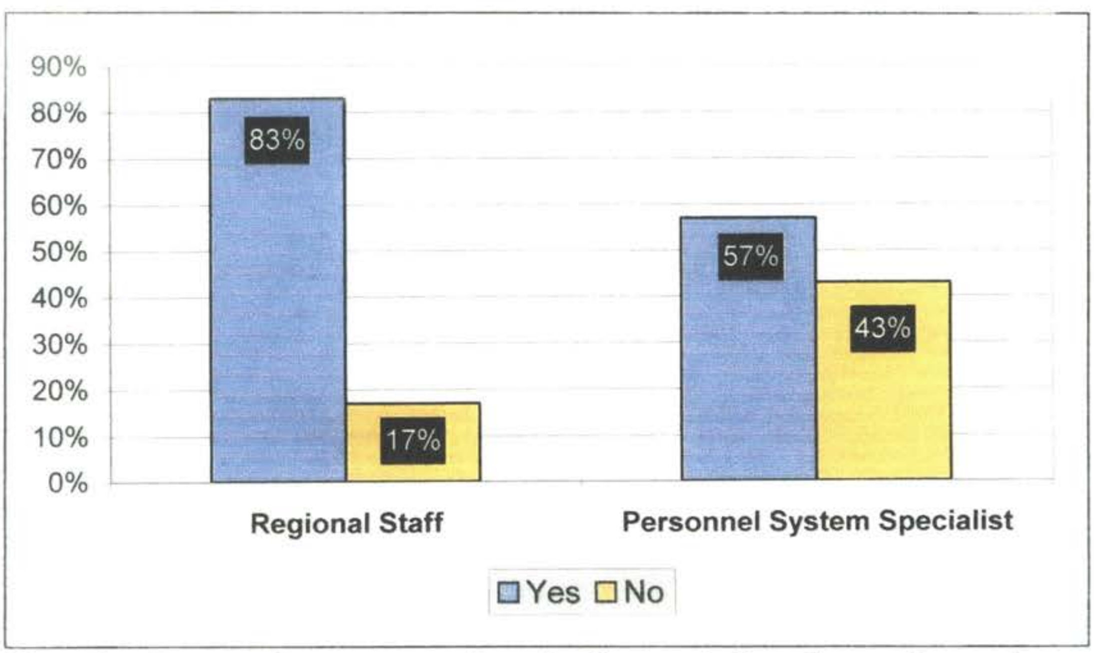

Figure 9. Response Percentages to Question Seven - Is Your System Connection To CPMIS Reliable (Connection Made And Stable Nine Out Of Ten Times)?

Question eight addresses another possible cause of dissatisfaction, "*Are You Currently Satisfied with the Support You Receive When You Encounter Problems or System Failures?*" The overwhelming positive response from the regional staff and the, 74 percent and 80 percent respectively, indicate support can be discounted as a significant factor in the dissatisfaction of the users with the present system (see Figure 10). Only 26 percent of the regional staff and 20 percent of the personnel systems specialists answered no.

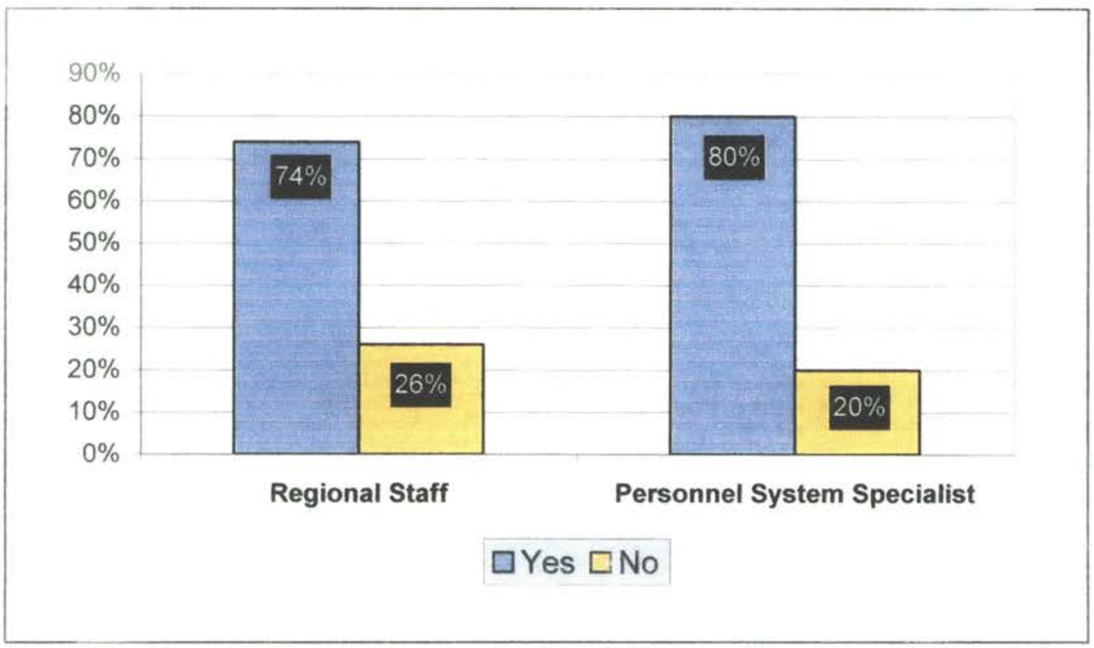

Figure 10. Response Percentages to Question Eight - Are You Currently Satisfied with the Support You Receive When You Encounter Problems or System Failures?

Answers to question number nine, "*If You Do Not Currently Have Access to CPMIS, Would a Read Only System Improve Your Ability to Perform Your Job?*" show that the intermediate and casual users of a redesigned system do not need the same level of functionality as the power users (see Figure 11). A system that would make the information accessible, without necessarily giving these users the ability to alter or enter information directly, would satisfy the immediate needs of the user.

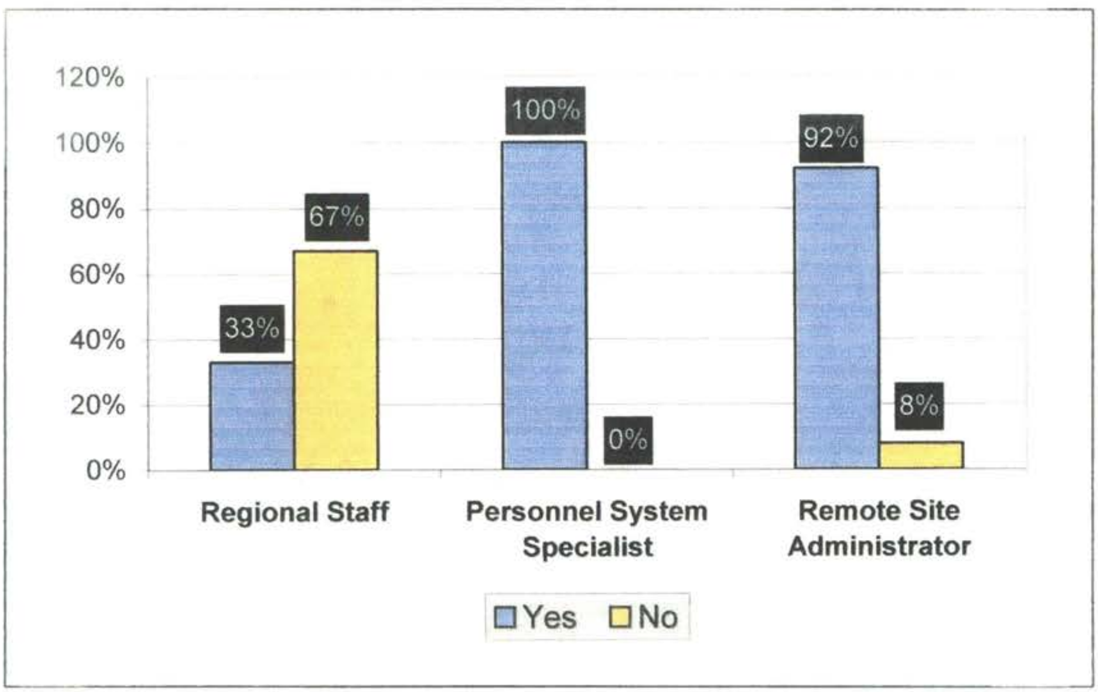

Figure 11. Response Percentages to Question Nine - If You Do Not Currently Have Access to CPMIS, Would a Read Only System Improve Your Ability to Perform Your Job?

Question ten on the survey, "*What Type of System Interface Do You Prefer?*" allowed respondents to choose between a text based or object oriented, as well as providing an open response option (see Figure 12). All of the respondents from the regional staff indicated a preference for an object-oriented interface. Thirty-one percent of the personnel systems specialists indicated preference for a text-based interface, 66 percent indicated preference for an object-oriented interface, and three percent responded "other." All of the "other" responses by the personnel systems specialists were

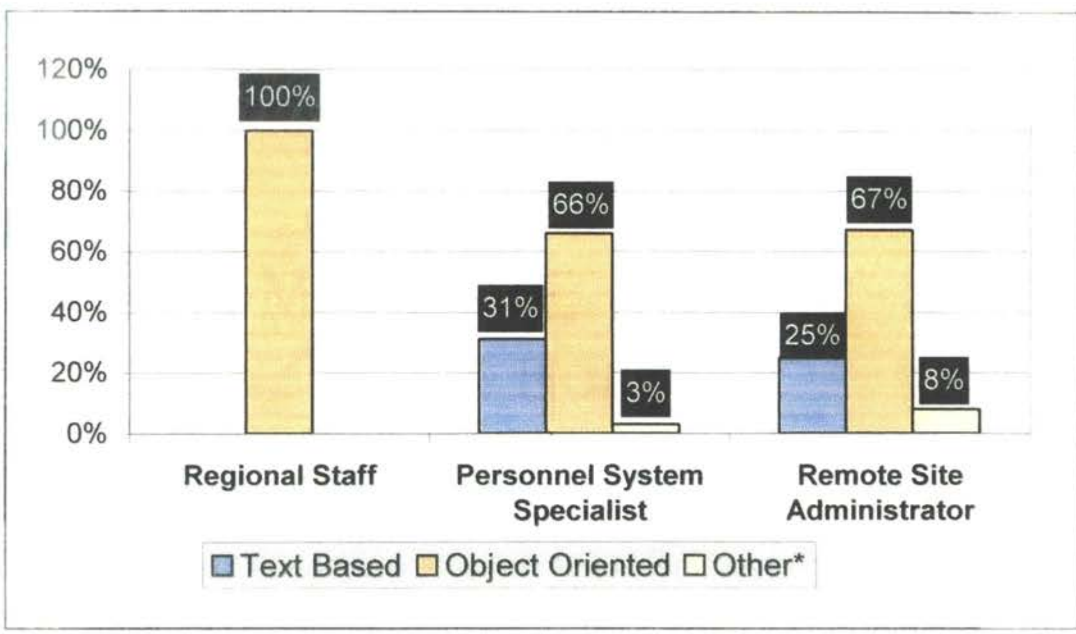

Figure 12. Response Percentages to Question Ten - What Type of System Interface Do You Prefer?

accompanied with a write in response specifying a preference for a windows interface, a very specific form of object-oriented interface. Twenty-five percent of the remote site administrators indicated a desire for text-based menu system, with 67 percent indicating a preference for an object-oriented interface. Eight percent of the remote site administrators utilized the free form "other" response. All of the "other" responses from the remote site administrators stated a preference for an interface that was a combination of text based and object oriented. The overwhelming response showed a strong desire for an object-oriented environment. This corroborated the opinion of the previous replacement project managers who indicated during their interviews that they had learned about this preference through their project experiences.

The priorities of the users for a variety of system aspects was explored with question 11, "*Rate the Following Items, From 1 (Most Important) To 7 (Least Important)*." The respondents were allowed to prioritize the following features:

a. Accuracy of information;

b. Timeliness of information;

c. Speed of access;

d. Reliability of the system;

e. Ease of set up and installation;

f. Ease of use; and

g. Help line support.

The responses were analyzed using descriptive statistics (see Figure 13). The mean, mode, median, standard of deviation and variance were calculated for the

Item	Mean	Mode	Median	σ	σ^2
Accuracy of Information	1.88	1	1	1.7	2.9
Timeliness of Information	2.67	2	2	1.4	1.9
Speed of Access	4.08	4	4	1.3	1.7
Reliability of System	3.53	3	3	1.1	1.3
Ease of setup and installation	5.73	7	6	1.6	2.5
Ease of use (User Friendly)	4.12	5	5	1.7	2.7
Help Line Support	5.98	7	6	1.3	1.8

Figure 13. Responses and Corresponding Statistics to Question Eleven - Rate the Following Items, from 1 (Most Important) to 7 (Least Important).

aggregate response of each item. The mean, or average ranking for each question corresponded with the mode of the responses for all items except the lowest ranked factors- ease of set up and installation, ease of use, and help line support. Ease of use had a mean response score of 4.12, with a mode of 5. Ease of setup and help line support had a mean of 5.73 and 5.98 respectively, while each had a mode of seven.

The standard of deviation and variance are greatest for the items at opposite ends of the response scale. Of particular note is the highest ranked item – accuracy of information. It has the highest standard of deviation, 1.7, and the highest variance, 2.9.

The median response and the mode of this item are both one. Considering this, along with the mean of 1.88, it appears that the respondents agree on the importance of the accuracy of information. The question then remains as to why the high standard of deviation and variance. Closer examination of the survey returns indicates that of the 61 respondents, over half ranked accuracy of information as one. Three respondents ranked it as seven, and one respondent ranked it as six. Similar results occurred on the lowest ranked items. In fact, the four respondents appear to have matched the majority responses, but in reverse order. It is highly probable then, that these four individuals misunderstood the ranking scale. In fact, discarding these four responses brings the standard of deviation for each item down below 1.5. In the case of the highest and lowest ranked items – accuracy of information and help line support – the standard of deviation and variance for each drops below 1.0 (see Figures 14 through 20).

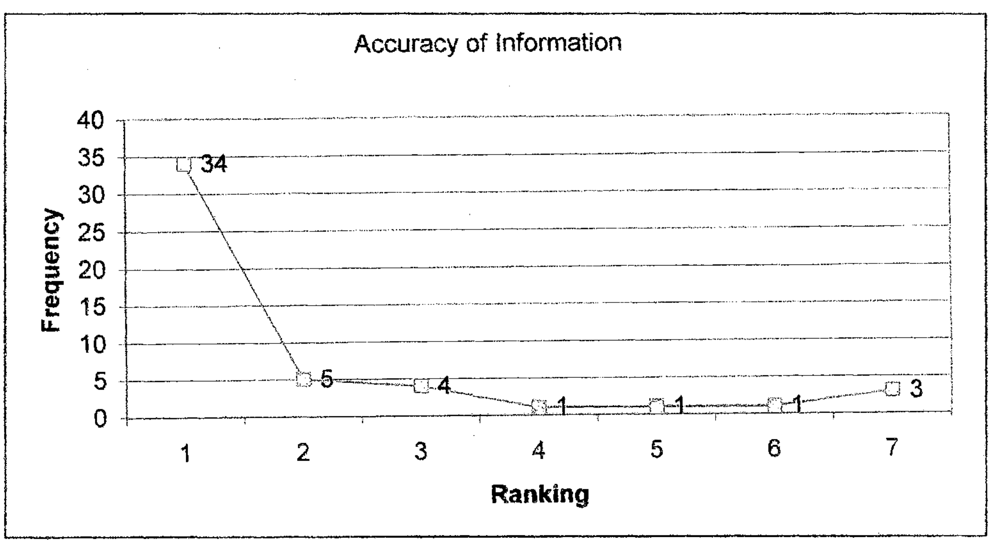

Figure 14. Response Distribution for Question Eleven Item - Accuracy of Information.

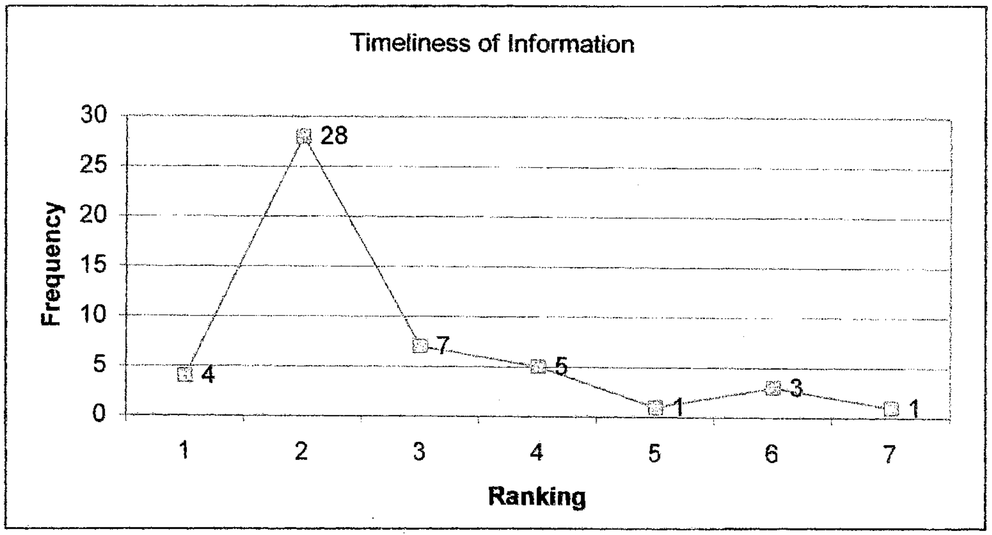

Figure 15. Response Distribution for Question Eleven Item - Timeliness of Information.

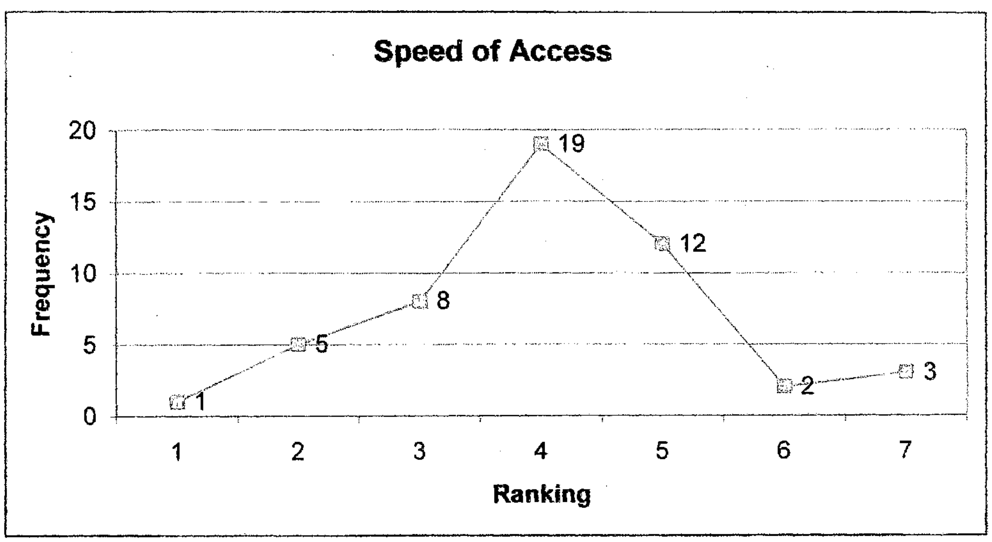

Figure 16. Response Distribution for Question Eleven Item - Speed of Access.

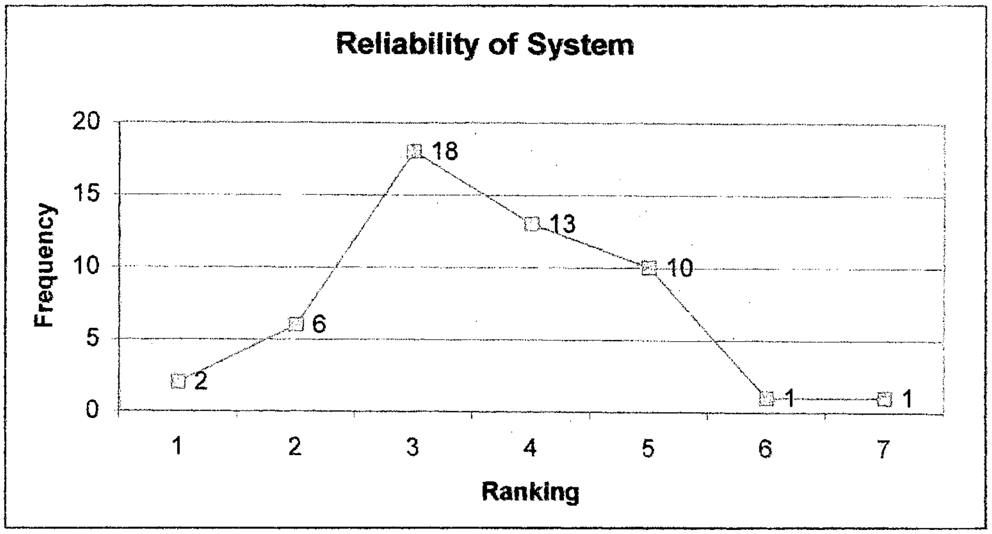

Figure 17. Response Distribution for Question Eleven Item - Reliability of System.

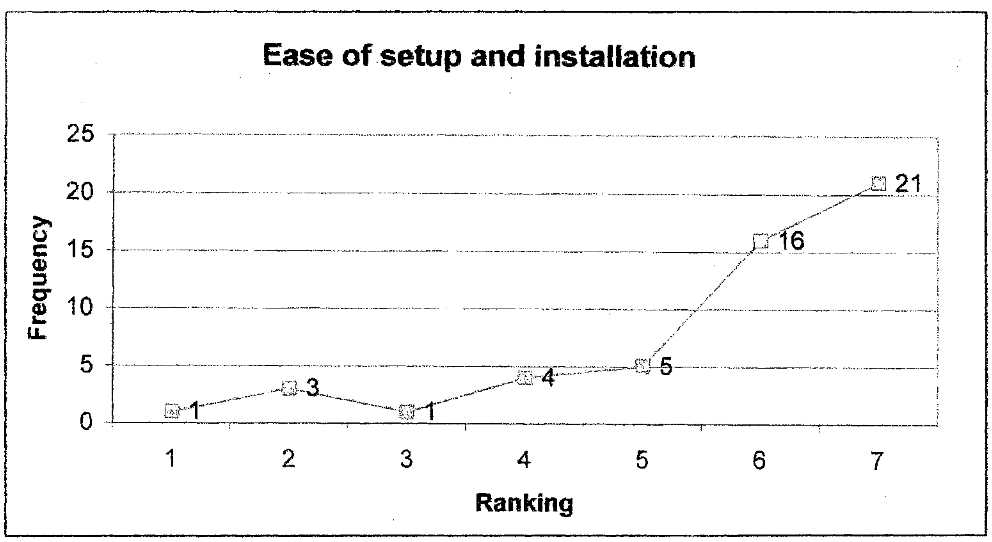

Figure 18. Response Distribution for Question Eleven Item - Ease of Setup and Installation.

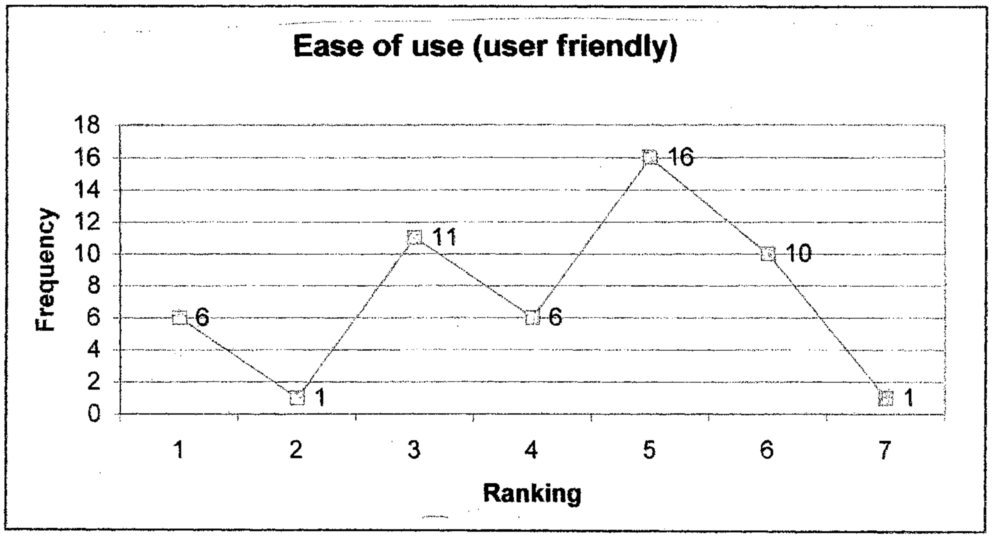

Figure 19. Response Distribution for Question Eleven Item - Ease of Use.

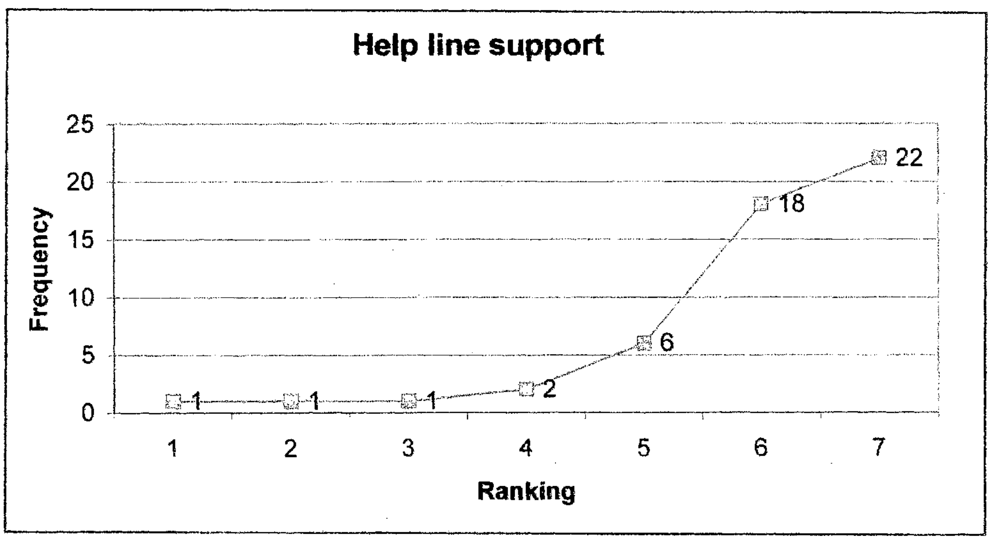

Figure 20. Response Distribution for Question Eleven Item - Help Line Support.

Mirroring the sentiments expressed by the focus group, answers to question eleven of the survey instrument showed strongly that the most important features of any replacement system must be the accuracy and currency of information. In fact, despite the responses indicating dissatisfaction with the current system interface, the responses to this question show that the user community is willing to trade off the ease of use as long as the information available through a replacement system is accurate and current. Answers to question number 12 reinforced this finding by indicating that data older than one day is unacceptable to the majority of the users (see Figure 21).

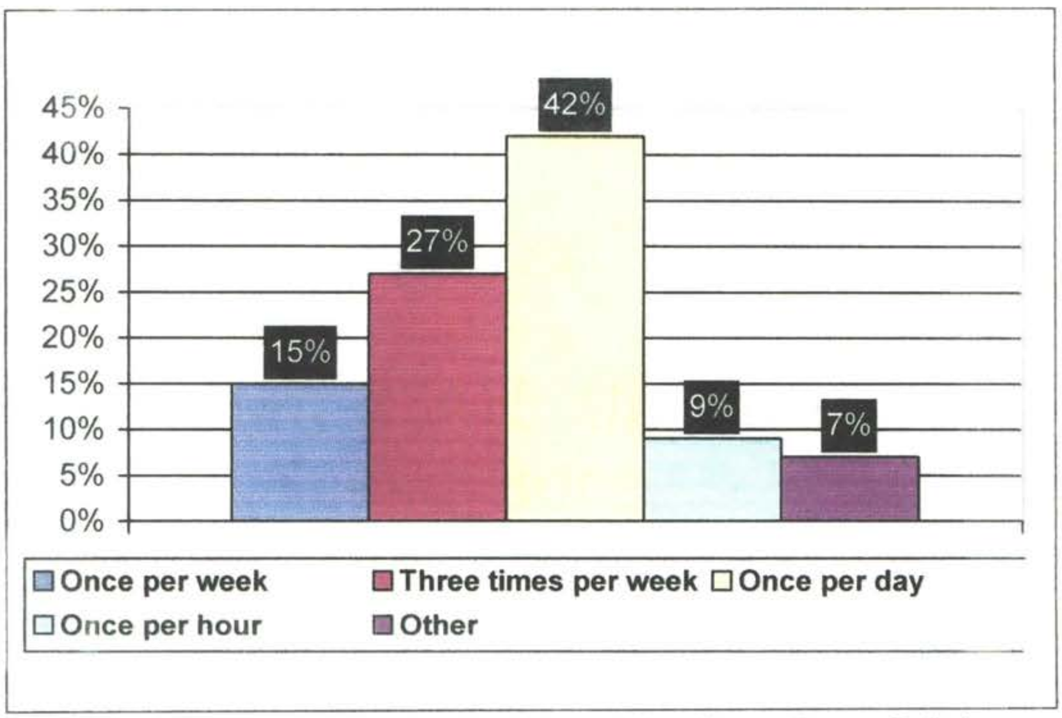

Figure 21. Responses to Question Twelve - A Client/Server System Is Being Considered That Would Regularly Download CPMIS Information and Display That Information to Remote Users. If Such a System Were Implemented What Is the Minimum Frequency of Information Updates That Would Be Acceptable for You to Perform Your Job Duties as Training Administrator?

The focus group had indicated some concern about a system that would download information from CPMIS. The concern was focused on the aspect of how often information might be updated, since changes such as revised class dates or prerequisite requirements can be occur frequently. Question 12 was used to determine what frequency of updates would be acceptable to the users. Forty-two percent of the 59 respondents answered that a daily update would be adequate, while only nine percent, or five respondents, stated a more frequent update was needed.

Question 13, "*The Following Information Is Examples of The Type of Data That May Be Downloaded and Displayed on The New System. Please Rate Items on The Order of Importance to You From 1 (Most Important) to 7 (Least Important)*," explored what types of information the users would like to access. The respondents were asked to rank the following items:

a. Class schedules;

b. Course descriptions;

c. Prerequisite listings;

d. Quota distribution;

e. Enrollment status;

f. Exam equivalencies; and

g. Course equivalencies,

The two highest rated items (quota distribution and enrollment status) are information to which the users currently do not have access on the present legacy system (see Figure 22). Quota distribution also had the lowest standard of deviation number and

Item	Mean	Mode	Median	σ	σ^2
Class Schedules	3.63	3	3	2.9	1.7
Course Descriptions	4.46	5	5	1.9	1.4
Prerequisite Listings	3.76	4	4	1.7	1.3
Quota Distribution	2.50	2	2	1.3	1.1
Enrollment Status	2.30	1	2	2.5	1.6
Exam Equivalencies	5.89	7	6	2.7	1.7
Course Equivalencies	5.41	6	6	1.8	1.3

Figure 22. Responses and Corresponding Statistics to Question Thirteen -The Following Information Is Examples of the Type of Data That May Be Downloaded and Displayed on the New System. Please Rate Item on the Order of Importance to You from 1 (Most Important) to 7 (Least Important).

variance, number indicating a strong consensus among the respondents that this feature represents the greatest need. Based on enrollment status ranked as the number two need; however, it had a much higher standard of deviation number and variance number. In fact although the median and mode of each response resulted in a general rank order, the mean scores relatively close, separated by a range of only 3.6. A range of 0.83 separated the three middle ranked items- class schedules, course descriptions, and prerequisite listings. That fact, coupled with the high variances indicates that other than the highest priority item (quota distribution) and the lowest priority item (exam equivalencies) there was no strong consensus among the users on the priority of the other six items.

The final question on the survey instrument, "*What Type of Remote Network Access Do You Have*?" was used to determine remote network access types. This will enable a more accurate means of designing a replacement system with maximum cost efficiencies. The most common network access was the Internet. Fifty-five percent of the regional staff, 35 percent of the personnel system specialists, and 48% of the remote site administrators reported access to the Internet. The next most common network access is the remote maintenance monitoring (RMM) statistical time division multiplexing (StatMUX) network. This network is a dedicated data line for field navigation systems and radar sites to feed status information to centralized monitoring locations. Thirty two percent of the regional staff, 38 percent of the personnel system specialists, and 23% of the remote sites have access to the RMM StatMUX network interfaces. Another option available to the agency are dedicated agency phone lines through a system known as Automated Data Terminal Network (ADTN) 2000. Less than ten percent of any of the participants reported access to ADTN 2000. The final option for remote access would be through public telephone lines using a dial-up modem. Twenty-four percent of the remote sites and 22 percent of the personnel system specialists reported availability of dial-up modems, while only ten percent of the regional staff reported this availability. The results demonstrate that no single type of network access is universally available to all sites, indicating composite solution must be considered.

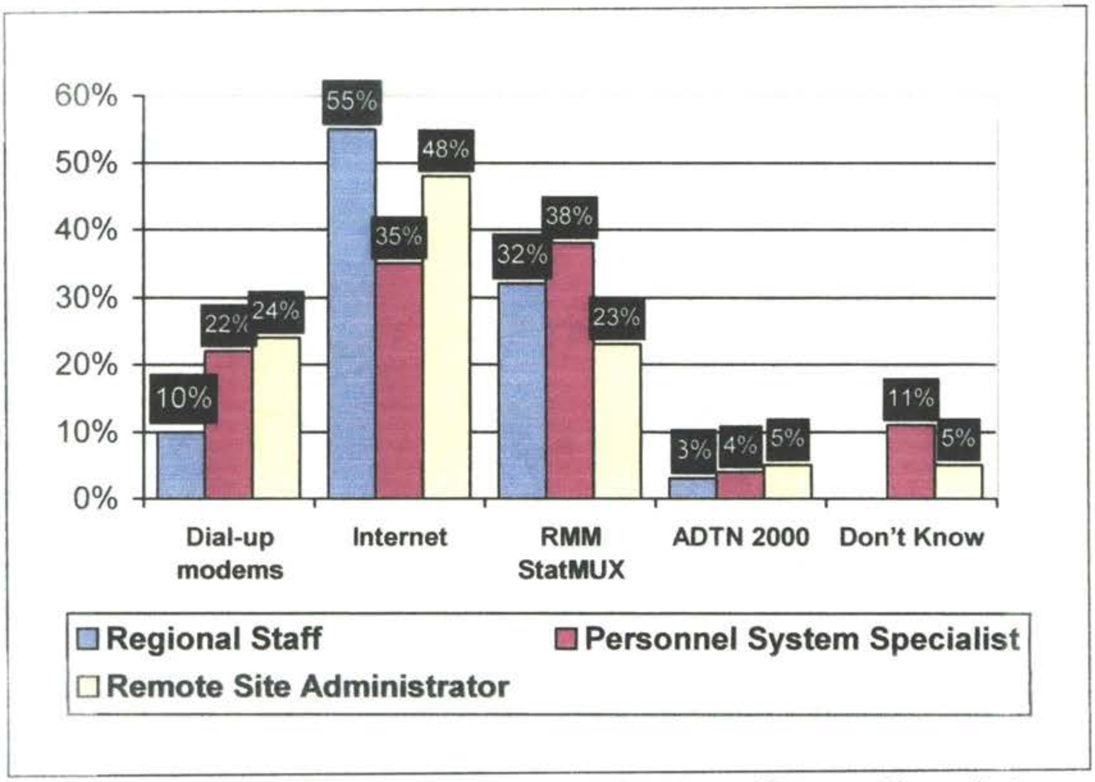

Figure 23. Responses to Question Fourteen - What Type of Remote Network Access Do You Have? (Check All That Apply).

Summary

Following the methodology outlined, information was gathered to determine the feasibility of using thin-client architecture to access the FAA's legacy database systems. Interviews were of personnel associated with the previous replacement projects were conducted to gather lessons learned. Considerations needed to meet user needs were obtained from various groups and levels of users. This was done first by conducting a focus group of selected regional training administration personnel. Based on the results of the focus group a 14-question survey instrument was distributed to all regional training personnel, personnel systems specialists, and a random sampling of remote site administrators. The information gathered in the interviews and focus group was descriptive statistics were used to analyze the survey results. Conclusions and recommendations can now be drawn from these findings.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Like many large organizations across the United States, the Federal Aviation Administration (FAA) is hampered with the operation of a number of large, complex legacy database systems. The dilemma for the agency is that it cannot afford to lose the data contained in these systems, nor can it continue to bear the increasing costs and burden of maintaining these systems. The FAA has been mandated by congress to replace these legacy databases as part of the reinvention of government initiatives to become more efficient and cost effective. One of the most critical systems, the Consolidated Personnel Management Information System (CPMIS) has been the target of several replacement attempts over the past ten years, without success. Increasing costs and lack of sustainability of the CPMIS legacy database mandate that the FAA find a viable alternative. To avoid repeating previous replacement failures any new system must meet the needs of the users both in functionality and usability.

A review of the literature revealed the complexity in replacing the CPMIS legacy system. CPMIS has the added impediment of having been developed by the FAA using a proprietary language and data structure that hampers its ability to be easily migrated into today's modern database system architectures. However, migration of the data from CPMIS is only one of the problems faced in a replacement effort. The most expensive attempt to produce a replacement system, called the Integrated Personnel and Payroll System (IPPS), was rejected by the users because of the difficult and ambiguous user interface (Coopers & Lybrand, 1996). As noted by Tuffley (1996), understanding the user's real requirements is a critical component to the development of successful information systems.

Case studies show that other large organizations have been able to successfully handle similar legacy system replacement problems using a new technology called thin-client architecture. This variation of the older client-server technology provides increased capacity for clients and remote users of the system. In the end, the success of the project will be measured by the client's usability (Mathers & Genoway, 1999).

This research study was designed to identify considerations in the development of an alternative to replacing the CPMIS legacy system, with emphasis given to utilizing thin-client architecture. To aid in the design of an effective model, the following research questions were addressed:

1. What are the "lessons learned" from previous replacement attempts?
2. What features of an information system are most desired by the end user?
3. What characteristics of a thin-client system architecture could benefit the FAA in future CPMIS replacement efforts?

The study was accomplished by conducting interviews, focus groups, and surveys of personnel responsible for administering the Airway Facilities technical training program within the FAA. The results were used to formulate the following conclusions.

Conclusions

Research Question One – What Are the "Lessons Learned" from Previous Replacement Attempts?

Exploring the methodology and design decisions made on these projects provided insight into causes for past failures and an opportunity to assess the goals for any future replacement initiative. The interviews with former project managers revealed common sentiments regarding negative and positive lessons resulting from previous replacement attempts.

Lesson learned number one is to keep realistic expectations in regard to management of the project. Both managers emphasized the importance of using a proven methodology to estimate the time and cost for the project. They both stressed that it is of critical importance to trust the results of the estimates provided by the methodology. In both previous attempts the original estimates came out to be very accurate when compared with the final results. However, in both cases the results of the estimates projected a time and cost that were unpalatable to the higher management of the agency. Altering the cost estimate results in order to gain approval of the project ultimately resulted in the failure of the projects when time and cost overruns occurred.

Lesson learned number two is to avoid the occurrence of "requirements creep". Accurate identification of requirements is an essential part of obtaining an accurate cost and time estimate. In order to accurately define the requirements the gathering stage cannot be shortcut. It is important to involve the full range of users of the system, from the low end to the power users, as well as the technical specialists, to fully identify the aspects of the system that are required in order for the system to meet the needs. This can be time consuming, but it allows the estimate to be accurate and prevents requirements being added to the system while in development. Once the requirements are determined it is essential that the requirements are base-lined and adhered to until project completion. Any new requirements identified during development must be held until future enhancements of the system are developed.

Lesson learned number three is that the project manager must carefully consider the qualifications and background of the people working on the project. It is important to have the full range of users involved in requirement gathering as well as in the actual development. This involvement ensures buy-in for the end results and minimizes the potential for rejection by the user community. Because of the high rate of failure of large development projects it is also important to hand pick the development team. The members of the team should be the best people available. This includes people who work on the legacy system targeted for replacement. This allows leveraging of their knowledge and expertise on the legacy system and helps to develop a system that will transition the users smoothly.

Lesson learned number four is the importance of the user interface. Acceptance of the interface by the user community plays a key role in whether or not the users deem the new product a success. The most widely popular portion of the previous replacement products was one that used a Windows-based interface. Windows is a universally understood environment for the users, making many of the controls and functions intuitive for the user. This not only increases the comfort level of the user but reduces the amount of training required for the new system.

Research Question Two - What Features of an Information System Are Most Desired by the End User?

All of the users indicated a desire for access to data from the CPMIS legacy system. The most casual users, the remote site administrators needed at least read only access to the system data, an average of four times per week. The intermediate users, the personnel systems specialists were split on their desire to have read only or both read and write access to the system. Their usage averaged 19 times per week. Finally the power users, the regional staff, overwhelmingly indicated a need to read and write access, with an average use of the system at 53 times per week. Of the users that do not currently have access to CPMIS, only 33 percent of the power users would be satisfied with a read only system; however, 100 percent of the intermediate users and 92 percent of the casual users responded that a read-only system would improve their ability to do the job.

The users desire not only access to the information from CPMIS, but they require that the information be accurate and timely. Accuracy of information and timeliness were the top two rated items on the survey. Correlating with the desire for timeliness, 42 percent the users indicated that the information must be updated at least daily to ensure currency of the data.

The responses of the users, particularly in question 11, "Rate the Following Items, From 1 (Most Important) To 7 (Least Important)," indicate the users are more concerned with the capability of the tool than the technology that drives it. Ease of set up, help support, and user friendliness were rated lower than the need for accuracy and timeliness of the information presented by the system. As earlier attributed to Yohe (1996) the users want to have whatever information they need, whenever they want it, wherever they want it, and however they want it. The concern of the users in the focus group as well as on the survey instrument made it clear the concern was more with what the system will do for them than how it will perform its purpose. Functionality of the tool is more vital than the technology behind it. The information must be accurate, up to date, and above all, accessible.

Research Question Three – What Characteristics of a Thin-Client System Architecture Could Benefit the Faa in Future CPMIS Replacement Efforts?

Many of the characteristics of thin-client architecture will benefit the FAA because of the match with the desires and needs indicated by the users. First and foremost is the flexibility of thin-client to utilize the widest variety of client hardware, operating systems, and network protocols. Thin-client is a variation of the traditional client-server architecture. Unlike the client-server environment, thin-client runs the application directly on the server with only keystroke updates transmitting across the network. This lowers the bandwidth requirements for network architecture. Lower bandwidth requirements equate to a lower network architecture costs and higher performance for the users. Lower bandwidth also allows for a wide variety of network solutions. This will allow the FAA to leverage the existing network architectures, further reducing the cost for a replacement system. Allocated resources can be concentrated upon development of a tool that will meet the functionality needs of the users, as opposed to a costly investment in new hardware for the user community.

The capability of thin-client to utilize multiple network protocols additionally ensures that the new system can meet the number one need of the user- that of access to the system data. A multiprotocol solution is required to seamlessly access applications tying to complex legacy systems from industry-standard web browsers and interface tools. Regardless of what network capability is currently available to the user community, a thin-client architecture will give the users the means to access the system.

The next characteristic of thin-client that will benefit the FAA is its ability to support a Windows' interface environment. The users overwhelmingly indicated a preference for a graphical user interface (GUI). Windows interface designs are synonymous with GUI. The ability of thin-client to support this type of interface will allow the replacement system to be intuitive and transparent to the users. They can focus their attention on the data, rather than the interface.

Running an application from a central server with thin-client will allow system developers to design a system without a need to accommodate differing client platforms and operating systems. This will speed up the design process, equating to development of a replacement system for much less expense. Future upgrades to applications are rapid and cost effective, because the only upgrade performed is on the server. Client systems are unaffected. This is crucial in the type of migration project dictated by replacement of a legacy database. Typically the migration is done in phases. Thin-client will allow the migration to be transparent for the user, other than the pleasant experience of finding additional capabilities available as the phases of the project progress.

Another characteristic of thin-client that will benefit the users and the agency is the speed of data transfer. The unique, compressed protocols of thin-client will ensure that even the slowest network access available to the user will provide a rapid transfer of information. Users will see no difference in performance or function whether they are located in any of the agency's globally remote locations, or at one of the centralized facilities. That increased speed of data transfer means not only less frustration on the part of the user awaiting screen updates, but it also helps ensure the system is more reliable. The rapid transfer reduces the likelihood that "bumps" across the network or telephone lines will compromise data integrity or break the connection with the user.

Thin-client has another characteristic that will increase the ability to meet the reliability demands of the user. The greatest concern of a traditional client-server environment is that the dependence of the client on the server creates a single point of failure. Any problem with the server creates disruption for all of the clients. In a thin-client environment. however, multiple servers can be economically configured together. If any one server fails the thin-client software can transparently switch the user to another server with minimal disruption. Additionally, the increased reliability and ease of support in a thin-client architecture reduces the probability for failures or interrupted service to the clients.

Recommendations

The first recommendation from this study is for the FAA to strongly consider use of thin-client architecture in any future legacy system replacement projects. Thin-client architecture has the capability of meeting the needs of the users while offering benefits around leveraging existing hardware and networks in place. Determination of which vendor or specific product will best meet the needs is more problematic. Technology is such a fluid and volatile area that any recommendation would be outdated almost as soon as it is made. Based upon the table of vendor comparisons and the results of the survey instrument, Citrix Winframe appears to be the most promising alternative at this time. Citrix has the most flexibility in leveraging existing client hardware and network architectures.

The second recommendation is that the FAA start with a small pilot project to migrate a portion of a legacy system using the thin-client architecture. A small pilot would be more manageable and easily discarded if results were not as anticipated. The crucial areas to consider in order to define the goals and scope for such pilot projects are (Hughes, 1998):

1. User Satisfaction – Define user needs and expectations of system performance.
2. System Productivity – Determine the overall data throughput required of the system.
3. System Cost – Examine the cost of the system and weigh it against benefits expected.

Using these as guideposts to define the goals for the project will increase the probability for success. The FAA should thoroughly examine any lessons learned from such a pilot and undertake a project of more significant scale. Ideally this should not be a project that the FAA can afford to have fail, but rather, one that is manageable enough to make strategic revisions along the way. After each incremental step the development team and the executive managers of the FAA should stop to evaluate results against the key aspects of system architecture.

Recommendations for Further Study

The first recommendation for further study is to extend is to expand this study to encompass the other lines of business within the FAA. Results will provide a holistic look into new system requirements. Each line of business has unique training needs with different approaches to administering training to meet those needs. For example, Air Traffic controllers receive a larger portion of their training as on-the-job training (OJT). The OJT is repetitive and continuous in nature to ensure controllers remain proficient at handling traffic within his/her facility's individual airspace. This training is not entered into CPMIS, but instead is kept within a hardcopy folder that the employee hand carries when transferring to any new facility. Another example of unique training needs is Regulatory Standards. A large portion of training for the safety inspectors is conducted at contractor facilities. The training conducted at the FAA Academy contains safety inspectors from the agency and individuals from the private sector of the airline business. The process for enrolling in the out-of-agency training courses, as well as the process to enroll non-FAA employees differs from that of employees attending Academy courses. Because of the unique training needs of each line of business, it is essential that this research study be expanded to include the user community from the other LOB's to create a holistic solution for the agency.

The second recommendation for further study is to conduct a study within the FAA that would examine the reengineering of some of the training administration processes. It would be beneficial to determine what capabilities and features the users need to perform their functions optimally. This would help to avoid incorporate inefficient processes into any replacement system, further increasing the cost efficiencies gained by the effort.

The third recommendation for further study is to explore the impact that personnel changes have on large-scale projects. Due to the transitory nature of government employees it was extremely difficult to capture lessons learned from the previous projects. Personnel working on the replacement project teams frequently left the project to pursue new career opportunities, join other organizations, and/or receive positions with higher grades and salaries. The project manager changed multiple times within the course of the project as well as the team members changing. Literature indicates a disproportionate number of large-scale information-technology (IT) projects fail. The results of a study on the impact of these personnel changes would be invaluable to the FAA and the IT industry.

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APPENDIXES

APPENDIX A

DATA COLLECTION DOCUMENTS

Project Managers Interview

What was the original proposed cost of the CPMIS replacement?

What method was used to determine the cost/benefit for project justification?

What was the result of the cost benefit?

How were the user requirements determined (methodology)?

How were the interface requirements defined?

Looking back on the project, what three things would you repeat (consider successful)?

Looking back on the project, what three things would you do differently (consider unsuccessful)?

Consent Form

I, ________________, hereby authorize Judy A. Holcomb to perform the following procedure:

Conduct an interview to facilitate a descriptive study that will outline a cost efficient model to utilize client/server information technology to access legacy system databases within the Federal Aviation Administration Academy. The model will address the following areas:

- Accessing information in legacy systems
- Defining user needs
- Influences on user and IT relationships;
- Cost factors of various alternative approaches

All responses to interviews will be recorded on an anonymous basis. After results of the interviews are compiled into the study the original notes and records will be destroyed.

I understand I have been chosen because of my involvement with the current Consolidated Personnel Management Information System (CPMIS) legacy database or one of the previous CPMIS replacement efforts.

I understand that participation is voluntary and that I will not be penalized if I choose not to participate. I also understand that I am free to withdraw my consent and end my participation in this project at any time without penalty after I notify the project director.

I have read and fully understand the consent form. I sign it freely and voluntarily. A copy has been given to me.

Date: ____________________ Time: ____________________(a.m./p.m.)

Signed: ____

I certify that I have personally explained all elements of this form to the subject before requesting the subject to sign it.

Signed: ____
Project director

Consent for Participation in a Research Project

Date

Participant's Name
Address
City,State Zip

Dear Participant:

You are being asked to participate in a study to design a cost effective model for using client/server technology to access information in the legacy Consolidated Personnel Management Information System (CPMIS). As a training administrator your experience and expertise will play a critical role in designing a system of maximum benefit to the agency. Judy A. Holcomb, a doctoral student in the department of Aviation and Space Education at Oklahoma State University, is conducting this study.

Your involvement will require you to answer the accompanying questionnaire and return it in the provided envelope. Following transposing of the answers to tabular format the questionnaires will be destroyed. All responses are anonymous. You will not be identified as an informant nor will the name of your facility or organization be divulged in any publication or presentation. Your participation in this study is voluntary. Return of the completed questionnaire shall signify your consent to participate in this study.

Your participation in this study is greatly appreciated. Please accept this bookmark as a small gift in advance for your support of this important research.

Should you have any further questions about this study, please contact me, Judy A. Holcomb, at (405) 954-5791. Should you have questions about your rights as a research subject, you may contact Gay Clarkson, Institutional Review Board Executive Secretary, 305 Whitehurst, Oklahoma State University, Stillwater, OK 74078; telephone number: (405) 744-5700.

Sincerely,

Judy A. Holcomb
Doctoral Candidate
Oklahoma State University

Questionnaire for Training Administrators

1. Which of the following best describes your role as a training administrator?
   - ☐ Regional 420 Staff
   - ☐ Personnel System Specialist
   - ☐ Remote Site Administrator

2. How many times per week do you need access to CPMIS data in the performance of your job? ____________________

3. Which type of access to CPMIS do you need, **AS A MINIMUM**, to successfully perform your job? ☐ Read & Write ☐ Read only

4. Do you currently have direct access to CPMIS? ☐ Yes ☐ No

If you answered No to question 4, skip to question 9

5. Which of the following best describes your opinion of CPMIS?
   - ☐ I am satisfied with the current CPMIS.
   - ☐ The system is difficult to use.
   - ☐ The system access is unreliable.
   - ☐ Other (please explain) ________________________________

   ____

6. Did you receive training on CPMIS? ☐ Yes ☐ No

7. Is your system connection to CPMIS reliable (Connection made and stable 9 out of ten times)? ☐ Yes ☐ No

8. Are you currently satisfied with the support you receive when you encounter problems or system failures? ☐ Yes ☐ No

9. If you do not currently have access to CPMIS, would a read only system improve your ability to perform your job? ☐ Yes ☐ No

10. What type of system interface do you prefer?
    - _______a)Text based menu system
    - _______b)Object oriented (buttons & icons)
    - _______c)Other (please explain) ____________________________

CONTINUED ON NEXT PAGE ⟶

11. Rank the following items, from 1 to 7 in order of importance to you.

______ Accuracy of information.

______ Timeliness of information (Frequency of updates)

______ Speed of access

______ Reliability of system

______ Ease of setup and installation

______ Ease of use (User friendly)

______ Help line support

12. A client/server system is being considered that would regularly download CPMIS information and display that information to remote users.. If such a system were implemented what is the minimum frequency of information updates that would be acceptable for you to perform your job duties as training administrator?
    - ☐ Once per week
    - ☐ Three times per week
    - ☐ Once per day
    - ☐ Once per hour
    - ☐ Other (please specify)

13. The following information is examples of the type of data that may be downloaded and displayed on the new system. Please rank each item on the order of importance to you from 1 (most important) to 7 (least important).

    ______ Class schedules
    ______ Course descriptions
    ______ Prerequisite listings
    ______ Quota distribution
    ______ Enrollment status
    ______ Exam equivalencies
    ______ Course Equivalencies

14. What type of remote network access do you have? (Check all that apply)
    - ☐ Dial-up modems
    - ☐ Internet
    - ☐ ADTN 2000
    - ☐ RMM Statmux
    - ☐ Don't Know

APPENDIX B

INSTITUTIONAL REVIEW BOARD

APPROVAL FORM

OKLAHOMA STATE UNIVERSITY
INSTITUTIONAL REVIEW BOARD

Date:	March 16, 2000	IRB #:	ED-00-225
Proposal Title:	"A COST EFFICIENT MODEL FOR DESIGN AND IMPLEMENTATION OF CLIENT/SERVER TECHNOLOGY TO ACCESS LEGACY SYSTEM DATABASES WITHIN THE FEDERAL AVIATION ADMINISTRATION ACADEMY"		
Principal Investigator(s):	H.C. McClure Judy Holcomb		
Reviewed and Processed as:	Exempt		

Approval Status Recommended by Reviewer(s): Approved

Signature:

Carol Olson, Director of University Research Compliance

March 16, 2000
Date

Approvals are valid for one calendar year, after which time a request for continuation must be submitted. Any modification to the research project approved by the IRB must be submitted for approval with the advisor's signature. The IRB office MUST be notified in writing when a project is complete. Approved projects are subject to monitoring by the IRB. Expedited and exempt projects may be reviewed by the full Institutional Review Board.

VITA 2

Judy A. Holcomb

Candidate for the Degree of

Doctor of Education

Thesis: USING THIN-CLIENT ARCHITECTURE TO ACCESS THE LEGACY TRAINING DATABASE WITHIN THE FEDERAL AVIATION ADMINISTRATION ACADEMY

Major Field: Applied Educational Studies

Biographical:

Personal Data: Born in Sodus, New York, on July 30, 1955, the daughter of Eldon and Beverly Cook.

Education: Graduated from North Rose-Wolcott High School, Wolcott, New York in June 1973; received an Associate of Engineering Technology degree from Oklahoma City Community College, Oklahoma City, Oklahoma in May 1986; received a Bachelor of Science degree from Oklahoma City University in December 1990; received a Master of Science degree from Oklahoma State University, Stillwater, Oklahoma, in May 1999. Completed the requirements for the Doctor of Education degree with a major in Applied Educational Studies with an emphasis in Aviation and Space Science at Oklahoma State University in May 2002.

Experience: Began working for the Federal Aviation Administration (FAA) as a clerk-typist in December 1979. Selected as a developmental electronics technician for the FAA Logistics Center in August 1980. Progressed to lead technician-in-depth, and remained at the Logistics center until 1988. Selected as an Electronics Instructor by the FAA Academy in February 1988. Converted to an Electronics Engineer Instructor for the Academy in 1990. Became a first level supervisor for the Academy in June, 1991. Selected as the Assistant Division Manager for the Airway Facilities Division of the FAA Academy in October 1997.

Professional Memberships: National Federation of Business and Professional Women; Technical Women's Organization; Aircraft Owner and Pilot Association